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Optimizing Scientific Literacy Through Differentiated Instruction Based on Problem Based Learning (PBL) in Grade VII Students at SMP Negeri 7 Tidore Kepulauan

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Abstract

This study aims to improve students' science literacy at SMP Negeri 7 Tidore Kepulauan through the implementation of differentiated learning based on Problem Based Learning (PBL). The research design used is a quasi-experiment with a pretest-posttest control group. The research sample consisted of two groups: the experimental group, which implemented differentiated learning based on PBL, and the control group, which followed conventional instruction. Data were collected through science literacy tests, classroom observations, and interviews. The analysis results showed a significant improvement in science literacy among students in the experimental group compared to the control group. The average post-test score of the experimental group reached 82.30, while the control group scored 67.46. The independent sample t-test showed a significant difference between the two groups ($p < 0.05$). These findings indicate that the differentiated PBL approach is effective in optimizing students' science literacy skills. The implications of this research support the implementation of learning strategies that are responsive to students' needs within the context of the Merdeka Curriculum.

Keywords: Science Literacy, Differentiated Learning, PBL, Merdeka Curriculum.

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INTRODUCTION

Science education at the junior high school level plays a strategic role in equipping students with a conceptual understanding of scientific knowledge and developing critical, creative, and analytical thinking skills. In this context, scientific literacy includes the ability to understand, evaluate, and communicate scientific information related to real-world phenomena (Suparya et al., 2022). A strong foundation in scientific literacy enables a generation to make rational, evidence-based decisions and enhances students' competence in physics literacy and scientific communication skills (Siombone et al., 2024).

According to Ernawati et al. (2022), the level of scientific literacy among students in Indonesia remains relatively low. Many students struggle to grasp basic science concepts and fail to relate the learning material to everyday life contexts. One of the main causes of this issue is the uniform approach in teaching, which often overlooks the diverse characteristics of students, such as their abilities, interests, and learning styles (Herwina, 2021).

In practice, the "one-size-fits-all" approach is still commonly found in classroom learning (Latifah, 2023). When learning models do not incorporate differentiation, some students may face difficulties in understanding the material,

while others feel unchallenged due to the mismatch with their skill levels (Sari et al., 2023). This situation demands that teachers become more adaptive in designing flexible learning strategies that are responsive to the diverse learning needs of their students (Ferlianti et al., 2022).

One approach considered effective in addressing this challenge is differentiated instruction (Herwina, 2021). This approach allows teachers to adjust the content, process, product, and learning environment based on students' profiles and needs (Atikah et al., 2024). Through this strategy, students can learn in ways that align with their learning styles, interests, and skill levels, making the learning experience more personalized and meaningful. Recent studies have shown that implementing differentiated instruction can enhance scientific literacy and student engagement (Kamal et al., 2021).

The implementation of differentiated instruction should be paired with a learning model that promotes active student engagement (Alhamadi, 2024). One relevant model is Problem Based Learning (PBL) (Aiman, 2020). PBL is a student-centered learning model that begins with solving real-world problems as a trigger for the learning process (Pagala, 2024). In this process, students are encouraged to collaborate, think critically, and construct knowledge through exploration and investigation of contextual issues (Anti & Ikhwan, 2024).

The integration of differentiated instruction and Problem Based Learning (PBL) is expected to create a science learning process that not only addresses individual student needs but also fosters 21st-century skills such as collaboration, communication, and problem-solving (Larasati & Agustina, 2025). Several studies have stated that implementing PBL significantly increases students' motivation and active participation, as well as strengthens the connection between theoretical concepts and real-life applications (Amrilizia et al., 2023).

This approach is highly relevant for SMP Negeri 7 Tidore Kepulauan, which faces challenges in improving scientific literacy, particularly due to the significant variations in students' academic abilities and the limited learning resources available. Although the national curriculum promotes active and student-centered learning, its implementation in the field still encounters various obstacles, especially in applying responsive and contextual learning strategies.

Based on this background, this study focuses on optimizing scientific literacy through the implementation of differentiated instruction based on Problem Based Learning (PBL) among seventh-grade students at SMP Negeri 7 Tidore Kepulauan. The study aims to evaluate the effectiveness of this approach in enhancing students' scientific literacy and to contribute to the development of innovative and inclusive science learning strategies.

RESEARCH METHOD

This study employed a quantitative approach with a quasi-experimental design. The design used was the Nonequivalent Control Group Design, consisting of two groups: the experimental group and the control group. The experimental group received differentiated instruction based on Problem Based Learning (PBL), while the control group received conventional instruction. The study was conducted at SMP Negeri 7 Tidore Kepulauan, North Maluku, during the second semester of the 2024/2025 academic year, specifically between February and April 2025. The

population of this study consisted of all seventh-grade students at SMP Negeri 7 Tidore Kepulauan.

The sampling technique used was purposive sampling, taking into account the academic equivalence of student characteristics and the readiness of teachers to implement the treatment. The sample consisted of two classes: Class VII-A as the experimental group (n = 26) and Class VII-B as the control group (n = 26). The variables in this study included: Independent variable: the differentiated instruction model based on Problem Based Learning (PBL), and Dependent variable: students' scientific literacy skills.

The main research instrument was a scientific literacy test developed based on the literacy indicators from PISA (OECD, 2022), which include: Context – the ability to apply science in daily life; Scientific processes – investigative and reasoning skills; and Content – mastery of science concepts. The instrument was tested for validity and reliability prior to its use in the study. Data collection techniques included:Pretest and posttest to measure the level of scientific literacy before and after the treatment; Observation of the teaching process to ensure fidelity in the implementation of the instructional model; and Documentation as a supporting source for quantitative data.

The data were analyzed quantitatively using SPSS version 25 with the following steps: Normality test – to determine whether the data were normally distributed. The Kolmogorov-Smirnov test was used at a 0.05 significance level; Homogeneity test – to ensure equal variance between the experimental and control groups, a necessary prerequisite for parametric statistical testing; Paired sample t-test – to determine the differences between the pretest and posttest within each group; and Independent sample t-test – to examine differences in scientific literacy outcomes between the experimental and control groups after the intervention. Interpretation of the results was based on the significance values (p-value) and the differences in average scientific literacy scores between the two groups.

Pretest: Before the instructional treatment, all students in both the experimental and control groups were given a pretest to assess their baseline scientific literacy. This test consisted of questions that measured basic understanding of scientific concepts, critical thinking skills, and the ability to communicate scientific ideas. Treatment for the Experimental Group: The experimental group was taught using the differentiated instruction model based on PBL. Each student received science material tailored to their ability level and interests. Students worked in small groups to solve real-life science-related problems. During this process, the teacher facilitated discussions and provided feedback that aligned with each group's specific needs. Meanwhile, the control group was taught using conventional instructional methods. The teacher delivered content through lectures and demonstrations. Students completed individual assignments based on the teacher's instructions without significant modifications to the learning approach.

Posttest After completing the instructional sessions, both groups were given the same scientific literacy test as in the pretest. The purpose of the posttest was to measure the improvement in students' scientific literacy after participating in different instructional models. Scientific Literacy Test: This test was designed to assess students' levels of scientific literacy before and after the implementation of

differentiated instruction based on PBL. It consisted of various types of questions, including multiple-choice, short answers, and analytical questions that evaluated students' understanding of basic science concepts, critical thinking skills, and scientific communication abilities. The items were developed in alignment with the indicators of scientific literacy set by PISA (Programme for International Student Assessment) (PISA, 2022).

RESULTS AND DISCUSSION

This study aims to determine the effectiveness of implementing a differentiated instruction model based on Problem Based Learning (PBL) in improving the scientific literacy of seventh-grade students. The research findings were obtained through pretest and posttest assessments conducted on two groups: the experimental group and the control group.

Figure 1. Experimental Group

Figure 2. Control Group

1. Pretest and Posttest Results of Scientific Literacy

Table 1. Mean Scores of Pretest and Posttest in Scientific Literacy

Group	N	Pretest Mean	Posttest Mean	Difference	Description
Experimental	26	56.15	82.30	26.15	Significantly increased
Control	26	54.88	67.46	12.58	Increased, but to a lesser extent

The table above presents the comparative data of the average pretest and posttest scores of scientific literacy between two groups, each consisting of 26 students. The experimental group showed a significant improvement in scientific literacy. Their mean pretest score was 56.15, which increased to 82.30 in the posttest, resulting in a difference of 26.15 points. This indicates that the implementation of differentiated instruction based on Problem Based Learning (PBL) has a positive and effective impact on improving students' scientific literacy.

Meanwhile, the control group also experienced an improvement, although not as substantial as the experimental group. Their mean pretest score was 54.88, which rose to 67.46 in the posttest, showing a difference of 12.58 points. The substantial improvement in the experimental group demonstrates that the differentiated PBL approach positively influences students' scientific literacy. This finding is in line with Latifah (2023), who stated that differentiated instruction allows students to learn according to their individual learning styles, interests, and needs. When combined with the PBL model, which emphasizes real-world problem

solving, students become more active, critical, and creative in constructing scientific knowledge (Alhamadi et al., 2024).

Practically, students in the experimental class were more engaged in the learning process as they were given the opportunity to explore solutions to contextual problems they encountered. In other words, PBL provides a more authentic and meaningful learning experience, resulting in a deeper understanding of scientific concepts (Alfath et al., 2023). This is supported by the findings of Fitra (2022), which show that the PBL model can enhance students' motivation and learning independence. In contrast, students in the control class who were taught using conventional lecture-based methods tended to be more passive and less motivated to explore the material in depth. As a result, although there was an increase in scores, it was not as significant as that of the experimental class. This highlights the limitations of one-way instructional approaches that do not address the diverse learning needs of students (Rohimat et al., 2023).

Overall, these findings reinforce the importance of using student-centered learning strategies, such as differentiated instruction and PBL, to enhance scientific literacy. These approaches not only consider the unique characteristics of each student but also empower them to apply scientific knowledge to solve real-world problems.

2. Normality and Homogeneity Tests

Table 2. Normality and Homogeneity Test Results

Type of Test	Group	p-value	Description
Normality (Kolmogorov-Smirnov, α = 0.05)	Pretest Experimental	0.120	Normal (p > 0.05)
	Pretest Control	0.086	Normal (p > 0.05)
	Posttest Experimental	0.143	Normal (p > 0.05)
	Posttest Control	0.097	Normal (p > 0.05)
Homogeneity (Levene's Test)	Pretest	0.312	Homogeneous (p > 0.05)
	Posttest	0.418	Homogeneous (p > 0.05)

The table presents the results of two essential statistical assumption tests prior to further analysis: the normality test and the homogeneity test. These tests aim to ensure that the data meet the requirements for conducting parametric statistical tests such as the t-test.

a. Normality Test (Kolmogorov-Smirnov, α = 0.05)

The normality test was conducted to determine whether the pretest and posttest scores in each group were normally distributed. Pretest Experimental: p = 0.120 Pretest Control: p = 0.086 Posttest Experimental: p = 0.143 Posttest Control: p = 0.097 Since all p-values are greater than 0.05, it can be concluded that the data in all four groups are normally distributed. This indicates that the assumption of normality is not violated.

b. Homogeneity Test (Levene's Test, α = 0.05)

The homogeneity test was conducted to determine whether the variances between the experimental and control groups are homogeneous (equal). Pretest: p = 0.312 Posttest: p = 0.418 As both p-values are greater than 0.05, it can be concluded that the data have homogeneous variances in both the pretest and posttest phases.

3. Paired Sample t-Test

To determine improvements within each group, a paired sample t-test was conducted:

Table 3. Paired Sample t-Test Results

Group	t-value	Sig. (2-tailed)	Conclusion
Experimental	12.879	0.000	Significant improvement
Control	6.321	0.000	Significant improvement

The paired sample t-test was used to determine whether there was a statistically significant difference between the pretest and posttest scores within each group (experimental and control). This test was appropriate since the measurements were taken from the same subjects before and after the intervention.

Results for the Experimental Group t-value = 12.879 Sig. (2-tailed) = 0.000 Since the p-value < 0.05, the result is statistically significant. Conclusion There was a significant improvement in students' scientific literacy after participating in differentiated learning based on Problem Based Learning (PBL).

Results for the Control Group t-value = 6.321 Sig. (2-tailed) = 0.000 Similarly, the p-value < 0.05, indicating a statistically significant result. Conclusion There was a significant improvement in scientific literacy in the control group after conventional instruction, although the increase was not as substantial as in the experimental group. These results indicate that both groups showed significant improvements from pretest to posttest (p < 0.05), but the magnitude of improvement was greater in the experimental group.

4. Independent Sample t-Test

To examine the difference in learning gains between groups, an independent sample t-test was conducted:

Table 4. Independent Sample t-Test Results for Posttest Scores and Gain Scores

Variable	t-value	Sig. (2-tailed)	Conclusion
Posttest	4.715	0.000	Significant difference between groups
Gain Score	5.012	0.000	Differentiated PBL learning is more effective

The independent sample t-test was used to determine whether there was a statistically significant difference between two independent groups: the experimental group (using differentiated learning based on PBL) and the control group (using conventional learning).

Results for Posttest Scores t-value = 4.715 Sig. (2-tailed) = 0.000 Since the p-value is less than 0.05, it can be concluded that there is a statistically significant difference between the posttest scores of the two groups. Interpretation: After the treatment, students who participated in differentiated learning based on PBL achieved significantly higher scientific literacy scores than those who received conventional instruction. Results for Gain Scores (difference between pretest and posttest) t-value = 5.012 Sig. (2-tailed) = 0.000 The p-value < 0.05 also indicates a statistically significant difference in the gain scores between the two groups.
Interpretation: The improvement in scientific literacy was significantly greater among students taught using the differentiated PBL approach, demonstrating its higher effectiveness compared to conventional learning.

CONCLUSION

Based on the results of the study, it can be concluded that differentiated learning based on Problem Based Learning (PBL) is proven to be effective in improving the scientific literacy of seventh-grade students. This is evidenced by a significant increase in the posttest scores of the experimental group compared to the control group. The average scientific literacy score of students in the experimental class increased from 56.15 to 82.30, whereas in the control class it only increased from 54.88 to 67.46. This difference in improvement indicates that the differentiated PBL approach has a stronger positive impact on students' scientific literacy skills. This learning model enables students to learn according to their readiness, interests, and learning styles, while simultaneously fostering critical thinking, collaboration, and problem-solving skills through a contextual, problem-based approach. The implementation of this strategy also encourages active student participation in the learning process and creates a more meaningful and enjoyable learning environment. Therefore, differentiated learning based on Problem Based Learning is recommended as an innovative alternative for enhancing students' scientific literacy at the lower secondary education level, particularly in supporting the implementation of the Merdeka Curriculum, which emphasizes student-centered learning.

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