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Effectiveness of Differentiated Learning Strategies with The Problem Based Learning Model in Improving Students' Learning Outcomes

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Abstract – *The topic of work and energy is one of the fundamental aspects of physics education, but many students have difficulty understanding its abstract concepts. This study explores the effectiveness of differentiated learning strategies combined with the Problem-Based Learning (PBL) model to improve students' understanding of work and energy at Sekadau Hilir State Junior High School 8. The research used a pre-experimental design with a one-group pretest-posttest approach, involving 36 eighth-grade students selected through purposive sampling. Data were collected through pre- and post-intervention tests and questionnaires, focusing on the student's conceptual understanding of the material. The intervention involved four sessions, with the PBL model tailored to students' individual learning styles. The results demonstrated a significant improvement in students' learning outcomes, as indicated by the posttest scores (mean = 82.22) compared to the pretest scores (mean = 33.47), with a p-value of 0.000, indicating a statistically significant difference. The effectiveness of the intervention was further supported by a high Cohen's effect size of 3.650, categorizing it as highly effective. The study concludes that differentiated learning, when integrated with the PBL model, effectively enhances students' understanding of complex physics topics. This approach not only addresses diverse learning styles but also encourages active participation and problem-solving, making it a promising strategy for improving science education outcomes in junior high schools. Future studies should explore the broader application of this model to other physics topics to confirm its generalizability.*

Keywords: *differentiated learning; learning outcomes; problem-based learning*

I. INTRODUCTION

The topic of work and energy is one of the fundamental in physics education, as it introduces key concepts such as force, motion, and energy transformation. However, due to its abstract nature, many students find these concepts challenging to grasp (Rivaldo et al., 2020). Differentiated learning strategies can be particularly effective for teaching such complex topics, as they allow teachers to accommodate students' diverse learning needs and styles. By incorporating various instructional techniques such as visual aids, hands-on activities, and collaborative tasks these strategies can enhance student engagement and comprehension (Dalila et al., 2022).

Learning in the classroom is a dynamic process that involves interaction between teachers and students. However, students' ability to absorb knowledge can vary significantly, necessitating a supportive learning environment. This may include peer support or study groups where students can exchange ideas, especially in science subjects, which often involve complex concepts and calculations (Hidayana et al., 2022). Natural science, in particular, requires an in depth understanding of various principles and laws (Hidayah et al., 2020).

A preliminary study at Sekadau Hilir State Junior High School 8 revealed that, despite the school's "A" accreditation, students' learning outcomes in science particularly in the topic of work and energy were suboptimal. This conclusion was drawn from interviews with two science teachers, document analysis of daily test scores, and direct classroom observations. The interviews indicated that the average score for this topic was 66, below the school's Minimum Completion Criteria of 70. Furthermore, classroom observations revealed that the lessons were predominantly teacher-centered, with students mainly engaged in note-taking and limited active participation. This lack of engagement led to students being inattentive and uninterested in the lessons, ultimately affecting their learning outcomes.

The traditional teacher-centered approach has proven ineffective in fostering deep understanding and engagement. This highlights the need for alternative teaching methods, such as differentiated learning, which tailors' instruction to students' individual needs and promotes more active, student-centered learning. Historically, traditional teacher-centered methods mainly lectures, and note-taking have been the primary approaches in classrooms. However, these methods fail to address students' diverse learning needs, particularly for complex topics like work and energy (Sulastry et al., 2023). As a result, students often struggle to understand the material, leading to poor academic performance (Lamalelang, 2017). Therefore, teaching strategies need to be more dynamic, providing frameworks that allow for greater student involvement and engagement.

To address these issues, this study introduces differentiated learning in conjunction with the Problem-Based Learning (PBL) model. Differentiated learning adapts instruction to students' learning profiles, while PBL encourages active student engagement by solving real-world problems. According to Tomlinson (2000) in Asriadi et al. (2023), PBL and differentiated learning together can enhance critical thinking, student engagement, and overall learning outcomes. In PBL, students investigate real-world problems, developing practical solutions while learning core content (Syamsidah & Suryani, 2018). Asdar (2020) demonstrated the effectiveness of PBL, showing an average score increase from 12.82 to 17.15, proving its positive impact on student outcomes.

In line with this, Miqwati et al. (2023) found that differentiated learning significantly improved students’ science outcomes, with scores rising from 39.1% in the pre-cycle to 78.2% in cycle 1, and 87% in cycle 2 (Miqwati et al., 2023). Furthermore, previous research on the PBL model has shown that it enhances students’ science process skills, as reported by Noviyanti et al. (2023), namely an increase in scores from 28.90 to 72.00 after implementing PBL. What makes this study unique is the combination of differentiated learning with the PBL model, specifically targeting the topic of work and energy. While prior studies, such as those by Miqwati et al. (2023) and Noviyanti et al. (2023), have explored the individual effects of differentiated learning and PBL on student outcomes, few studies have examined their combined effect on a specific, challenging topic like work and energy in junior high school physics. This research fills this gap by providing empirical evidence on how this integrated approach can improve learning outcomes in a specific context.

Therefore, this study aims to assess how differentiated learning, combined with the PBL model, can enhance students' learning outcomes on the topic of work and energy at Sekadau Hilir State Junior High School 8. By investigating the impact of this approach, the study contributes to the growing body of literature on effective teaching strategies in science education and addresses a significant gap in existing research.

II. METHODE

This section outlines the quantitative approach employed in the study, which utilizes a pre-experimental design, specifically the one-group pretest-posttest design. This design was chosen because it enables a comparison of students' learning outcomes before and after the intervention (Sugiyono, 2019). However, the absence of a control group limits the ability to draw strong causal conclusions, as factors other than the intervention could potentially influence the results.

Pre-experimental designs are often selected in situations where it is not feasible to include a control group or when the primary goal is to gain initial insights into the effect of an intervention. In this study, the main objective was to examine whether there was a measurable improvement in students' understanding of work and energy after the treatment. The choice of a pre-experimental design was made to gain an initial understanding of the intervention's impact on students' learning outcomes despite the limitations of this design. One key limitation is the absence of a control group, which makes it difficult to rule out other factors that might have contributed to the observed changes in students' performance. Without a control group, it is not possible to definitively attribute any changes in learning outcomes solely to the intervention. Other variables, such as student motivation, prior knowledge, or external influences, could have affected the results. Despite these limitations, the study provides valuable insights into the potential effects of the intervention on students' understanding of work and energy, which could inform future research and educational practice.

The subjects of this study consisted of 36 eighth-grade students from Class VIII C at Sekadau Hilir State Junior High School 8, selected through purposive sampling. This class was chosen based on recommendations from the school's science teachers, who identified it as having relatively lower average learning outcomes compared to other classes. Additionally, the distribution of student achievement was relatively uniform across the class, providing a solid basis for examining the effects of the treatment (Sugiyono, 2017). By selecting this class, the research aimed to provide targeted support to students who could benefit from the intervention and assess whether such an intervention could improve their academic performance in physics.

The intervention was carried out over four sessions, each designed to target a specific aspect of the material related to work and energy. The first session served as a pretest aimed at measuring students' prior knowledge of work and energy. The pretest consisted of essay-type questions designed to assess students' understanding of key concepts, such as the definition of work, the physical quantities involved in work, and the basic principles of energy. This baseline measurement allowed the researcher to compare students' learning outcomes before and after the treatment.

The second and third sessions focused on the core topics of work and energy, respectively. In the second session, students were introduced to the concept of work in physics. The teacher explained that work occurs when a force is applied to an object, and the object moves a certain distance. The formula for calculating work (Work = Force × Distance) was introduced, and examples from everyday life were used to illustrate the concept. Students engaged in practical exercises to apply the formula, such as calculating the work done when lifting objects or pushing them across a surface. This hands-on approach helped students connect theoretical concepts to real-life scenarios. Additionally, the teacher facilitated discussions to ensure that students understood the conditions under which work is done and how the direction of force affects the amount of work performed.

In the third session, the focus shifted to energy, with an emphasis on the concepts of kinetic and potential energy. The teacher explained the basic principles of energy, including the law of conservation of energy and how energy can transform from one form to another. The relationship between potential and kinetic energy was discussed, and the relevant formulas (kinetic energy = $\frac{1}{2}mv^2$ and potential energy = mgh) were introduced. To help students grasp these concepts more effectively, the teacher used practical demonstrations, such as rolling a ball down a ramp to illustrate the conversion of potential energy to kinetic energy. Students were then given the opportunity to calculate the kinetic and potential energy of various objects using the provided formulas. This session encouraged active participation and critical thinking as students applied their newly acquired knowledge in various practical contexts.

The fourth session involved administering the posttest, which was identical in structure to the pretest. The posttest aimed to evaluate any changes in students' understanding of work and energy after the treatment sessions. By comparing the pretest and posttest results, the study assessed the effectiveness of the treatment in improving students' knowledge and understanding of these key physics concepts. The posttest consisted of essay questions similar to those in the pretest but with a higher expectation for students to demonstrate a deeper understanding and application of the concepts.

The research instruments used in this study included the pretest and posttest, a questionnaire, and a teaching module. Prior to using these instruments, their validity and reliability were tested to ensure their appropriateness for measuring the intended learning outcomes. The validity of the test items was assessed using Aiken's V formula, with a validity coefficient above 0.8, indicating high validity. The reliability of the instruments was evaluated using Cronbach's Alpha, with a reliability coefficient of $\alpha \geq 0.60$ deemed acceptable for this study. These steps ensured that the instruments were both valid and reliable for measuring students' understanding of the material.

Data collected from the pretest and posttest were analyzed using statistical software (SPSS version 25.0 for Windows). A normality test was performed using the Shapiro-Wilk test, given the small sample size. Based on the results of the normality test, either a Paired Sample T-test or a Wilcoxon Signed Rank Test was used to assess whether there was a statistically significant difference in students' learning outcomes before and after the treatment. According to Creswell & Creswell (2018), "The Shapiro-Wilk test is one of the most powerful methods for assessing normality, particularly for small sample sizes" (Creswell & Creswell, 2018). If the probability value (sig) > 0.05, the data were considered normally distributed; if the probability value (sig) < 0.05, the data were considered not normally distributed. For hypothesis testing, a Paired Sample T-test was used if the data were normally distributed, and the Wilcoxon Signed Rank Test was used if the data were not normally distributed. The effectiveness of the treatment was calculated using Cohen's effect size formula, adopted from Glass, which measures the magnitude of an effect independent of sample size. The effectiveness of the intervention was further evaluated using Cohen's effect size formula, which provided a measure of the magnitude of the treatment effect.

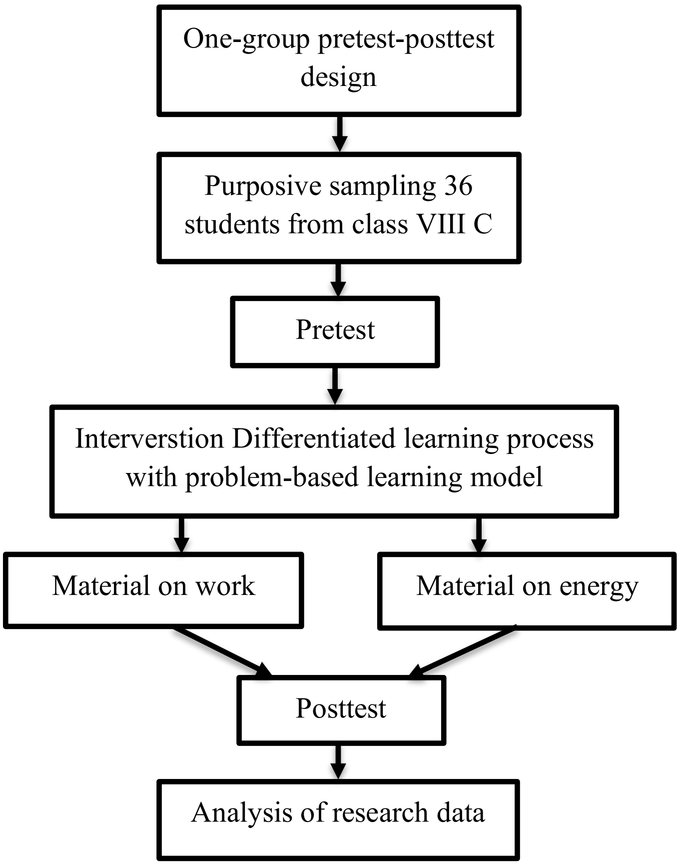

Figure 1. Research steps

III. RESULTS AND DISCUSSION

In this study, the differentiated learning process with the PBL model includes several stages. According to Minasari (2023), the process begins by orienting the problem, which is related to the students' environment. Then, students are divided into small groups according to their learning styles. Following that, students conduct an investigation under the guidance of the teacher to solve the problem. Next, each group presents the results of their investigation to the class, and finally, the teacher and students together evaluate the results of each group's investigation. After administering the pretest, the differentiated learning with the PBL model on the topics of work and energy was implemented, and the posttest was conducted. The pretest and posttest responses from students were collected and scored. Subsequently, the total pretest and posttest scores for each student were analyzed using SPSS version 25.0 for Windows.

Pretest Data Analysis & Posttest

The pretest was conducted to assess the students' learning outcomes regarding the material presented. The pretest scores were analyzed using SPSS version 25.0 for Windows. After processing the pretest data, it was found that the total number of students was 36; the average score was 33.47. The median was 35.00, the lowest score was 10, the highest score was 55, and the standard deviation was 13.353.

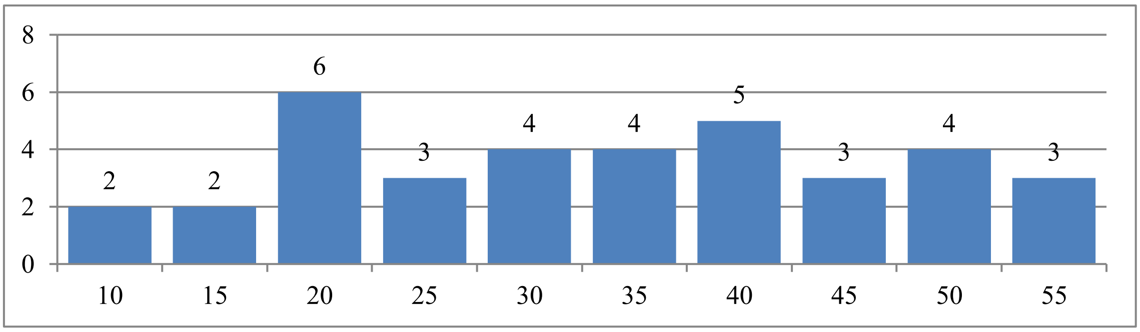

Figure 2. Distribution of pretest scores

Based on the data in Figure 2, the distribution of pretest scores reveals variation in the student's initial understanding of the material. Out of 36 students in Class VIII C, two students scored the lowest (10), indicating a very minimal understanding. The majority of students scored between 20 and 40, reflecting an average level of understanding but still needing additional learning to reach the expected competence. Only a few students reached the highest score (55), indicating that only a small number of students had a fairly good understanding even before the intervention. This score distribution suggests a significant gap in the students' initial understanding. It highlights the need for a learning approach that can address the individual needs of students, such as differentiated learning strategies combined with the PBL model. This approach allows students with lower understanding to receive more support, while those with better understanding can continue to progress at their own pace.

The post-test data were obtained after the intervention was administered to the students. The posttest scores were analyzed using SPSS version 25.0 for Windows. After processing the post-test data, the results showed that the total number of students was 36. The average score was 82.22, the median was 85.00, the lowest score was 60, the highest score was 100, and the standard deviation was 9.369.

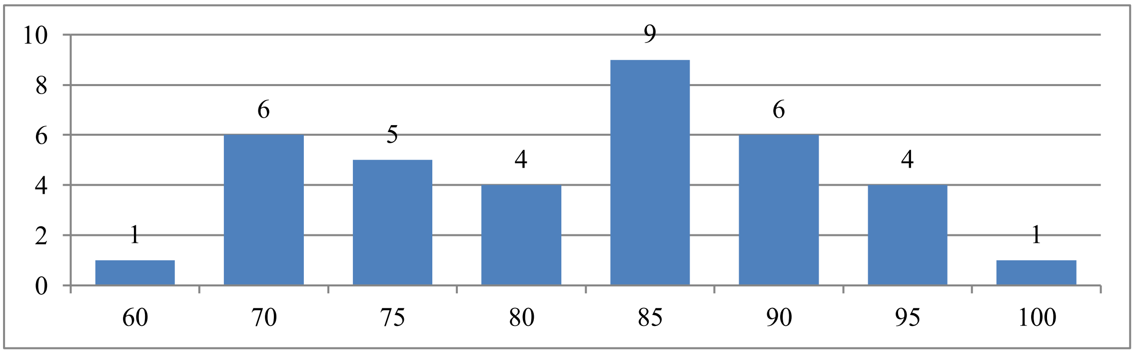

Figure 3. Distribution of post-test scores

Based on Figure 3, the post-test results show that most students scored between 70 and 90, indicating a significant improvement in their understanding of the material. With 19 students scoring between 80 and 90, it is clear that the intervention was effective for the majority. A few students, including one scoring 100, demonstrated mastery, while one student scored 60 and several others scored in the 70s, suggesting that some students still struggled with the concepts. Overall, the data show positive improvement but also highlight the need for additional support for students who require further assistance.

Based on the analysis of the pretest and posttest data, the comparison of the pretest and posttest results is shown in Table 1.

Table 1. Pretest and posttest categories of learning outcomes

Criteria	Pretest	Postest
Very Low	10 (27.9%)	0.0
Low	16 (44.4%)	0.0
Moderate	10 (27.7%)	1 (2.8%)
High	0.0	15 (41.7%)
Very High	0.0	20 (55.6%)

Table 1 shows the distribution of the number and percentage of students categorized as very low, low, moderate, high, and very high. The pretest data indicates that the students' learning outcomes on the topic of work and energy were still quite low.

Analysis of Learning Outcomes Improvement

Table 2. Paired Sample t-Test Results

Paired Differences Pre-Post			
Mean	**SD**	**t**	**Sig (2tiled)**
-48.75	11.61	-25.10	.000

Table 2 shows the results of the Paired Sample T-test, which indicate that the significance value (Sig. 2-tailed) = 0.000 < 0.05. This result suggests a significant difference in student learning outcomes before and after the implementation of differentiated learning with the PBL model, indicating an improvement in student learning outcomes. In practical terms, the t-test result indicates that the change in student performance is not due to random chance but rather reflects the effectiveness of the differentiated learning strategy combined with the PBL model. The improvement in scores suggests that students were able to better understand the material and apply their knowledge after experiencing this tailored, interactive learning approach. Therefore, the intervention can be considered a successful strategy for enhancing student learning outcomes.

Table 1 shows a noticeable difference between the pretest and posttest scores of students on the learning material of work and energy. The pretest data, which represent the results before the implementation of differentiated learning with the PBL model, indicated that student learning outcomes were relatively low. This suggests that initially, students' understanding of the material was limited. Several internal and external factors contributed to these results. Internal factors, such as mental readiness, learning motivation, and individual abilities to comprehend the material, played a significant role, while external factors included support from the learning environment at both school and home (Djudin, 2018). This challenge can be addressed with an instructional approach that accommodates individual differences and facilitates students' deeper understanding of the material (Gunawardena et al., 2024). Differentiated learning with the PBL model offers an appropriate solution (Deep et al., 2019).

Differentiated learning can accommodate various learning styles, whether visual, auditory, or kinesthetic, allowing each individual to experience learning according to their needs (Sudiarta, 2019). This approach supports the theoretical framework of constructivist learning, where learners actively build upon their existing knowledge and experiences. By addressing different learning styles, differentiated learning enhances engagement and retention of information. The PBL model, which focuses on providing real and relevant problems, complements this approach by helping students connect theoretical concepts to real-world situations (Arviani et al., 2023). The combination of differentiated learning and PBL encourages critical thinking, problem-solving, and a deeper understanding of the material. Therefore, the improvement in student outcomes observed in this study can be explained by the theoretical benefits of these strategies, as they promote active learning and facilitate meaningful connections between theory and practice.

After implementing differentiated learning with the PBL model, students' learning outcomes showed significant improvement. This is evident from the changes that occurred after applying the differentiated learning strategy with the PBL model in the lessons. The differentiated learning strategy with the PBL model focuses on real-world problems and group investigations, combining students' learning styles. The PBL model requires students to solve problems, collaborate in groups, and clearly communicate their ideas (Widiastuti et al., 2023).

This improvement in learning outcomes is consistent with findings from previous studies that show differentiated learning, and PBL can enhance student learning outcomes. A study by Iksan et al. (2023) found that using differentiated learning resulted in an increase in student learning outcomes, where the learning completion rate in the pre-cycle was 33.3%, rising to 60% in the first cycle, and increasing to 86.6% in the second cycle. Research by Maulana (2023) showed that the use of the PBL model resulted in a 90.68% increase in student learning outcomes.

However, other factors, such as increased motivation or familiarity with the test format, could also explain the improvement. Students might have been more engaged or comfortable with the test format, leading to better performance (Polack & Miller, 2022). While the intervention likely played a significant role, further research is needed to determine the specific impact of these factors (Budiman et al., 2023).

The findings of this study show a substantial improvement in students' learning outcomes after the implementation of the differentiated learning strategy with the PBL model, indicating a significant change in their understanding of the material on work and energy. The significant difference between the pretest and posttest results after the implementation of differentiated learning with PBL also demonstrates the effectiveness of this teaching model. Based on statistical tests, the results indicate that the application of this model can enhance student learning outcomes.

According to the researcher, differentiated learning with the PBL model, when implemented correctly according to its learning steps, will show improvement in student learning outcomes. This aligns with research conducted by Solikhin et al. (2023), which found that differentiated learning with the PBL model can indeed improve student learning outcomes. This is consistent with research by Nadiyah et al. (2022), which states that students' orientation toward problems in learning reached 75%, meaning that most students were able to adapt to the problems presented. This adaptation becomes a crucial foundation in differentiated learning with the PBL model because it not only requires students to understand the material but also trains them to identify and analyze problems independently (Mardhani et al., 2022).

Furthermore, students were divided into several small, heterogeneously designed groups based on their learning styles. In each group, there were students with visual, auditory, and kinesthetic learning styles, distributed evenly. This combination created a more diverse and rich discussion dynamic, allowing each student to contribute according to their learning strengths and preferences (Amir, 2016). The diversity in learning styles within the group encouraged students to actively collaborate, especially during the investigation phase to solve the problems presented in the Student Worksheet. This process not only enriched their learning experiences but also strengthened their teamwork, communication, and problem-solving skills. With effective collaboration, each group member had the opportunity to complement one another and reach the best solution to the problems they faced (Sirait et al., 2022).

Research by Zuana et al. (2023) showed that out of 112 respondents, 56 students with visual learning styles learned more effectively using visual aids, such as pictures and diagrams. Twenty-one students with auditory learning styles succeeded more through discussions or lectures. Meanwhile, 13 students with kinesthetic learning styles understood the material better through physical activities or direct experiments. Ten students with a combination of visual and auditory learning styles were able to benefit from both methods. Students with visual and kinesthetic learning styles (6 students) required approaches that incorporated both images and practical activities, while 4 students with auditory and kinesthetic learning styles were more successful through discussions and practice. Finally, 2 students with all three learning styles performed well with a flexible approach combining visual, auditory, and kinesthetic methods. This diversity in learning styles significantly influences the success of the teaching model.

The study by Angrasari (2018) found that students' learning styles were predominantly visual, followed by auditory and kinesthetic styles. A significant positive relationship was found between learning styles and physics learning outcomes, with correlation values of r = 0.4630 for visual, r = 0.6475 for auditory, and r = 0.6227 for kinesthetic. Overall, the correlation between learning styles and physics learning outcomes was r = 0.5321, indicating a moderate positive relationship between the two variables. The approach to learning styles allows students to access the material in ways that best match their preferences, which in turn enhances their understanding and engagement in learning (Shady, 2024). Group discussions allow students to develop a more comprehensive understanding of the material being studied, as well as enhance their communication skills (Syafruddin, 2017). This is supported by research from Mulyani (2016), which showed that the average score of the experimental group increased from 15.3 (pretest) to 21.5 (posttest), an improvement of 6.2 points. This provides evidence that group discussion techniques in group guidance can serve as an alternative approach for enhancing students' understanding of a topic.

After the groups finished discussing and solving the problems, students were asked to present their findings to the class. This presentation has significant benefits in improving public speaking skills and students' ability to present ideas clearly and systematically. According to Hattie & Timperley (2007) as cited in Widari (2024), constructive feedback during or after the presentation can accelerate the learning process, as students receive information about their strengths and weaknesses in presenting the material. Therefore, presentations not only serve as an assessment tool for learning outcomes but also provide an opportunity to enhance speaking skills and self-reflection abilities.

The next step after the presentation is for the teacher and students to jointly evaluate the results of each group's investigation. This evaluation is crucial, as it provides an opportunity for students to view the different perspectives and approaches used by other groups in solving the problem (Idrus, 2019). According to Solikhin et al. (2023), evaluations involving both the teacher and students can enhance understanding of the material, as students are encouraged to think critically and assess the results from various perspectives. This process also helps students identify and correct mistakes, reinforcing their understanding of the material being taught.

According to the researcher, another benefit of applying differentiated learning with the PBL model is the increased involvement of students in the learning process, tailored to their individual learning styles. The book by Kristiani et al. (2021) “differentiated learning development model” states that differentiation in the learning process based on learning styles allows students to optimize their potential, where each learning style (visual, auditory, or kinesthetic) can contribute to problem-solving. The study by Fatmawati et al. (2022) found that female students were predominantly visual learners, while most male students had a kinesthetic learning style.

This supports a more personal and meaningful learning experience, as students can process information in the most effective way for them (Sappaile et al., 2023). For example, students with a visual learning style tend to understand better through diagrams, charts, or concept maps. Meanwhile, auditory learners are more engaged in verbal discussions and presentations, while kinesthetic learners excel in hands-on activities such as simulations or experiments (Yotta, 2023). The combination of these learning styles within a group helps create synergy, where students complement each other to achieve the best solution to the given problem (Hijriati et al., 2024).

This aligns with the opinion of Hendriana et al. (2018), which showed that the implementation of the PBL model in Social Studies learning in the 4th grade at Bina Anak Muslim Private Elementary School in Singkawang significantly improved student learning outcomes, with an average score of 82.44. Students' learning styles also impacted the outcomes, with visual learners showing the highest results, averaging 83.68, followed by auditory and kinesthetic learners. The application of PBL had the most significant impact on visual learners.

The application of differentiated learning processes based on learning styles also supports the development of interpersonal skills, which are essential in 21st-century learning. In addition to understanding the subject matter, students are trained to think critically, collaborate, and solve problems in contexts relevant to real-life situations (Solikhin et al., 2023). This is supported by research from Turmuzi & Lu’luilmaknun, (2023), which shows that the application of differentiated learning with the PBL model positively affects the learning outcomes of grade VIII students at SMP Negeri 13 Medan. The study found a significant difference between the PBL class and the control class. Additionally, regression analysis with a positive coefficient of 0.31 indicates a positive relationship between the PBL model and the improvement of student learning outcomes.

The effectiveness of improving student learning outcomes after implementing differentiated learning strategies with the PBL model on the topic of work and energy was calculated using Effect Size. The resulting Effect Size value of 3.650 was categorized as high. This calculation indicates that differentiated learning with PBL has a significant impact on enhancing student learning outcomes. The high Effect Size value demonstrates that the application of this model is highly effective in improving student learning outcomes (Kraft, 2020). A significant increase in posttest scores compared to pretest scores suggests that the differentiated learning strategy with PBL successfully optimized the learning process, provided a deeper learning experience, and developed students' skills overall (Nurhaedah et al., 2022).

These findings align with the research by Yanti et al. (2024) which showed an improvement in learning outcomes before and after the implementation of differentiated learning based on the PBL model, with an average score of 70.65 and an n-gain value of 0.478. Based on the Effect Size calculation, the PBL model was shown to be effective in improving student learning outcomes, with a value of 0.999, categorized as high. This indicates that the PBL model can be effectively used to enhance student learning outcomes.

IV. CONCLUSION AND SUGGESTIONS

Based on the research conducted, it can be concluded that the implementation of differentiated learning strategies with the PBL model was highly effective in improving student learning outcomes on the topic of work and energy at Sekadau Hilir State Junior High School 8. Data analysis of the pretest and posttest results revealed a significant improvement in student performance following the implementation of these strategies. The key elements of the PBL model solving real-world problems, fostering group collaboration, and facilitating joint evaluation proved particularly beneficial. These aspects helped develop students' social, cognitive, and communication skills, while also enhancing their motivation and participation in the learning process. In particular, the integration of differentiated learning within the PBL framework was instrumental in tailoring lessons to the diverse learning styles of students. This allowed for more active student participation in discussions and problem-solving, making it easier for students to apply theoretical knowledge in practical contexts. The combination of PBL and differentiated learning maximized students' potential by encouraging collaboration, critical thinking, and a deeper understanding of the material.

For future improvements, it is recommended that teachers continue to implement differentiated learning with the PBL model in a consistent and evolving manner. By doing so, science learning can become even more student-centered, with teachers taking on the role of facilitators rather than direct knowledge providers. Additionally, future research could explore the application of differentiated learning with the PBL model to other physics topics, which could help further validate its effectiveness across different areas of the curriculum.

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