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The Influence of the Problem-Based Learning Model With a Differentiated Approach on the Problem-Solving Ability of Sound Wave Concepts of High School Students

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ABSTRACT

Problem-solving skills are important skills in physics learning. However, learning practices in schools are still dominated by conventional methods that are less able to accommodate differences in learning styles and student readiness levels. Therefore, the application of the Problem Based Learning (PBL) model with a differentiated approach is seen as effective in improving students' critical, creative, and analytical thinking skills, especially in sound wave materials. This study uses a quantitative method with a quasi-experiment design. The subject of the study was grade XI students of SMA Negeri 1 Kabila which consisted of one experimental class and two replication classes. The research instrument is in the form of pretest and posttest essay questions to measure problem-solving skills. Data analysis was carried out through Liliefors normality test, Alpha Cronbach reliability, paired sample t-test, and N-Gain calculation. The results of the study showed a significant increase in the average pretest and posttest scores in all classes. The normality test states that the data is normally distributed, while the reliability test confirms that the instrument is classified as reliable. The hypothesis test proved that H_0 was rejected, with an average N-Gain of more than 0.7 which meant a very high increase. Thus, the application of the differentiated PBL model has been proven to have a positive effect on problem-solving skills and encourage students to be more active, involved, motivated, and able to solve contextual problems according to learning styles.

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INTRODUCTION

Education is a conscious and planned effort to create a learning atmosphere that allows students to develop their potential optimally (Law No. 20 of 2003). In science learning, especially physics, this potential can be honed through understanding concepts and high-level thinking skills. Physics itself is an important foundation for the development of science, so understanding its concepts is not enough just through memorization, but requires learning experiences that emphasize discovery and problem-solving (Aziziyah et al, (2022); Kusdiastuti et al., 2019). However, in practice many students still consider physics to be a difficult subject. They tend to memorize formulas without understanding the meaning of concepts in depth, so they have difficulties when facing complex problems. This condition has an impact on students' low problem-solving skills, even though these skills are one of the main goals of physics learning (Safitri, R & Fauziah, 2021). One of the models that is believed to be able to overcome these problems is Problem Based Learning (PBL). This model emphasizes the active involvement of students in identifying, analyzing, and solving real problems, so as to develop critical and systematic thinking skills (Rosana, 2020). However, the effectiveness of PBL still depends on the suitability of the strategy with the characteristics of the students. Many teachers still apply a uniform approach without paying attention to the differences in learning styles, interests, and readiness of students, which actually makes students passive Dhera et al, 2024; (Aulia, F. N. & Amin, 2020).

The differentiated approach is present as a solution by adjusting learning strategies to the learning profile of students, both in terms of learning styles, interests, and readiness levels. Through differentiation, teachers can create more adaptive learning so that all students have an optimal opportunity to develop critical thinking and problem-solving skills (Sukamti et al., 2019); Fitriyah & Bisri, 2023; Hidayah et al., 2024). Therefore, the integration of PBL with a differentiated approach is a potential strategy in improving students' problem-solving abilities in physics learning.

Based on this background, this study aims to analyze the effect of the application of the Problem Based Learning model with a differentiated approach to students' problem-solving abilities on the concept of sound waves in high school.

METHOD

This study uses an experimental method with a one group pretest-posttest design. The subject of the study is grade XI students of SMA Negeri 1 Kabila in the even semester of the 2024/2025 school year. The independent variable in this study is the application of the Problem Based Learning (PBL) model with a differentiated approach, while the bound variable is the student's problem-solving ability. Data was collected through tests (pretest and posttest) as well as non-test instruments. The instrument has gone through a test of the validity of the question item and reliability using the Alpha Cronbach coefficient, and is declared suitable for use. Data analysis was carried out through normality tests, hypothesis tests using paired sample t-tests, and N-Gain calculations to determine the effectiveness of the application of the learning model.

RESULTS

This study examines the influence on students' sound wave concept problem-solving ability. Learning was carried out in three meetings, each of 3 × 45 minutes, for approximately one month. Tests were given before (pretest) and after learning (posttest) in the experimental class and two replication classes. The average results of pretest and posttest scores are as follows:

Table 1. Average score of pretest postest

Class	Pretest	Posttest
Experiment	53,36	80,16
Replication 1	49,44	83,36
Replication 2	37,72	81,44

The results showed a significant improvement in all classes, showing that differentiated PBL was effective in improving students' ability to understand, analyze, and solve problems related to sound wave concepts.

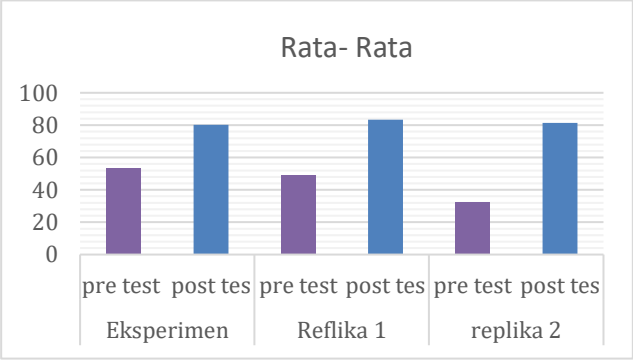

Diagram 1. Average Calculation Results

The increase in grades was consistent in all three classes, both the experimental class and the two replication classes, which showed that the learning interventions applied had a positive influence on student learning achievement. When compared directly, the average posttest score after learning treatment is higher than the pretest score, which illustrates the increase in students' understanding of the concepts taught. Thus, it can be concluded that the application of innovative and adaptive learning models to the needs of students contributes significantly to improving cognitive skills, especially in solving problems related to the concept of subject matter.

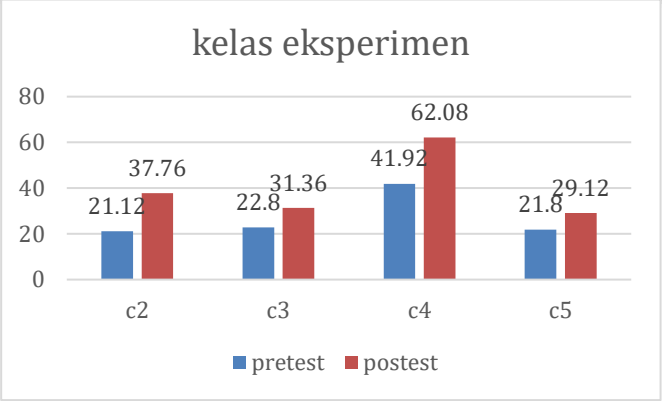

Diagram 2. Pretest and Posttest Results Based on Cognitive Level

Based on the comparison chart of students' problem-solving ability scores between pretest and posttest in the experimental class, a significant increase was seen at all cognitive levels, namely C2 (understanding), C3 (applying), C4 (analyzing), and C5 (evaluating). The most notable increase occurred at the C4 level, from 41.92 to 62.08, which showed that students' ability to analyze and draw conclusions from information increased noticeably. The C2 level increased from 21.12 to 37.76, indicating a deeper understanding of the basic concepts of physics, while the C3 level increased from 22.8 to 31.36, demonstrating the ability to apply the principles of physics in a daily context. The C5 level rises from 21.8 to 29.12, indicating that students are able to assess alternative solutions and reflect on the accuracy of the completion. These findings are in line with opinion (Polya, 2014), (Afriani, R., Rosana, D., n.d.) , which emphasizes the importance of problem understanding, active engagement in problem-based learning, and exploration of solution strategies. Overall, improvements across cognitive domains suggest that the application of PBL with a differentiated approach is effective in supporting the development of overall problem-solving skills

Data Normality Testing

The normality test was carried out to ensure that the posttest data of the three classes (experimental, replication 1, and replication 2) was distributed normally so that it met the requirements of parametric analysis. The test used the Liliefors test at a significance level of 5% ($\alpha = 0.05$).

Table 2. Data Normality Testing

Class	L Count	L Table (α=0.05)	Information
Experiment	0,1556	0,180	Normal distribution
Replication 1	0,1694	0,180	Normal distribution
Replication 2	0,1505	0,180	Normal distribution

The results show all the L values calculated < L tables in all classes so that the posttest data is distributed normally. Thus, the assumption of normality is fulfilled for the entire research class.

Hypothesis Testing

Hypothesis testing was carried out to determine the influence of the Problem Based Learning (PBL) model with a differentiated approach on students' problem-solving abilities. The test used was a single-sample t-test at a significance level of 5% ($\alpha = 0.05$) with a degree of freedom of 24.

Table 3. Hypothesis Testing

Class	t count	t table (α=0.05)	Information
Experiment	2,0129	1,711	H_0 rejected
Replication 1	2,0687	1,711	H_0 rejected
Replication 2	2,6866	1,711	H_0 rejected

The results show that the entire t-value of the t-table is calculated > t, so that the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This means that the differentiated PBL model has a significant effect on improving students' problem-solving skills.

N-Gain Testing

The N-gain test is used to measure learning effectiveness by looking at the increase in pretest scores to normalized posttests. Based on the classification of Hake (1998), the N-gain value ≥ 0.70 is in the high category.

Table 4. N-Gain Testing

Class	Pretest	Posttest	N-Gain	Category
Experiment	53,36	80,16	0,72	Tall
Replication 1	49,44	83,36	0,72	Tall
Replication 2	37,72	81,44	0,72	Tall

All three classes obtained an N-gain value of 0.72 (high category), indicating a significant improvement in learning outcomes after the application of the PBL model with a differentiated approach. Replication class 2 despite having the lowest pretest scores still achieved a high N-gain, confirming that this approach is effective for a wide range of students' initial abilities. The PBL model is differentiated adaptively because it pays attention to the diversity of student characteristics and transformative because it increases low initial achievement to high learning outcomes.

DISCUSSION

This study involved one experimental class and two replication classes to test the consistency of the application of the Problem Based Learning (PBL) model with a differentiated approach. This model combines contextual problem-based learning with differentiation according to students' readiness, interests, and learning styles so as to encourage equal understanding of concepts and higher-level thinking skills (Tomlinson, 2019).

The results showed a significant increase in posttest scores in all three classes with an N-gain value of 0.72 (high category) and t calculation > t table in all classes. The replication 2 class that had the lowest pretest scores still showed the highest improvement, confirming the effectiveness of this approach in bridging students' differences in initial abilities. This model is also relevant to the findings (Edison., n.d.2021) and (Erviana, D., n.d 2022.)that the combination of PBL and differentiation improves understanding of concepts and learning outcomes.

The learning process is designed through authentic problem orientation, group work, self-investigation, presentation of results, and evaluation. Students not only understand the concept of sound waves theoretically, but also relate them to real-life phenomena such as resonance, sound interference, the Doppler effect, and everyday technology. The differentiated approach provides space for students to learn according to their respective learning styles, while teachers act as facilitators who provide incremental support as needed (Vygotsky, n.d.)

The average posttest score in all three classes was above the KKM (≥75): experiment 80.16; replication 1 83.36; replication 2 81.44. A large pretest–posttest score difference indicates a significant increase in problem-solving ability. The differentiated PBL syntax also supports the completeness of learning and collaborative work (Jamila, 2023).

This approach has a positive impact not only on cognitive outcomes, but also on affective and social aspects: increased activeness, confidence, communication skills, and cooperation. Some students whose scores are close to KKM are influenced by low motivation and involvement, according to the findings (Nurfadillah, n.d.2023)and (Suharto, A., n.d.)2021. Teachers can overcome this by differentiating materials, methods, and media according to individual needs, in line with the principles of equitable learning of the Independent Curriculum (Ministry of Education and Culture, 2022).

Analysis per cognitive level showed significant improvements in C2–C5 in all grades. In the experimental class, the highest increase occurred in C4 (41.92→62.08); replication 1 on C4 (39.61→63.36); and replication 2 on C4 (24.32→63.2). These results support the view of Polya (2014) and Afriani (2020) that problem understanding is an important stage in problem solving, as well as research (Hidayat, n.d.2020)and (Kurniasari, D., Susilowati, E., & Prasetyo, n.d.2021)about the importance of open-ended question exercises and reflective questions to hone students' analysis and evaluation.

The implementation of PBL is differentiated in line with the principles of the Independent Curriculum which is student-centered, fun, meaningful, and hone 21st century skills such as critical thinking, collaboration, communication, and creativity ((Marlina, n.d.2022); (Fitriana, D., n.d.2023)). Thus, the combination of PBL and differentiation has been proven to be effective and consistently improve the problem-solving ability of high school students on sound wave material.

CONCLUSION

This study proves that the application of the Problem Based Learning (PBL) model with a differentiated approach is effective in improving the problem-solving ability of high school students in sound wave materials. The results showed a significant increase in posttest scores in all classes with an N-gain value of 0.72 which was included in the high category and the calculated t value was greater than the t table at a significance level of 5 percent. The consistency of the results across the two replication classes suggests that this model can be applied to a wide range of characteristics of students with comparable positive outcomes. The application of this model also has an impact on improving cognitive abilities from C2 to C5 evenly, especially at the analysis level (C4), as well as making a positive contribution to affective and social aspects such as activeness, confidence, communication skills, and student cooperation. The differentiated approach allows learning to be more adaptive according to the needs and learning characteristics of students, so that it is in line with the principles of the Independent Curriculum that is student-centered and hone 21st century skills. Thus, the differentiated PBL model has been proven to be adaptive, consistent, and effective in accommodating students' differences in initial abilities, improving understanding of physics concepts, and developing high-level thinking skills and students' character as a whole.

SUGGESTION

Based on the results of this study, teachers are advised to implement the Problem Based Learning (PBL) model with a continuous differentiated approach to other material at the high school level because it has been proven to be effective in improving students' problem-solving abilities and high-level thinking skills. Teachers should also map learning styles and student readiness levels from the beginning so that learning differentiation can be more targeted. In addition, schools can support the implementation of this model by providing contextual learning facilities, audio-visual media, and sufficient time for discussion and exploration. Further research is suggested to expand the scope of subjects and learning materials, examine other variables such as learning motivation or 21st century skills more specifically, and explore the application of these models to different levels of education. With the right policy and innovation support, the differentiated PBL model has the potential to become a sustainable learning strategy to improve the quality of education.

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