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Problem Based Learning: An Effective Solution for Enhancing Conceptual Understanding of Simple Machines in Eighth Grade

A. Mustajab[1], S. Bahri[2], G. A. Fatmala [3]
[12]Pendidikan Fisika, STKIP Melawi, Nanga Pinoh
[3]Mahasiswa Pendidikan Fisika, STKIP Melawi, Nanga Pinoh
e-mail: aminmustajab53@gmail.com, samsulbahri804@gmail.com, gistaayu46@gmail.com

Abstract

This study discussed the effectiveness of the Problem-Based Learning (PBL) model in improving eighth-grade students' understanding of simple machines in the Natural Sciences curriculum. Conducted at SMP Negeri 6 Satap Sekayam, the research employed a quantitative approach with a pre-experimental design involving 22 students. The results indicated that after the implementation of PBL, the average student score significantly increased from 73.81 to 92.32, reflecting an enhancement in conceptual understanding and application. Statistical analysis, including the Wilcoxon test, confirmed that the PBL model had a significant positive impact on students' conceptual understanding. These findings suggested that PBL promoted active engagement, collaboration, and deeper learning, making it a promising instructional strategy in physics education. Additionally, PBL was found to enhance higher-order thinking skills, social skills, and students' readiness to face future challenges. While most students showed significant improvement, one student did not make progress, highlighting the need for individualized support. Overall, this study affirmed the effectiveness of PBL in enhancing the quality of education and preparing students with essential life skills.

Keywords: *Problem Based Learning, conceptual understanding, science education, higher-order thinking skills, student collaboration.*

1. Introduction

The study of Natural Sciences is an educational process aimed at understanding natural phenomena and improving problem-solving abilities in real-world situations (Nur'ariyani *et al*., 2023; Septiliana & Surul, 2023). The goal of science education is for students to not only gain knowledge of the subject but also to apply this knowledge effectively in their daily lives (Wicaksono & Rahman, 2022). To achieve this, it is essential to implement teaching models that foster a deep, practical understanding of science concepts.

The ability to grasp content, and apply it in multiple scenarios is referred to as conceptual understanding in educational terms, as stated by (Yilmaz, 2011). It is suggested by (Takda *et al.*, 2022) that the mastery of the material, and the interpretation of data along with the use of concepts based on multiple cognitive frameworks that students have are involved in this understanding. Students need careful design in learning models, so they can master and apply concepts well. It is stated by (Gumisirizah *et al.*, 2024) that several important aspects are included by indicators of conceptual understanding, which include the ability to restate a concept, classify objects based on specific characteristics, provide examples, and non-examples of a concept and appropriately select and use necessary procedures or operations. Many important indicators guarantee that students truly grasp the concepts being taught and they can apply these ideas in many situations (Saija *et al.*, 2022).

In practice, the material covered in Natural Sciences can often feel abstract and complex, making it challenging for students to both understand and apply what they learn (Muakhirin, 2014; Mustajab *et al.*, 2020). To tackle these challenges, it is crucial for science teachers to create innovative and effective learning models. Traditional teaching methods, like lectures and question-and-answer sessions, often fail to engage students in a meaningful way (Verawati & Sarjan, 2023).

Observations in an eighth-grade classroom revealed several issues with the way Natural Sciences were being taught. The reliance on lectures and Q&A formats left many students struggling to grasp concepts related to simple machines. This lack of engagement often led to decreased motivation and involvement in the learning process (Haryanto & Arty, 2019). It is vital to address this issue because a solid understanding of science concepts is essential for students to solve problems and apply their knowledge in real-life situations (Muakhirin, 2014). If these teaching methods do not improve, students may not only struggle with current material but also face difficulties in more advanced science topics (Saija *et al.*, 2022). Therefore, exploring and implementing more effective learning models is essential.

One promising alternative to enhance students' understanding of Natural Sciences, especially regarding simple machines, is the Problem-Based Learning (PBL) model. PBL focuses on solving real-world problems, which can help stimulate higher-order thinking skills and encourage active participation from students (Hung, 2015; Widiawati *et al.*, 2018). This approach goes beyond just theoretical knowledge; it emphasizes applying what students learn in relevant contexts (Loyens *et al.*, 2015). By engaging students in real-life problem-solving, PBL can help them better understand concepts and apply them in their everyday lives (Alifatun Ni'mah *et al.*, 2024). This methodology is expected to effectively address the challenges students face in grasping material related to simple machines.

The Problem-Based Learning (PBL) model shows great potential for improving students' conceptual understanding by fostering a more interactive and relevant learning environment. PBL focuses on solving real-life problems, which can significantly enhance student engagement and help them better grasp material in practical contexts (Gumisirizah *et al.*, 2024). This research aims to evaluate the effectiveness of PBL in enhancing eighth-grade students' understanding of simple machines, a crucial topic in the Natural Sciences curriculum.

Implementing PBL in science education offers a more innovative and effective alternative to traditional teaching methods. By actively involving students in the problem-solving process, PBL not only deepens their comprehension of the subject matter but also boosts their motivation and participation in learning. This approach can lead to long-term benefits for students' academic growth and their readiness for future educational challenges.

The primary goal of this study is to investigate how the PBL model influences eighth-grade students' understanding of simple machines. The researcher aims to explore how PBL can enhance students' comprehension and practical application of simple machine concepts in real-life situations. It is anticipated that this research will contribute valuable insights into developing more effective instructional strategies tailored to meet the specific needs of learners in the field of physics education.

2. Methode

This study employs a quantitative approach with a pre-experimental design of the one group pretest-posttest type (Creswell, 2009). The research was conducted at SMP Negeri 6 Satap Sekayam in April 2024, involving a population of 22 eighth-grade students. A saturated sampling technique was utilized to include the entire population as the sample (Creswell, 2009). Data collection instruments included observations through teacher interview sheets, observation sheets for learning implementation, and validation sheets, while the assessment involved descriptive tests measuring various conceptual indicators such as restating, providing examples, and classifying objects (Cohen *et al.*, 2002). Content validity was assessed by comparing the instruments to the material that had been taught. Normality testing was conducted using the chi-square test to evaluate data distribution (Howell, 2011), while the Wilcoxon test was applied to assess the impact of the contextual treatment by comparing pretest and posttest data (Howell, 2011). A change was considered significant if the Asymp. Sig. (2-tailed) value was less than 0.05 , leading to the rejection of the null hypothesis (Ho) in favor of the alternative hypothesis (Ha).

3. Results and Discussion

In this study, instrument validation is a critical phase to ensure that the tools used for research meet the necessary standards of validity and quality. The validated instruments comprise two main components: the Lesson Plan and ten essay questions, divided into five questions for the pretest and five for the posttest. The validation process was conducted by a lecturer serving as a validator, utilizing assessment criteria that included four categories: poor, fair, good, and very good.

Based on the validation results, the lesson plan received a score of 3, indicating that the document is categorized as "good." The pretest essay questions averaged a score of 5.6, while the posttest essay questions averaged 5.8, both falling within the "very good" category. These results indicate that both instruments—Lesson Plan and essay questions—meet the expected validity standards. Therefore, the instruments are deemed valid and ready for use in the research, ensuring that the data collected will be accurate and relevant to the study's objectives.

Statistical analysis revealed that the average pretest score for the 22 students was 73.81. From the data collected, it was observed that 54.55% of students scored below the class average, indicating that more than half of the participants performed below this benchmark. Conversely, 45.45% of students achieved scores above the class average, reflecting that nearly half of the group performed better than the average. This distribution of scores provides insight into the variation in academic performance among students prior to the treatment being implemented.

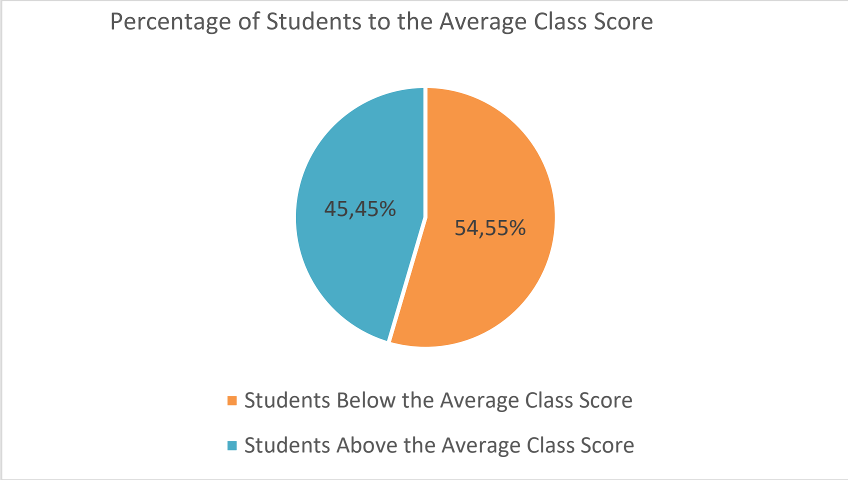

Figure 1. Percentage of Students to the Average Class Score prior to the treatment being implemented

After the treatment, a post-test was conducted for the experimental group. This post-test included five essay questions that differed from those in the pre-test, maintaining consistency in the participants and test duration. The data from this post-test will be used to evaluate the effectiveness of the treatment by comparing it to the average pre-test scores. Following the implementation of Problem-Based Learning (PBL), the research findings indicate a significant change in the academic achievement of the participants. Out of 22 students involved, the class average score increased to 92.32. This data suggests that the majority of students have demonstrated improvement in their understanding and application of the subject matter. Specifically, 55% of the students scored above the class average, indicating better performance and a deeper understanding of the concepts taught. Conversely, 45% of the students remained below the class average, suggesting that they may require additional approaches or further support to meet the expected standards. Overall, the application of Problem-Based Learning has positively impacted learning outcomes, although there remains room for further improvement for some students.

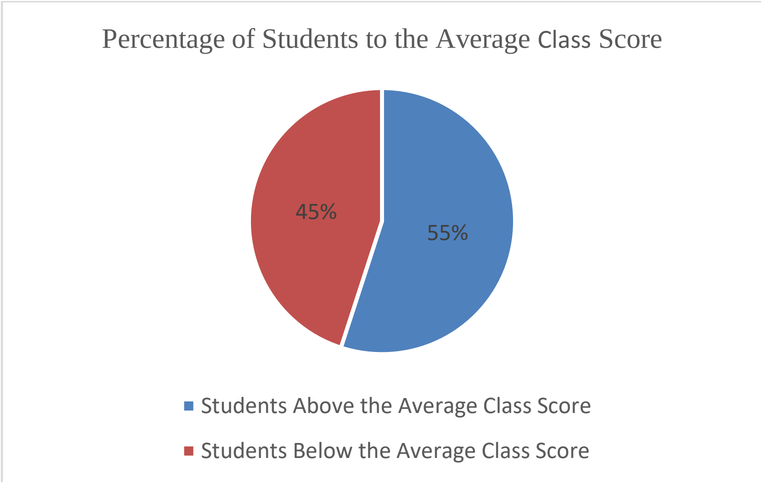

Figure 2. Percentage of Students to the Average Class Score after to the treatment being implemented

Based on the normality test conducted on the pre-test data, the Shapiro-Wilk test was used. The results indicate a significance value (Sig.) greater than 0.05. It can be concluded that the pre-test data is normally distributed. This finding suggests that there is no significant deviation from normal distribution in the pre-test data, indicating that the distribution of pre-test scores follows the expected normal distribution pattern.

Tabel 1. Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test	,158	22	,164	,936	22	,163
Post-Test	,154	22	,191	,882	22	,013

a. Lilliefors Significance Correction

The research findings indicate that the normality test for the post-test data was conducted using the Shapiro-Wilk test. The calculations yielded a significance value (Sig.) of less than 0.05. It can be concluded that the post-test data is not normally distributed. This means that the distribution of post-test scores does not follow the expected normal distribution pattern, thus the assumption of normality for this data cannot be accepted. This indicates that the post-test data shows a significant deviation from normal distribution, which is important for the validity of further statistical analyses.

Tabel 2. Ranks of Students Score

		N	Mean Rank	Sum of Ranks
Post-Test - Pre-Test	Negative Ranks	0[a]	,00	,00
	Positive Ranks	22[b]	11,50	253,00
	Ties	0[c]		
	Total	22		

a. Post-Test < Pre-Test

b. Post-Test > Pre-Test

c. Post-Test = Pre-Test

Tabel 3. Test Statistics[a]

	Post-Test - Pre-Test
Z	-4,109[b]
Asymp. Sig. (2-tailed)	,000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Based on the analysis using the Wilcoxon test, it was found that the Asymp. Sig. (2-tailed) value is less than 0.05. Consequently, the null hypothesis (Ho) is rejected, and the alternative hypothesis (Ha) is accepted. The conclusion from this result is that the use of the Problem-Based Learning model has a significant effect on the students' conceptual understanding. In other words, the implementation of this instructional model has had a significant positive impact on the enhancement of students' conceptual understanding in this study.

The results of this study indicate that the implementation of the Problem-Based Learning (PBL) model significantly affects students' conceptual understanding of simple machines, specifically inclined planes. The Wilcoxon test revealed a statistically significant difference between the pre-test and post-test scores of the groups assessed before and after the application of the PBL model. This finding demonstrates that the implementation of PBL successfully enhanced students' understanding significantly. This aligns with the findings of (Rafiq *et al.*, 2023), which indicate that the student learning outcomes data show the highest achievements were obtained by students taught using the PBL method.

Before the application of the PBL model, the average understanding score of students was 73.81. However, after the implementation of PBL, the average score significantly increased to 92.31. This increase in average scores reflects the success of the PBL model in improving students' comprehension of the topic of inclined planes. It indicates that this instructional method is not only effective in enhancing learning outcomes but also in improving the quality of students' understanding (Nicholus *et al.*, 2024).

Furthermore, the validation of the implementation of PBL showed a very good score of 8.6. This validation score indicates that the application of the PBL model was carried out with high quality and in accordance with established procedures. This supports the results of the Wilcoxon test and affirms that the PBL model can be effectively implemented in the learning context, providing a positive impact on students' understanding.

The Problem-Based Learning (PBL) model offers several advantages that make it highly effective in deepening conceptual understanding. One of its strengths is that it encourages students to actively seek and construct their own knowledge. By engaging directly in the discovery process, students do not merely receive information passively but participate actively in their learning (Hmelo-Silver, 2004). This engagement facilitates a deeper and more sustainable understanding, as the knowledge acquired is not just new information but is integrated with their existing experiences and knowledge (Gusman, 2023). This process leads to a more meaningful and contextual learning experience, where the concepts learned become more relevant and applicable in everyday life. Additionally, PBL emphasizes the importance of collaboration and communication in the learning process, which can foster critical and creative thinking skills (Gunawan *et al.*, 2023). Thus, students not only gain knowledge but also develop essential skills for effective problem-solving and decision-making in the future.

Secondly, the implementation of the Problem-Based Learning (PBL) model significantly involves students in problem-solving tasks that require them to use higher-order thinking skills (Chadziqoh & Abdulkarim, 2018). The PBL process demands that students analyze complex situations, formulate and explore various potential solutions, and evaluate the outcomes of each proposed solution. This activity is not merely an intellectual process but also an intensive exercise that stimulates the development of critical and creative thinking skills (Annuuru *et al*., 2017). Through in-depth analysis and continuous evaluation, students learn to consider various perspectives and assess the effectiveness of their solutions within a broader context.

Furthermore, the critical and creative thinking skills developed through PBL have a significant impact on students' academic success and life skills (Ramdani, 2018). In an academic context, these skills support students' ability to tackle complex challenges and solve problems that do not have a single answer. Additionally, these skills are highly valuable in the future workforce, where effective problem-solving, innovation, and adaptability to change are key to success (Alshamali & Daher, 2016). Therefore, PBL not only enhances deep conceptual understanding but also prepares students to be adaptive and creative thinkers who can face various challenges they may encounter in the future (Palloan *et al.*, 2019).

Lastly, the Problem-Based Learning (PBL) model provides an additional advantage by enabling knowledge to be effectively embedded within students' mental schemas (Baran & Sozbilir, 2018), making the learning process more meaningful and integrated. Mental schemas are cognitive structures that help organize and understand new information by referencing existing knowledge. In the context of PBL, students are confronted with real-world problem situations that encourage them to connect new knowledge with schemas already present in their minds. This process not only aids in their deeper understanding of new concepts but also facilitates the application of that knowledge in relevant contexts.

By connecting new knowledge with existing mental schemas, students can create a stronger and more structured network of information, facilitating their ability to recall and apply that knowledge (Font Fernández, 2019). For instance, when students solve problems related to mathematical concepts in real-life situations, they do not just learn new formulas; they also contextualize those formulas, reinforcing their understanding. This leads to more holistic and applicable learning, where information is not merely stored in short-term memory but becomes an integral part of their knowledge that can be accessed and utilized efficiently in the future. In this way, PBL enhances the quality of learning by creating strong connections between theory and practice, deepening students' comprehension of the subject matter.

The Problem-Based Learning (PBL) model also significantly contributes to the development of students' independence and maturity. Through this approach, students are faced with problem situations that require them to actively collaborate with classmates, communicate effectively, and manage and complete tasks independently. In the PBL process, students seek solutions not only individually but also collaboratively in groups, which demands that they listen to and appreciate diverse opinions while contributing constructively to discussions.

Such interactions help students develop essential social skills, such as communication, empathy, and teamwork. Furthermore, the PBL process requires them to take responsibility for their own learning, plan problem-solving steps, and evaluate their work independently. This fosters independence and personal initiative, teaching students to be more proactive in overcoming challenges.

The independence and communication skills gained through PBL are invaluable in preparing students to face various future challenges, both academically and in everyday life. With these skills, students are not only ready to tackle situations that demand effective problem-solving but are also capable of working well in collaborative environments, adapting to change, and contributing positively to society. Therefore, PBL focuses not only on mastering subject matter but also on developing life skills that are crucial for students' long-term success.

Finally, placing students in interactive learning groups can enhance their overall achievement. By learning in groups, students can support each other and collaborate to achieve common learning goals. This creates a positive and productive learning environment where students can grow and reach their full potential.

However, it is important to note that there was one subject in this study who did not show improvement either before or after the implementation of the PBL model. This was due to a lack of conceptual understanding in that particular student. Although the majority of students exhibited significant improvement, the subject who did not experience change highlights the need for individualized approaches and additional support for students who may struggle with understanding the material.

Overall, this study demonstrates that the Problem-Based Learning (PBL) model effectively enhances conceptual understanding of the topic of simple machines, specifically inclined planes. PBL not only improves learning outcomes but also fosters critical thinking skills, independence, and social attitudes among students. The implementation of this model in the learning process can provide substantial benefits and improve the overall quality of education.

4. Conclusion and Recommendations

Based on the analysis results using the Wilcoxon test, which showed an Asymp. Sig. (2-tailed) value of less than 0.05, it can be concluded that there is a significant difference in students' conceptual understanding before and after the implementation of the Problem-Based Learning (PBL) model. In other words, the PBL model effectively enhances students' understanding of the topic of inclined planes.

Before the implementation of the PBL model, the average understanding score of students was 73.81, which significantly increased to 92.31 after the model was applied. This improvement reflects the success of PBL in deepening students' understanding and demonstrates a significant positive impact on learning outcomes. Additionally, the validation of PBL implementation yielded a score of 8.6, indicating that the model was applied with high quality according to established procedures.

The PBL model not only enhances conceptual understanding but also facilitates the development of critical thinking, creativity, and independence skills. This approach requires students to engage actively in problem-solving processes, collaborate with peers, and integrate new knowledge with their existing mental frameworks. These results support the fact that PBL is not only effective in improving learning outcomes but also in enhancing the quality of students' understanding and building essential life skills for the future.

Although most students showed significant improvement, one subject who did not experience any change highlights the need for an individualized approach to support students facing difficulties. Overall, this study confirms that the implementation of the Problem-Based

Learning (PBL) model provides substantial benefits in enhancing conceptual understanding, fostering critical and social thinking skills, and preparing students to face future challenges.

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