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The Influence of the Problem Based Learning (PBL) Model with a Metacognitive Approach on Self-Regulated Learning (SRL) and Learning Outcomes

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Abstract: The implementation of Problem Based Learning (PBL) supported by a metacognitive approach has the potential to not only improve student learning outcomes but also develop Self-Regulated Learning (SRL) abilities. This study aims to examine the implementation of the Problem Based Learning (PBL) learning model with a metacognitive approach on student learning outcomes and self-regulated learning on Virus material. The study used a quasi-experimental method with a pretest-posttest control group design. The research subjects consisted of two classes, namely the experimental class given PBL treatment with a metacognitive approach, and the control class using the discovery learning model. Data analysis used an independent sample t-test and Pearson product moment with a significance level of 0.05. The results of the study on the effect of the application of PBL with a metacognitive approach on learning outcomes showed a sig. 0.00 <0.05. The results of the study on SRL showed that it was in the sufficient category. The results of the study on the relationship between SRL and learning outcomes showed a sig. 0.00 <0.05. Based on data analysis, it can be concluded that the application of the PBL model with a metacognitive approach has an effect on students' SRL abilities and learning outcomes. The SRL category of students in the experimental class was higher than that of the control class and was in the sufficient category. There is a significant relationship between SRL and student learning outcomes.

Keywords: Learning outcomes; Metacognitive; Problem based learning; Self-Regulated Learning; Viruses

Introduction

Self-Regulated Learning (SRL) is very important in the student learning process because students who are involved in SRL will be able to control their own learning process (Azevedo & Gašević, 2019). Students who are able to manage themselves in their learning activities will be able to learn actively and their motivation will grow (Moning & Roelle, 2021; Glogger-Frey et al., 2022). This will be able to bring students to continue the learning phases such as the preparation phase, performance phase, and assessment phase (Moreno-Marcos et al., 2020; Glogger-Frey et al., 2022). Self-regulated students have the most effective cognitive learning activities, both in practice, elaboration, and in terms of note-taking (Jansen et al., 2019; Matcha et al., 2020). Based on the results of interviews conducted with biology teachers at SMA Negeri 3 and SMA Negeri 15 Takengon, Aceh Tengah Regency, in the odd semester of the 2023/2024 academic year, it was found that student learning outcomes were still relatively low during the face-to-face learning process. A biology teacher at SMA Negeri 3 Takengon revealed that only 22 students had completed the learning outcomes based on the virus

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material, while 34 other students did not complete it. Furthermore, at SMA Negeri 15 Takengon, only 26 students completed the learning objectives for the virus material and 32 students did not complete it.

The PBL learning model with a metacognitive approach is considered suitable for implementation in learning activities, especially in improving student independence and learning outcomes (Gusmaweti et al., 2023). Through the implementation of the PBL learning model, it is hoped that students can receive and understand the learning well (Saiz, 2022; Gusti Alfiyanti & Erita, 2023). Through the implementation of the PBL learning model, it is hoped that students will be able to receive and understand the learning well. Metacognition is crucial for successful learning because it allows individuals to manage their cognitive skills and identify weaknesses that can be improved by designing new cognitive skills. (Wang et al., 2021; Nusivera et al., 2025). Metacognitive knowledge can control and stimulate students to know how to learn, determine good learning strategies for them (Kyriakides et al., 2020; Musyaddad & Suyanto, 2019). Independence can encourage students to have the desire to take the initiative in learning, organize learning needs to be able to utilize and find sources related to the material being studied. High student learning independence will help high student learning outcomes (Mulyadi et al., 2025; Suprijono et al., 2025).

Research that examines the metacognitive approach to SRL is a study from Geng et al. (2025) which states that there is a correlation between SRL and metacognition of students in biology subjects in class XI MIPA SMA Negeri 2 Tasikmalaya in the 2021/2022 academic year which is quite strong. Research from Efklides (2011) states that metacognition is closely related to SRL. Research conducted by Tran et al. (2022) and Nusivera et al. (2025) states that metacognition makes it easier for students to organize and guide understanding in learning so that students become accustomed to independent learning. The urgency of this research lies in the need to update and strengthen the learning models and approaches used in the biology learning process, especially virus material, which demands conceptual understanding and high-level thinking skills.

Method

This study uses a quantitative approach with the type of applied research. The method used is Quasi Experimental with a Non-equivalent Control Group Design research design. The groups in this study consisted of an experimental group and a control group. The research sample consisted of 119 students consisting of students at SMA Negeri 3 and SMA Negeri 15 class X Takengon Aceh Tengah. Data analysis used the independent sample t-test, the interval succession method (MSI), and the Pearson product moment correlation test.

Result and Discussion

The Effect of Implementing the PBL Model with a Metacognitive Approach on Improving Learning Outcomes and SRL

The average posttest score in the experimental class implementing the PBL learning model with a metacognitive approach was higher than the average posttest score in the control class. The average pretest score for the experimental class (40) and the control class (37) indicated that students had similar initial abilities. The average posttest score for the experimental class (83) and the control class (52). The average N-Gain score for the experimental class was 0.76, while the control class was 0.43. The results of the data analysis on the differences in learning outcomes between the experimental and control classes can be seen in Table 1.

Table 1. Results of Data Analysis on Differences in Learning Outcomes

Class	Average N-Gain	Test t*	
		t Count	Sig. (2-tailed)
Control	0.43		
Experiment	0.76	23.330	0.000 (Significant)

*Independent sample t-test (Hypothesis accepted, Significant <0.05).

Based on Table 1, the average N-Gain for the experimental class was 0.76, categorized as high, while the control class was categorized as medium with an average N-Gain of 0.43. The results of the normality test for the experimental and control classes were normal (0.200), and the homogeneity test for both classes was also homogeneous (0.067). A significant difference in the mean N-Gain between the experimental and control classes was found (p=0.000). Therefore, it can be concluded that the implementation of the PBL model with a metacognitive approach significantly impacts student learning outcomes and SRL. The results of the study showed no significant difference in the average pretest scores between the experimental and control classes. This is important because it provides a fair basis for comparing the treatments given to each class. After implementing the PBL learning model with a metacognitive approach in the experimental class, there was a significant increase in learning outcomes. Analysis of learning outcomes showed that the control class achieved a low N-Gain.

Meanwhile, the experimental class, which implemented the PBL model with a metacognitive

approach, achieved a high N-Gain. This significant difference indicates that implementing PBL with a metacognitive approach is more effective in improving student learning outcomes than discovery learning. This research is in accordance with the study conducted by (Pertiwi et al., 2022) states that this approach allows students to actively construct knowledge through contextual problem solving while simultaneously training awareness and control of their own thinking processes (metacognition). Research from Abdelrahman (2020) and O'Neill et al. (2025) states that developing metacognitive abilities helps students plan, monitor, and evaluate their learning strategies, thus having a positive impact on improving conceptual understanding. Thus, the high N-Gain value in the experimental class strengthens the evidence that the integration of PBL and metacognitive approaches can encourage more meaningful and in-depth learning.

Student SRL Categories After Implementing the PBL Model

The results of the SRL data analysis in the experimental class, with a standard deviation of 10.20, yielded a mean score ranging from 69 to 74, categorized as quite good for all SRL aspects. The control class, with a standard deviation of 5.40, obtained the highest mean scores for the aspect of seeking help (62), the aspect of environmental arrangement (60) categorized as good, the aspect of time management (49) categorized as poor, and the other SRL aspects categorized as quite good, with scores ranging from 53 to 57. The average scores for each SRL aspect are presented in Figure 1. Learning in the experimental class showed that students' SRL abilities developed quite well in all aspects measured. Students appeared to be better able to set clear learning goals and demonstrate initiative in seeking help when facing difficulties. Their ability to organize the learning environment, manage task-solving strategies, and manage time was also at a fairly good level, although there was still room for improvement, particularly in self-evaluation skills. In general, this pattern indicates that the learning implemented in the experimental class encourages students to be more active, independent, and involved in the process of regulating their own learning (Rincón et al., 2025; Amiruddin et al., 2023).

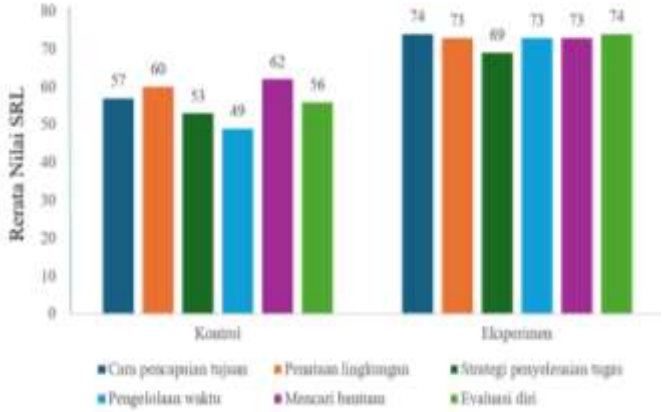

Figure 1. Average value of each SRL aspect in the control and experimental classes

In contrast to the experimental class, SRL achievement in the control class tended to show a more moderate pattern. While some aspects, such as organizing the learning environment and setting goals, did appear to be quite developed, other aspects, such as task strategies, time management, seeking help, and self-evaluation, remained at a lower level. This suggests that conventional learning tends to produce more uniform self-regulation skills, but not as strong as the developments seen in the experimental class. Student independence in the control class appeared to have not yet developed optimally, especially in aspects requiring active initiative from the students (Novalia et al., 2025).

Relationship between SRL and Learning Outcomes

The relationship between SRL and learning outcomes after implementing the PBL model with a metacognitive approach was analyzed using the Pearson Product Moment test. The results of the Pearson Product Moment correlation analysis are presented in Table 2.

Table 2. Pearson Product Moment Correlation Test

Average Learning Outcomes	Average SRL Value	Correlation Value		Meaning
		r Count	r Table	
83	94	0.39	0.21	Significance

The correlation is significant at the 0.05 level (2-tailed). Based on Table 2, the Pearson product-moment correlation test shows that the calculated r-value of 0.258 is greater than the table r-value of 0.256 at the 5% significance level (0.05). This indicates a positive relationship between the implementation of the PBL model and a metacognitive approach on students' SRL. This means that the better the implementation of the PBL learning model coupled with a metacognitive approach, the greater the students' ability to regulate and control their learning process independently. These results indicate that the use of a learning model that emphasizes active student involvement in problem-solving and metacognitive reflection can encourage students to be more independent, planned, and responsible for their own learning process. These results are in line with

research Liu et al. (2020) which shows that the application of the PBL model can improve students' metacognitive abilities and have an impact on improving SRL (Masruro et al., 2021; Cao, 2024).

In problem-based learning, students are encouraged to think critically, plan problem-solving steps, and reflect on their thinking processes. Further relevant research was conducted by Gestiardi et al. (2020) stated that through a metacognitive approach, students learn to recognize and control their own learning strategies, thus making the learning process more effective and independent. Therefore, this significant positive relationship confirms that the integration of the PBL model and the metacognitive approach plays a crucial role in fostering students' self-regulation skills in learning (Payoungkiattikun et al., 2025; Fitrah et al., 2025). Furthermore, based on the calculation results, the average SRL score of students in the control class was lower by a standard deviation than the average SRL score in the experimental class (Tursynkulova et al., 2023; Han, 2025). This difference indicates that students' self-regulation skills in learning in the experimental class were significantly higher than in the control class. The experimental class implemented the PBL model combined with a metacognitive approach, while the control class did not explicitly use this approach (Wu, 2024; Magaji et al., 2024).

The large standard deviation difference in SRL scores in the experimental class indicates that the implementation of PBL and the metacognitive approach had a positive influence on the development of students' SRL skills (Rivas et al., 2022; Shekh-Abed, 2024). This is understandable because PBL encourages students to actively solve problems, design strategies, and reflect on important components of SRL. The metacognitive approach strengthens these processes by helping students recognize and regulate their own thinking processes during learning (Anthonysamy et al., 2025; Guamanga et al., 2025). This strategy encourages students to be more aware of their thinking processes, plan their learning steps, and monitor and evaluate their own understanding, especially when studying abstract concepts such as viruses. These findings reinforce the fact that problem-based learning combined with a metacognitive approach is not only effective in improving learning outcomes but also in fostering student independence and responsibility for their learning (Bhardwaj et al., 2025; Jayanti et al., 2025).

Conclusion

Based on the results of research on the implementation of the PBL model with a metacognitive approach to improving learning outcomes and SRL on virus material, it can be concluded that there is an effect of the application of the PBL model with a metacognitive approach on students' SRL on virus material. The SRL category of students in the experimental class is quite good and the control class is categorized as good, quite good and less good with different standard deviations. There is a positive and significant relationship between the application of the PBL model with a metacognitive approach to the SRL of students in the experimental class.

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Author Contributions

Conceptualization; elementary school; methodology; HR; validation; elementary school; formal analysis; HR; investigation; elementary school; resources; HR; data curation: SD; writing—original draft preparation. AUTP, S.; writing—review and editing: HR; visualization: SD All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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