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Effect of the Problem-Based Learning Model on Problem-Solving Ability in the Materials of Matter and Its Changes

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Abstract: Problem-solving ability is a crucial competency in science learning that still requires improvement, particularly in the topic of matter and its changes. The low level of this skill highlights the need for more innovative and student-centered instructional approaches. This study aims to examine the effect of the Problem-Based Learning (PBL) model on students' problem-solving abilities. This study aims to analyze the effect of the Problem-Based Learning (PBL) model on students' problem-solving abilities in the topic of Matter and Its Changes at SMP Negeri 1 Silaen. The background of this research is the low level of students' problem-solving skills due to the dominance of conventional, teacher-centered learning, which causes students to be passive and less trained in developing problem-solving strategies. This research uses a quantitative approach with a quasi-experimental design of the non-equivalent control group type. The sample was selected using purposive sampling, with Class VII-D (26 students) as the experimental group, taught using the PBL model, and Class VII-E (25 students) as the control group, taught using conventional methods. Data were collected through problem-solving ability tests in the form of essay questions administered during the pretest and posttest. The hypothesis was tested using the Independent Sample T-Test. The results showed a positive and significant effect of the Problem-Based Learning model on students' problem-solving abilities. This is evidenced by the t-value of 4.404 at a significance level of 0.005 and a significance value of 0.000, which is smaller than 0.005; thus, H_0 is rejected. Descriptively, the average posttest score of the experimental class (77.76) is higher than that of the control class (63.76), with a mean difference of 13.437. It can be concluded that the Problem-Based Learning model is effective in improving students' problem-solving abilities through active engagement, inquiry, and the development of critical thinking skills.

Keywords: Matter and Its Changes; Problem-Based Learning; Problem-Solving Ability.

Introduction

Science education plays an important role in developing students' understanding of natural phenomena and essential skills such as critical thinking and problem-solving. In junior high school, science learning is expected not only to emphasize conceptual mastery but also to train students to apply scientific knowledge in solving problems encountered in daily life [1]. Effective learning should be designed to facilitate the aplication of knowledge in meaningful learning contexts [2]. Physics, as a branch of science, is closely related to scientific processes, including observation, problem identification, experimentation, and conclusion drawing, which require students to think logically and systematically [3].

In practice, however, science learning in schools often remains dominated by teacher-centered instructional approaches, particularly conventional lecture-based methods. This learning orientation tends to limit students' active participation and reduce opportunities for them to construct knowledge independently. As a result, students often become passive recipients of information and struggle with problems requiring analytical and critical thinking [4]. The importace of selecting learning strategis that encourage student activity and involvement in the learning process [5]. As a result, students often become passive recipients of information and struggle with problems requiring analytical and critical thinking [6]. Such conditions may hinder the development of higher-order thinking skills, especially problem-solving, a fundamental competency in science education.

Problem-solving skills are essential in helping students understand scientific concepts meaningfully and apply them in various contexts. Problem-solving ability is closely related to students' ability to communicate and process mathematical ideas [7]. Therefore, learning models that actively involve students in identifying and solving problems are required. One instructional model that has been widely recognized for this purpose is Problem-Based Learning (PBL). PBL is a student-centered learning model that uses contextual problems as the starting point of the learning process [8]. Through PBL, students are encouraged to analyze problems, search for relevant information, propose solutions, and evaluate the results collaboratively.

Previous studies have reported that implementing PBL can effectively improve students' problem-solving and critical thinking skills. Eki, Sugiarto, and Ardi (2018) found that Problem Based Learning was effective in improving students' problem-solving ability and curiosity [9]. Similarly, Nurjannah (2017) reported an improvement in students' problem-solving ability through the implementation of PBL in physics learning [10]. By engaging students in problem-

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oriented learning activities, PBL enables learners to connect theoretical knowledge with real-world situations, making learning more meaningful [11]. In addition, PBL encourages students to take responsibility for their own learning, enhances collaboration, and promotes a deeper understanding of scientific concepts.

Problem-solving ability is a fundamental competency required of students in 21st-century learning, particularly in science education. This ability extends beyond conceptual understanding to include critical, analytical, and systematic thinking in addressing real-world problems [12]. However, recent studies over the past five years have consistently reported that students' problem-solving skills remain relatively low, especially in abstract topics such as matter and its changes. This condition indicates a gap between curriculum expectations and actual classroom practices [13].

A growing body of recent research has explored the effectiveness of innovative instructional models in enhancing students' problem-solving abilities, with Problem-Based Learning (PBL) receiving considerable attention. PBL emphasizes learning through authentic problems, encouraging students to actively construct knowledge through inquiry, collaboration, and reflection. Rahmadi et al. report that PBL can also support the development of 21 st-century collaboration skills [14]. Empirical evidence suggests that PBL can improve higher-order thinking skills, including problem-solving and critical thinking. Nevertheless, findings across studies remain inconsistent, particularly regarding their implementation in specific subject-matter contexts and across diverse student characteristics [15].

Based on this review, a research gap can be identified in the limited number of studies examining the effectiveness of PBL in improving students' problem-solving abilities specifically on the topic of matter and its changes at the junior secondary level, particularly within the Indonesian educational context. Moreover, few studies have provided a comprehensive analysis of problem-solving skills using key indicators such as understanding the problem, planning solutions, implementing strategies, and evaluating results. The indicators are consistent with the systematic problem-solving process emphasized in learning research [16].

Therefore, this study aims to examine the effect of the Problem-Based Learning (PBL) model on students' problem-solving abilities in the topic of matter and its changes. The selection of a quantitative research approach aligns with the principles of educational research methodology [17]. This research is expected to contribute both theoretically to the development of innovative instructional models and practically to improving the quality of science teaching and learning [18].

Research Methods

This study employed a quantitative approach using a quasi-experimental design, specifically a non-equivalent control group design. The study involved two groups: an experimental group that received instruction through the Problem-Based Learning (PBL) model and a control group that received instruction using conventional methods. The sampling technique used was total sampling, in which the entire population was included in the sample. The sample comprised Class VII-D (26 students) as the experimental group and Class VII-E (25 students) as the control group. This clarification addresses the inconsistency in the sampling technique previously stated in the abstract [19].

The research instrument was a problem-solving ability test administered as essay questions during both the pretest and posttest. The instrument was developed based on four indicators of problem-solving ability: understanding the problem, planning the solution, implementing the strategy, and evaluating the results. Instrument validity was established through expert judgment involving subject matter experts and science teachers, followed by empirical validation using item analysis. The results indicated that all test items met the criteria for validity. Reliability testing was conducted using a reliability coefficient (e.g., Cronbach's alpha), which demonstrated that the instrument had a satisfactory level of internal consistency.

The research procedure consisted of three main stages: (1) administering a pretest to assess students' initial problem-solving ability, (2) implementing the instructional treatment, where the experimental group was taught using the PBL model through stages including problem orientation, student organization, investigation, development and presentation of results, and evaluation, and (3) administering a posttest to measure students' improvement after the intervention. The treatment was conducted over several instructional sessions in accordance with the allocated time for the topic matter and its changes.

Data analysis was conducted in several steps, including normality testing using the Kolmogorov–Smirnov test, homogeneity testing using Levene's test, and the calculation of learning gains using the normalized gain (N-Gain) score. Hypothesis testing was performed using the Independent Samples T-Test in SPSS to determine whether there was a statistically significant difference between the experimental and control groups. The use of SPSS for statistical analysis follows established guidance for educational data analysis [20].

Results and Discussion

This study was conducted at SMP Negeri 1 Silaen during the 2025/2026 academic year using a quasi-experimental, nonequivalent control group design. The research sample consisted of two intact classes: Class VII-D ($n = 26$), the experimental group, which received instruction through the Problem-Based Learning (PBL) model, and Class VII-E ($n = 25$), the control group, which received conventional instruction (Direct Instruction).

The pretest was administered to determine students' initial problem-solving ability prior to the implementation of the instructional treatment. The analysis revealed that the experimental group obtained a mean pretest score of 47.11, with a highest score of 68 and a lowest score of 31. Meanwhile, the control group achieved a mean score of 43.16, with a maximum score of 67 and a minimum score of 30.

The mean difference of 3.95 points indicates that the initial abilities of the two groups were relatively comparable. From a pedagogical perspective, these findings suggest that students in both classes demonstrated relatively low levels of problem-solving ability in understanding concepts related to matter and its changes. Students generally had difficulty identifying concept-based problems, linking theoretical principles to real-life phenomena, and systematically designing appropriate solutions.

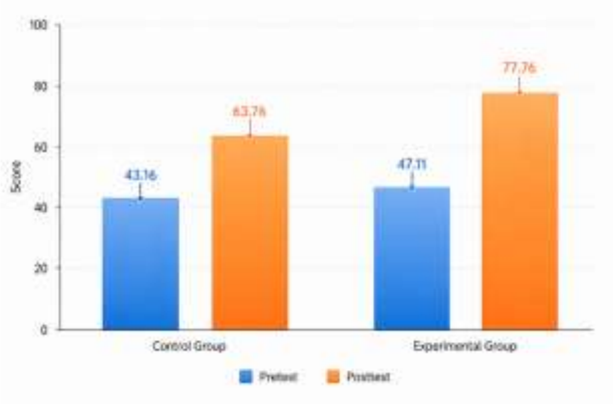

Figure 1. Comparison of Pretest and Posttest Scores Between the Experimental and Control Groups

Following the implementation of the instructional treatment on Matter and Its Changes, a posttest was administered to assess students' final problem-solving ability. The results of the analysis indicate that the mean posttest score of the experimental group increased to 77.76, with a highest score of 93 and a lowest score of 56. In contrast, the control group obtained a mean score of 63.76, with a maximum score of 83 and a minimum score of 50. Compared with the pretest results, the experimental group showed an improvement of 30.65 points, whereas the control group showed an improvement of 20.60 points. This difference in gain scores suggests that students taught using the Problem-Based Learning (PBL) model achieved greater improvement in problem-solving ability than those who received conventional instruction. Quantitatively, the mean difference in posttest scores between the two groups was 13.437 points, indicating a substantial difference in learning outcomes.

The normality test was conducted using the Shapiro–Wilk test in SPSS version 21. The results indicated that all pretest and posttest data in both groups yielded significance values greater than 0.05. Therefore, the data were considered to be normally distributed.

Table 1. Normality Test of Problem-Solving Skills Data in the Experimental and Control Classes

	Class		Shapiro-Wilk		Conclusion
		Statistic	df	Sig.	
Problem-Solving Ability Results	Experimental Pretest	.964	26	.481	Normal
	Control Pretest	.953	25	.298	Normal
	Experimental Posttest	.939	26	.129	Normal
	Control Posttest	.929	25	.081	Normal

Table 2. Homogeneity Test of Problem-Solving Ability Data for the Experimental and Control Groups

Variable	Class	Levene				Conclusion
		Statistic	df1	df2	Sig.	
Problem-Solving Skills	Experimental and Control *Posttest*	0.673	1	41	0.417	Homogen

Table 3. Hypothesis Testing of the Experimental and Control Groups

	Value	t-Count	Sig. (-2tailed)	Mean	Std. Deviation
Problem-Solving Skills	The variances of the two groups are considered equal	4.404	0.000	13.437	3.051
	The variances of the two groups are considered different	4.290	0.000	13.437	3.132

The normal distribution of the data suggests that the students' scores were proportionally dispersed without extreme deviations. This condition satisfies one of the key assumptions for parametric statistical analysis, thereby allowing the use of parametric tests in hypothesis testing. The homogeneity of variance was examined using Levene's Test to determine whether the experimental and control groups had equal variances in posttest scores. The analysis revealed a significance value of 0.417, which exceeds the 0.05 threshold. Therefore, the assumption of homogeneity of variance was satisfied.

From a statistical perspective, meeting the homogeneity assumption allows for the valid application of the independent samples t-test under the "equal variances assumed" condition. Furthermore, comparable variance across groups contributes to stronger internal validity in quasi-experimental research [21].

Thus, the homogeneity test results support the reliability of subsequent hypothesis testing and indicate that the comparison between the PBL and conventional instruction groups was conducted under statistically appropriate conditions. The results showed a t-value of 4.404 with 41 degrees of freedom and a significance value (Sig. 2-tailed) of 0.000. Since the significance value was less than 0.05, the null hypothesis (H_0) was rejected, and the alternative hypothesis (H_1) was accepted. This finding indicates a statistically significant difference in problem-solving ability between the two groups [22-23].

The mean difference of 13.437 points demonstrates that students in the experimental group achieved substantially higher posttest scores than those in the control group. This result suggests that implementing the PBL model had a positive and significant effect on students' problem-solving ability.

The effectiveness of PBL can be explained by its instructional characteristics. PBL engages students in authentic problem situations that require them to analyze information, formulate hypotheses, design solution strategies, and evaluate outcomes. Such processes promote higher-order thinking skills and deeper conceptual understanding. PBL enhances problem-solving competence by encouraging active knowledge construction rather than passive information reception [24-25].

The results of this study demonstrate that the Problem-Based Learning (PBL) model significantly improves students' problem-solving ability in the topic of Matter and Its Changes. The experimental group achieved significantly higher posttest scores than the control group, indicating that PBL was more effective than conventional instruction.

The effectiveness of PBL can be attributed to its student-centered and problem-oriented approach. Through authentic problem scenarios, students actively engage in identifying problems, analyzing concepts, developing solution strategies, and evaluating outcomes. This process promotes higher-order thinking skills and deeper conceptual understanding. The use of stuctured learning models to support active student engagement [26].

In contrast, conventional instruction tends to focus on teacher explanations, which may support factual understanding but provide limited opportunities for analytical thinking and independent inquiry. Although the control group showed improvement, the magnitude of gain was lower than that of the experimental group. Since the assumptions of normality and homogeneity were satisfied, the observed differences can be confidently attributed to the instructional treatment. Overall, the findings suggest that PBL is an effective instructional strategy for enhancing problem-solving skills in junior secondary science education. To strengthen the interpretation, the effect size was also estimated using Cohen's *d*, which indicated a moderate to high effect. This suggests that the observed difference is not only statistically significant but also practically meaningful in the context of classroom learning [27].

A more detailed analysis based on problem-solving indicators reveals that students in the experimental group showed notable improvement across all stages. In the problem-understanding stage, students demonstrated a better ability to identify relevant information. In the planning stage, they were able to design more systematic solution strategies. During the implementation stage, students showed improved procedural accuracy in solving problems, while in the evaluation stage, they became more capable of reviewing and verifying their results.

Conclusion

This study demonstrates that implementing the Problem-Based Learning (PBL) model significantly enhances students' problem-solving abilities in the topic of matter and its changes. The experimental group outperformed the control group, indicating that PBL is more effective than conventional instruction in fostering systematic problem-solving skills. Practically, these findings suggest that teachers should adopt PBL to promote active learning, critical thinking, and student engagement. However, the study is limited by a relatively small sample size and a quasi-experimental design, which may affect the generalizability of the results. Future research is recommended to involve larger sample sizes, employ more rigorous designs, and explore PBL across different subjects and educational levels. Overall, this study provides empirical support for the effectiveness of PBL and contributes to the advancement of innovative teaching practices.

Author's Contribution

N.O.S. Rejeki: Designed the research, conducted data collection, performed data analysis, and prepared the manuscript. R. Tanjung and Y.I. Tanjung: Provided conceptual guidance and supervised the research methodology.

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