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Optimising Biology Learning Outcomes of Grade X Students at MAN 1 Pamekasan through the Implementation of the Problem-Based Learning (PBL) Model

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Abstract
Low cognitive learning outcomes among students in Madrasah Aliyah continue to be a challenge for meaningful learning in biology. This study aimed to enhance the cognitive learning outcomes of Grade X students at MAN 1 Pamekasan by applying the Problem-Based Learning (PBL) model. This classroom action research employed the Kemmis and McTaggart model and was conducted in two cycles in one Grade X class at MAN 1 Pamekasan; each cycle consisted of planning, action, observation, and reflection stages. The research instruments were essay and short-answer tests covering cognitive domains C1 to C4. The results showed an increase in the students' mean score from 72.8 in Cycle I to 81.7 in Cycle II. The percentage of learning mastery increased from 82.6% to 87.0%. A paired-sample t-test indicated a statistically significant improvement ($t(22) = 2.64$, $p = 0.008$) with a medium effect size ($d = 0.549$). These findings indicate that the PBL model is effective for improving students' cognitive learning outcomes in Biology learning in madrasah aliyah.

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Introduction

Cognitive learning outcomes are an important indicator for assessing the success of Biology learning because they reflect students' level of knowledge mastery and the quality of their thinking processes. Cognitive learning outcomes are not only related to the ability to recall biological terms, concepts, and processes, but also include higher-order thinking skills, such as analyzing relationships among components within life systems, evaluating scientific evidence, and formulating solutions to health and environmental problems. Within the science literacy framework, students are expected to explain phenomena scientifically, design and/or evaluate investigations, and critically interpret data and evidence to make informed decisions (OECD, 2019). Therefore, conceptual understanding requires students to connect Biology content with real-life phenomena so that learning becomes meaningful and does not stop at memorization (Pandiangan, 2020). Through appropriate learning innovations, students not only acquire biological facts but also develop the ability to understand, relate to, and apply such knowledge critically and creatively in everyday life (Athoillah et al., 2024).

However, cognitive achievement is often suboptimal when conventional, teacher-centred practices still predominate in learning. A teacher-centred pattern tends to make students passive, less trained to ask questions, less accustomed to evidence-based reasoning, and less likely to gain experience in solving authentic problems; as a result, conceptual

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mastery becomes shallow and is easily forgotten. This condition aligns with findings that low cognitive achievement may be influenced by the use of conventional learning models that do not sufficiently stimulate critical thinking and problem-solving activities (Purwasila et al., 2024). Several studies also demonstrate that problem-based learning can enhance critical thinking skills by positioning students as active problem solvers through stages of analysis, information seeking, and conclusion (Anggraeni et al., 2023). In the science context, literature reviews indicate that PBL is effective for improving academic achievement, knowledge retention, and science concept development among learners (Merritt et al., 2017), and has positive effects on learning attitudes (Demirel & Dağyar, 2016). Moreover, an advanced meta-analysis (second-order meta-analysis) reported that PBL generally has a moderate to strong effect on both cognitive and affective learning outcomes compared to other approaches (Koçoğlu & Kanadlı, 2025).

Problem-Based Learning (PBL) is a learning model that presents contextual problems as learning triggers, encouraging students to collaborate, develop hypotheses or alternative solutions, seek and evaluate information, and present results with logical arguments. The teacher's role shifts to that of a facilitator who guides the inquiry process and ensures that learning proceeds systematically. PBL is considered relevant to Biology learning because it can connect abstract concepts (e.g., ecosystems, organ systems, and biotechnology) with real issues encountered by students. Studies in secondary education have shown that PBL supports the development of science skills through practices such as questioning, planning investigative steps, collecting data, and communicating findings (Pozuelo-Muñoz et al., 2023). Additionally, a meta-analysis in science learning has also reported that PBL is effective in improving academic achievement and science learning outcomes (Uluçınar, 2023). Evidence from Indonesia further supports the conclusion that the application of PBL can enhance the higher-order thinking skills required in science/Biology learning (Anazifa & Djukri, 2017).

Based on observations in one Grade X class at MAN 1 Pamekasan, students' cognitive learning outcomes in Biology were still relatively low. Initial observations indicated that the mean student score was only 57.8, and only 34.8% of students met the Minimum Mastery Criterion (KKM) of 70. This situation indicates the need for a learning strategy that is more active, contextual, and cognitively demanding. Therefore, Problem-Based Learning (PBL) was proposed as an alternative approach that has been proven effective in improving higher-order thinking skills and students' active engagement in solving contextual problems (Lasminawati et al., 2023). Accordingly, this study is important for evaluating the effectiveness of implementing the PBL model in improving cognitive learning outcomes in Biology among students in Class X-A at MAN 1 Pamekasan, while also providing empirical evidence for teachers in selecting a more appropriate learning model to enhance the quality of the learning process and outcomes.

Research Method

This study employed a Classroom Action Research (CAR) approach, utilizing the Kemmis and McTaggart model, which comprises four stages: planning, implementing actions, observation, and reflection (Tanjung et al., 2024). The research was conducted in two cycles, each lasting two weeks. The participants were 23 students in Class X-A at MAN 1 Pamekasan in the 2024/2025 academic year. The main instrument was a written test administered at the end of each cycle. The test consisted of essay and short-answer items that measured cognitive abilities from C1 (remembering) to C4 (analyzing), based on Bloom's Taxonomy.

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Learning-outcome data were analyzed quantitatively by calculating the class mean and the percentage of mastery learning in each cycle. Students were classified as achieving mastery if they obtained a score of 70 or higher in accordance with the Minimum Mastery Criterion (KKM) applied at MAN 1 Pamekasan. To test the significance of differences in learning outcomes between cycles, a one-tailed paired-sample t-test was conducted using JASP software (version 0.18) (Hardisman, 2020). The t-test was used to determine whether there was a statistically significant improvement in learning outcomes from Cycle I to Cycle II. In addition, effect size was calculated using Cohen's d to measure the strength of the PBL model implementation (Field et al., 2025).

Research Findings and Discussion

The implementation of the Problem-Based Learning (PBL) model across two cycles showed an improvement in the cognitive learning outcomes of Class X-A students at MAN 1 Pamekasan. In Cycle I, the students' mean score was 72.8, with 82.6% (19 out of 23 students) achieving the Minimum Mastery Criterion (KKM). In Cycle II, the mean score increased to 81.7, and mastery learning was achieved by 87.0% (20 out of 23 students). The mean learning outcomes from Cycle 1 to Cycle 2 are presented in Table 1, and the improvement is visualized in Figure 1.

Table 1. Mean Learning Outcomes in Cycle I and Cycle II

Cycle	N	Mean	Median	SD	SE
Cycle 1	23	72.8	72	13.3	2.77
Cycle 2	23	81.7	81	11.2	2.33

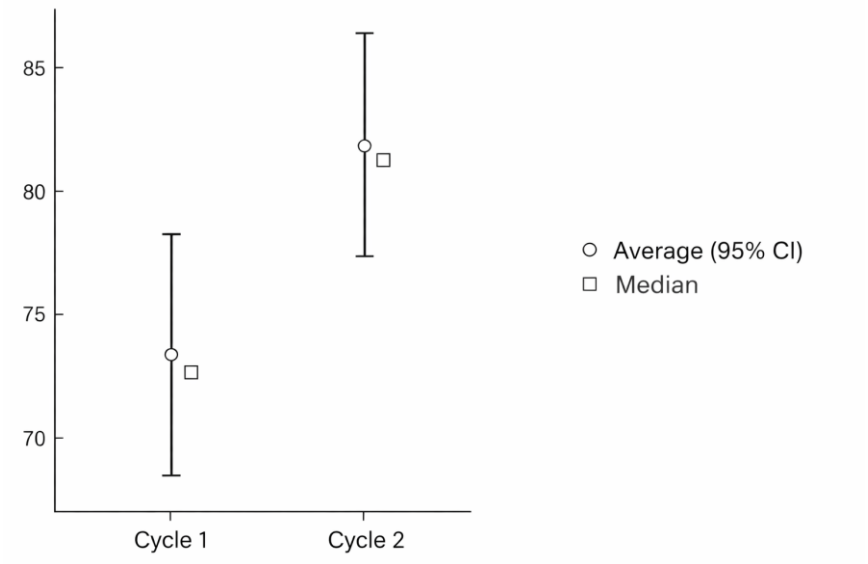

Figure 1. Mean Learning Outcomes from Cycle 1 to Cycle 2.

Inferential analysis using a one-tailed paired-sample t-test showed that the increase from Cycle I to Cycle II was statistically significant ($t(22) = 2.64$; $p = 0.008$) with a medium effect size (Cohen's $d = 0.549$)(Table 2). This indicates that implementing the PBL model had a meaningful impact on improving students' cognitive learning outcomes.

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Table 2. Statistical Increase in Mean Learning Outcomes from Cycle 1 to Cycle 2

Measure 1	Measure 2	Test	t	df	p	Effect size (type)	Effect size (value)
Cycle 1	Cycle 2	Student's t (paired)	-2.64	22	0.008	Cohen's d	-0.549

Note. H_a: μMeasure 1 − Measure 2 < 0

The increase in the cognitive learning outcomes of Class X-A students at MAN 1 Pamekasan following the implementation of the Problem-Based Learning (PBL) model demonstrates a clear and positive effect. The mean score increased from 72.8 in Cycle I to 81.7 in Cycle II, while the percentage of mastery learning increased from 82.6% to 87.0%. Statistically, this improvement was significant ($p = 0.008$) and was categorized as moderate based on the effect size value (Cohen's $d = 0.549$). This reinforces that PBL can be a strategic alternative to address low cognitive achievement at the senior high school/madrasah aliyah level, particularly in Biology.

These findings are consistent with Takndare (2024), who reported that PBL strengthens students' metacognitive skills through meaningful collaborative and problem-oriented experiences. A study by Sriamah et al. (2020) also showed that PBL can improve academic achievement and students' motivation in science learning. Sakti and Luthfiyah (2024), as well as Septiani et al. (2024), likewise found that PBL implementation can improve mastery learning and students' active participation in the classroom. The effectiveness of PBL in improving cognitive learning outcomes can be explained through the constructivist principles underlying the model. PBL encourages students to construct knowledge through exploration, discussion, and reflection on authentic and relevant problems. Interaction in small groups and individual responsibility for problem-solving help develop a deeper understanding of Biology concepts (Fitria & Indra, 2021). This finding is consistent with the evaluation results using Bloom's Taxonomy-based items, which measure lower to mid-level cognitive abilities.

The effectiveness of PBL in improving cognitive learning outcomes can also be understood in terms of the nature of conceptual understanding in Biology. Understanding Biological concepts is closely related to the ability to connect information across levels of biological organization, comprehend dynamic processes in biological systems, and apply these principles in real-world contexts (Widayanthi et al., 2024). PBL provides an authentic and challenging learning context in which students are encouraged to ask questions, examine information sources, and formulate solutions independently and collaboratively (Irwansyah & Perkasa, 2022). This process stimulates active engagement and reflective thinking, thereby strengthening higher-level information processing. Furthermore, group discussion and presentation of problem-solving results provide opportunities for students to build arguments based on logical and structured biological understanding. These activities activate cognitive processes such as analysis, synthesis, and evaluation. PBL not only helps students remember and understand Biology concepts but also encourages them to think critically, make connections among concepts, and apply knowledge meaningfully across contexts (Suhermi et al., 2025).

Although the results are encouraging, this study has several limitations. The focus was limited to cognitive aspects, while other dimensions, such as scientific process skills,

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scientific attitudes, or communication skills, were not examined. In addition, the two-cycle duration may not be sufficient to observe the long-term impact of PBL on concept retention and the development of independent learning dispositions. Further studies with longer time frames and multidimensional measurements are recommended to obtain a more comprehensive understanding of PBL effectiveness in Biology learning in madrasah aliyah.

Conclusion

Based on descriptive and inferential analyses, it can be concluded that implementing the Problem-Based Learning (PBL) model significantly improved students' cognitive learning outcomes in Biology. The mean score and the percentage of students achieving mastery increased meaningfully from Cycle I to Cycle II. These findings indicate that PBL is an effective approach for building conceptual understanding in Biology through students' active engagement in solving real-world problems.

Recommendations

Further research is recommended to broaden the focus to other variables, such as scientific attitudes, science process skills, or student collaboration, and to employ more extended time frames to test the stability of PBL impacts.

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