Journal on Biology and Instruction (JouBIns)
Vol. 5 No. 2 Tahun 2025 | 24 – 31 ISSN 2978-0863

An Innovative SETS-Based Problem-Based Learning Model to Improve Critical Thinking and Cognitive Outcomes in Biology

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Article information

Article history:
Received October 6th, 2025
Revised November 9th, 2025
Accepted December 31th, 2025

Keywords:
Problem-Based Learning (PBL)
SETS (Science, Environment, Technology, and Society)
Cognitive Learning Outcomes
Critical Thinking Skills
Industrial Agricultural Area

ABSTRACT

In order to enhance students' cognitive learning outcomes and critical thinking abilities in Biology classes, this study implements a SETS-based Problem-Based Learning (PBL) model. The purpose of this study was to determine the effect of the SETS-based Problem-Based Learning (PBL) model on the cognitive learning outcomes and critical thinking skills of Grade X Biology students in industrial agricultural settings. A quasi-experimental design was applied, consisting of a control class and an experimental class that was taught using the SETS-based PBL approach. Students' cognitive learning outcomes were evaluated through ANCOVA, while their critical thinking skills were analyzed using the non-parametric Mann–Whitney test. The ANCOVA results revealed a significance value of 0.041 (<0.05), indicating a significant improvement in students' cognitive learning outcomes, whereas the Mann–Whitney test produced a significance value of 0.002 (<0.05), confirming a significant enhancement in critical thinking skills. Based on these findings, it can be concluded that the implementation of the SETS-based PBL model effectively improves both cognitive learning outcomes and critical thinking skills of Grade X students in industrial agricultural areas.

INTRODUCTION

In the era of rapid scientific and technological advancement, Biology education plays a crucial role in developing students' critical and cognitive thinking skills necessary for solving real-world problems. Therefore, innovative learning approaches are needed to link scientific knowledge with environmental and societal issues. Learning is an activity or process with several objectives, including acquiring knowledge, improving personal skills, correcting behavior and attitudes, and strengthening one's personality (Harefa, 2022). The ongoing development of technology demands teachers to make the best use of technology in classroom learning and to connect it with scientific knowledge that will provide benefits for the environment in the future (Hidayah & Syahrani, 2022). In today's digital era, critical and creative thinking skills are essential for students to face global challenges. These skills are not only crucial in the academic world but also have significant impacts on professional and personal life (Nurfaizah et al., 2022; Siswati & Hariyadi, 2024).

Critical thinking skills are very important for students because they build logical reasoning, problem-solving abilities, and the capacity to make rational decisions that guide actions and beliefs (Susilawati et al., 2020). According to Hidayat et al. (2022), critical thinking skills are necessary for students in the 21st century. In this modern era, critical thinking skills prepare students to face life challenges, help them develop the competencies needed to compete in the economy, and adapt to the global environment (Alviona et al., 2020). Therefore, biology learning should be designed not only to transfer knowledge but also to train students to think critically when facing real-world problems. The rapid development of the education system requires learning models that align with educational goals (Albina et al., 2022).

Based on observations through interviews with all Biology teachers at SMAN Umbulsari—a senior high school located in Jember Regency, East Java, Indonesia, known for its agricultural surroundings and commitment to implementing environmentally oriented education programs—it was found that the learning process has not yet applied a learning model that directly connects the material with environmental issues. Problems in everyday life are quite complex, requiring sound thinking to find solutions. This condition indicates the need for innovative learning strategies that encourage students not only to memorize but also to analyze and solve problems in depth (Rahmawati et al., 2021).

One of the recommended learning models is Problem-Based Learning (PBL). This model is based on real-life problems, encouraging students to formulate problems, identify them based on prior knowledge, and present appropriate solutions (Yusup & Salsabila, 2023). The Problem-Based Learning (PBL) model is very effective in teaching the topic of genetic diversity in biology. PBL allows students to be actively involved in discussing real-world problems (Maryuningsih et al., 2022). The PBL model has a significant effect on students' 4C skills (Indriyani et al., 2025).

When integrated with the Science, Environment, Technology, and Society (SETS) framework, PBL further enhances learning outcomes by fostering active inquiry, emphasizing real-world relevance, and situating learning within socio-environmental problem contexts. This integration encourages students to connect biological concepts with environmental and societal applications, leading to deeper conceptual understanding and more sustainable attitudes toward problem-solving. These findings are consistent with Rahmawati et al. (2021), who reported similar gains in students' critical thinking through context-based inquiry learning, and align with Yusup and Salsabila (2023), who highlighted the benefits of problem-oriented instruction in enhancing analytical reasoning.

The learning model chosen by the researcher to improve students' critical thinking skills and cognitive learning outcomes is the Problem-Based Learning (PBL) model. The implementation of PBL by the researcher is expected to make students more active in the classroom learning process and have a positive impact on enhancing both critical thinking skills and cognitive learning outcomes (Tabroni et al., 2022). According to Indriyani et al., the PBL model has a significant effect on students' 4C skills (Indriyani et al., 2025). Similar to PBL, integrating the SETS approach into PBL allows students to see the interconnection between science, technology, environment, and society, making learning more holistic and relevant (Riwu et al., 2018; Rasyidi, 2020).

The main reason for using the SETS method is its orientation toward active student participation. Students are guided to develop critical thinking skills about environmental issues, technological advancements, and to actively engage in problem-solving. Using the SETS method can improve students' understanding of the nature of science and attitudes toward science compared to traditional learning. The SETS method also provides an understanding of the relationship between science, environment, technology, and society while fostering students' sensitivity to environmental impacts arising from scientific and technological developments (Poedjiadi, 2010). Thus, physics learning becomes more meaningful as it directly relates to real-world problems in daily life (Ramadhan & Mardin, 2023). Although various studies have explored either PBL or SETS independently, limited research has examined the integration of both models in Biology education, especially in industrial–agricultural learning contexts. Therefore, this study aims to analyze the effect of the SETS-based Problem-Based Learning model on students' cognitive learning outcomes and critical thinking skills. The findings are expected to contribute to the development of contextual and innovative learning models in Biology education.

METHOD

Data Collection Method

This research was conducted at SMAN Umbulsari, Jember Regency, East Java, Indonesia. The school was selected purposively because of its commitment to environmentally oriented education and the availability of parallel classes suitable for quasi-experimental design. The participants consisted of two intact classes of Grade XI students, totaling 64 learners—32 in the experimental group and 32 in the control group. The gender ratio was approximately 60% female and 40% male. The grouping of participants used intact classes rather than random assignment, which is common in school-based educational research (Sugiyono, 2019; Creswell & Creswell, 2023).

The experimental class was taught using the SETS-based Problem-Based Learning (PBL) model, while the control class received conventional instruction. Data collection was carried out through several stages: school observations, interviews with key informants (teachers and administrators), and the administration of tests. The assessments included a cognitive learning outcomes test and a critical thinking skills test, along with documentation of research activities (Rahmawati et al., 2021; Yusup & Salsabila, 2023).

Data Analysis

a) Normality and Homogeneity Tests

These tests were conducted to ensure that both control and experimental class data met the assumptions required for parametric testing. The Kolmogorov–Smirnov test was used for normality, and Levene's test was used for homogeneity. A significance value (p) above 0.05 indicates that the data are normally distributed and have homogeneous variances (Field, 2018).

b) ANCOVA (Analysis of Covariance)

The ANCOVA test was employed to examine the effect of the SETS-based PBL model on students' cognitive learning outcomes while controlling for pretest scores. This analysis is appropriate for quasi-experimental designs with pretest–posttest structures, as it adjusts for initial differences between groups (Tabachnick & Fidell, 2019). A significance value (p) below 0.05 indicates a statistically significant difference between the experimental and control groups.

c) Non-Parametric Test (Mann–Whitney U Test)

The Mann–Whitney U test was used to analyze data on students' critical thinking skills when normality or homogeneity assumptions were not met. A p-value less than 0.05 indicates that the hypothesis is accepted, showing significant differences in critical thinking performance between the two groups (Pallant, 2020).

RESULTS AND DISCUSSION

The data related to students' cognitive learning outcomes and critical thinking skills were analyzed using SPSS, beginning with normality and homogeneity tests before proceeding to the next stage of analysis. The normality test on students' cognitive learning outcomes revealed that the data followed a normal distribution, with significance values of 0.095 and 0.200, both exceeding 0.05. In contrast, the normality test for critical thinking skills produced a significance value of 0.000, indicating non-normal distribution because the value was below 0.05.

The homogeneity test results using SPSS showed that the significance value (sig.) for the pretest questions on students' cognitive learning outcomes was 0.921, and for the posttest it was 0.659, indicating that the data met the assumption of homogeneity of variance. However, the homogeneity test on critical thinking skills data showed a sig. value of 0.002, which means that the data variance was not homogeneous since the sig. value was < 0.05.

Table 1. Critical thinking scores of experimental and control classes.

Class	Number of Students	Average ± SD	Difference	F	Sig
Experiment	31	65,19 ± 11,96	12,61	52,926	0,000
Control	31	52,58 ± 18,82			

The researcher compiled data on students' critical thinking skills using established indicators of critical thinking. The test questions were administered in both classes (control and experimental). Since the prior tests revealed that the data were not normally distributed and lacked homogeneity of variance, the collected data were analyzed using the non-parametric Mann–Whitney test in SPSS.

Table 2 Mann Whitney non-parametric test, Test Statistics (Critical thinking)

Mann-Whitney U	271.500
Wilcoxon W	767.500
Z	-3.055
Asymp. Sig. (2-tailed)	.002

a. Grouping Variable: Class

As shown in Table 1, the experimental class achieved a higher average score on critical thinking (M = 65.19, SD = 11.96) than the control class (M = 52.58, SD = 18.82), indicating a substantial difference between the two groups. The Mann–Whitney U analysis presented in Table

2 further confirmed this difference, with U = 271.500 and p = 0.002 (< 0.05), demonstrating that the SETS-based Problem-Based Learning model had a significant impact on students' critical thinking abilities.

The critical thinking indicators used in this study were adapted from Ennis (2011), which include: (1) giving simple explanations, (2) building basic skills such as identifying assumptions and arguments, (3) drawing conclusions, (4) providing further explanations to support reasoning, and (5) organizing strategies and tactics to solve problems effectively. The average performance on these five indicators showed that students in the experimental class demonstrated strong achievement across all aspects, particularly in drawing conclusions and organizing strategies, whereas students in the control class showed only moderate performance.

The superior outcomes in the experimental class can be attributed to the characteristics of the SETS-based PBL model, which encourages active inquiry and integrates real-world socio-environmental contexts into the learning process. Through group collaboration and problem-solving activities, students are trained to connect scientific knowledge with technological, environmental, and societal dimensions (Yulianti & Gunawan, 2019; Rasyidi, 2020). This finding supports previous studies indicating that combining contextual approaches such as SETS with PBL can enhance students' analytical and critical thinking skills (Rahmawati et al., 2021; Yusup & Salsabila, 2023).

Cognitive Learning Outcomes, the comparison of pretest and posttest scores between the experimental and control classes is presented in Table 3.

Table 3. Comparison between pretest and post-test scores in experimental and control classes

Class	N	Average Pretest	Std. Deviation	Average Posttest	Std. Deviation	F	Sig.
Experiment	31	40,84	13,55	62,00	16,09	4,385	0,041
Control	31	38,74	13,48	53,58	14,33		

Based on the ANCOVA analysis, the obtained significance value was 0.041 (<0.05), indicating that the SETS-based Problem Based Learning (PBL) model had a significant impact on improving students' cognitive learning outcomes. Cognitive abilities were measured through pretest and posttest scores, where the experimental class achieved an average pretest score of 40.84 compared to 38.74 in the control class. After treatment, the experimental class reached an average posttest score of 62.00, while the control class scored 53.58.

Cognitive ability itself refers to an individual's capacity involving mental processes such as thinking, remembering, and understanding (Kusnandar, 2019). The improvement in cognitive learning outcomes among students in the experimental class was attributed to the implementation of the SETS-based PBL model, as this approach can foster students' problem-solving skills during classroom learning activities (Asiyah et al., 2021). SETS-based learning also leads students to think broadly and make decisions in solving problems related to everyday life.

According to Eliyanti et al. (2019), students are trained to be sensitive to the environment and equipped with the ability to connect scientific knowledge with other elements contained in SETS.

Similarly, Sari et al. (2020) found that integrating SETS into inquiry-based learning significantly improved students' analytical and reasoning abilities in environmental topics. In addition, Rahayu and Yuliana (2021) reported that students taught using a SETS-oriented approach demonstrated higher conceptual understanding and retained learning outcomes longer than those taught conventionally. These findings align with the present study, confirming that SETS-based models not only enhance cognitive abilities but also strengthen students' awareness of the interconnectedness between science, technology, society, and the environment.

Based on the research process and findings, some recomendation can be provided as follows:

1. Pedagogical Implications: The results suggest that integrating the SETS approach into PBL can be adopted by teachers to promote deeper scientific reasoning, environmental awareness, and critical thinking among students, particularly in agricultural-industrial schools. Teachers are encouraged to design problem-based learning activities that incorporate SETS elements to make lessons more relevant, engaging, and meaningful.
2. Limitations: This study was limited to a single school context; therefore, the generalizability of the results remains constrained. Factors such as student background, teacher competence, and school infrastructure may have influenced the effectiveness of the model's implementation.
3. Future Research Directions: Further studies are recommended to explore the long-term impact of SETS-based PBL on students' retention of knowledge and its influence on affective learning outcomes, such as motivation, collaboration, and environmental attitudes. Future research across diverse educational levels and learning contexts would also help strengthen the empirical evidence supporting this instructional approach.

CONCLUSION

The findings of this study indicate that the integration of the *Science, Environment, Technology, and Society* (SETS)-based *Problem-Based Learning* (PBL) model had a significant effect on improving both students' critical thinking skills and cognitive learning outcomes in Grade X classes within agricultural-industrial settings. The results of the non-parametric Mann–Whitney test (sig. = 0.002 < 0.05) confirmed that the SETS-based PBL model effectively enhanced students' critical thinking abilities. Similarly, the ANCOVA test (sig. = 0.041 < 0.05) demonstrated that the model significantly improved students' cognitive learning outcomes. Integrating the SETS framework into PBL encourages students to connect scientific concepts with real-world contexts while fostering environmental awareness and socio-technological understanding. Consequently, learning extends beyond content mastery to promote higher-order thinking, contextual problem solving, and meaningful engagement with socio-environmental issues.

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