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Implementation of Problem-Based Learning (PBL) Model Integrated with Augmented Reality to Improve Learning Outcomes of Class XI MAN 2 Tidore Kepulauan on Uniform Linear Motion Material

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ABSTRACT

This research investigates the effect of integrating the Problem-Based Learning (PBL) model with Augmented Reality (AR) in improving student learning outcomes in physics, specifically in the material of Regular Straight Motion (GLB). Conducted at MAN 2 Tidore Islands, the study involved grade XI students during the odd semester of the 2025/2026 school year. Using a quantitative approach with a Pretest-Posttest Control Group Design, the results showed significant improvements in the experimental group. The average final score of the experimental class was 62.46, while the control class scored 40.23, with a p-value of 0.005 (< 0.05), confirming that AR-based PBL effectively enhanced learning outcomes. The N-Gain analysis revealed a 73.35% improvement in the experimental class, categorized as quite effective, compared to 24.58% in the control class. The integration of AR provided interactive, engaging, and accessible visualizations of abstract concepts, fostering better understanding and active student involvement. This study highlights the potential of AR-assisted PBL as an innovative teaching strategy to improve the quality of physics learning and suggests further exploration of this model in other educational contexts.

KEYWORDS basid learning problem, augmented realty, learning outcomes.

INTRODUCTION

21st-century education demands that learners master not only cognitive skills but also non-cognitive abilities such as critical thinking, problem-solving, creativity, communication, and collaboration (Rahman et al., 2022). These competencies are an important foundation for forming a generation that is adaptive to global dynamics. In this context, the role of teachers is increasingly complex, not only as conveyors of knowledge but also as facilitators who present innovative and transformative learning. The integration of educational technology is the main strategy to create an effective, meaningful, and relevant learning experience that meets the needs of today's students. The development of digital technology in the last decade has opened up significant opportunities for learning innovation. The interactive media available not only enrich learning methods but also increase the active participation of students. Banarsari et al. (2023) emphasized that the use of digital technology provides personalized learning according to individual needs and strengthens the interaction between teachers and students. Priantini et al. (2022) added that interactive media plays a role in increasing student engagement while developing critical, creative, collaborative, and communicative thinking skills. Furthermore, Sofyan & Hidayat (2022) emphasized that the use of technology can optimize students' potential and improve learning outcomes. However, learning transformation through technology integration is not just an alternative but a necessity to ensure that the learning process takes place interactively, contextually, and adaptively according to the characteristics of students.

Physics learning at the secondary school level still faces fundamental problems, especially related to student involvement and understanding of concepts, which contribute to low student learning outcomes. The learning process, which tends to be teacher-centered, causes students to be passive and only receive information without being actively involved in thinking. This has an impact on low critical thinking skills, problem-solving, and difficulty understanding abstract concepts, such as Regular Straight Motion (GLB). In addition, the limited use of interactive and contextual learning media makes it difficult for students to relate physics concepts to real-life phenomena. Based on an interview with a physics teacher at Madrasah Aliyah Negeri 2 Tidore Islands, it is known that the Minimum Completeness Criteria (KKM) for physics subjects is set at 74. However, of the 138 students in grade XI, 64 students have grades below the KKM. The lowest score a student received was 40, while the highest score was only 68. The data shows that the majority of students have not been able to master the Regular Straight Motion material optimally.

This condition emphasizes the importance of the teacher's role in integrating the right learning model with the support of digital technology. One relevant approach in physics learning is Problem-Based Learning (PBL) combined with Augmented Reality (AR). PBL is a learning model focused on improving critical thinking skills, problem-solving, and student collaboration. Meanwhile, AR serves as a medium that can visualize abstract concepts using 3D simulations and project them into real environments in real-time (Wenthe et al., 2021). The integration of these two methods allows students to visually represent abstract concepts, making the material more concrete and engaging, and potentially increasing students' conceptual understanding and active engagement. The integration of PBL with AR not only increases motivation and understanding of concepts but also creates an interactive, contextual, and immersive learning experience.

The results of previous research on the effectiveness of Problem-Based Learning (PBL) and Augmented Reality (AR) separately include Hidayana et al. (2022), who stated that the application of the PBL model can increase learning completeness and student activity in physics learning. This finding is in line with the research by (Azzahra et al., 2023), which concluded that the PBL model is effective in improving both individual and collective learning outcomes in straight motion kinematics material. On the other hand, research by Ramadhan et al. (2023) and (Hartono, 2022) proves that the use of AR-based media can increase student motivation, effectiveness, and learning completeness. However, most of these studies have focused on the application of models or media separately and have not explored much research on the integration of PBL and AR in a cohesive manner. The integration of these two approaches has the potential to deliver more interactive, contextual, and immersive learning experiences, while improving students' conceptual understanding, motivation, and critical thinking skills. Therefore, this study aims to apply AR-based PBL as an integrated approach in physics learning, specifically in Regular Straight Motion (GLB) material.

RESEARCH METHOD

This study uses a quantitative approach with a Pretest-Posttest Control Group Design (Listiani et al., 2024). The research location at Madrasah Aliyah Negeri 2 Tidore Islands in grade XI students in the odd semester of the 2025/2026 school year, with 52 students as samples, consisting of 26 students in grades XI-A and 26 students in grades XI-B. The data obtained is in the form of learning outcome data obtained from the test. The test was carried out in both experimental and control classes using instruments in the form of cognitive test questions and critical thinking related to the concepts used in the learning model. The learning outcome data was analyzed using inferential statistics, namely a t-test to compare the learning outcomes between the experimental and control classes with equation 1.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \text{ .... (1)}$$

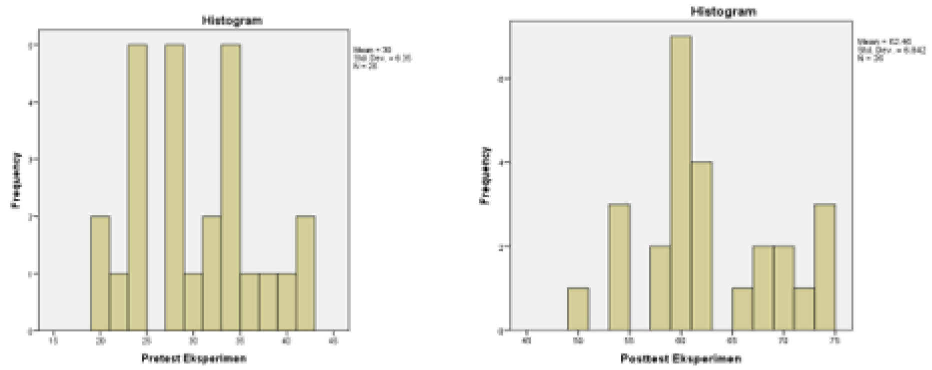
$$X = \frac{skor\ yang\ diperoleh}{skor\ maksimum} \times 100\% \text{............. (2)}$$

Next, using the N-Gain test according to equation 3 to measure the level of effectiveness of using the Augmented Reality (AR)-based Problem Based Learning (PBL) model:

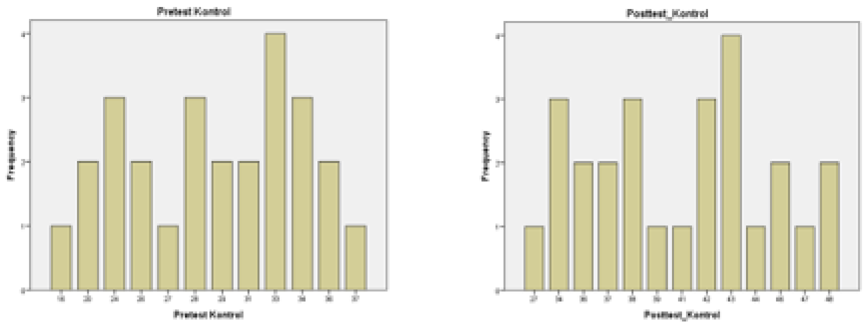
$$\text{N-Gain} = \frac{skor\ posttest - skor\ pretest}{skor\ ideal - skor\ pretest} \text{......... (3)}$$

RESULTS AND DISCUSSION

The test instrument initially consisted of 10 questions. After the trial and through the validity and reliability test stages, 8 questions were obtained that were suitable for use for pretest and posttest in the experimental class and the control class. The data on the results of the pretest and posttest are presented in Graphs 1 and 2.



Graph 1. Assessment of Student Learning Outcomes in Experimental Class



Graph 2. Student Learning Outcomes Score Control Class

The students' initial learning outcomes (pretest) and final (posttest) in the experimental class showed higher scores compared to the control class. Based on the data, in the experimental class, the minimum pretest score of 20 increased to 50 in the posttest, with a difference of 30 points. The maximum score has also increased from 42 to 74, with a difference of 32 points. Meanwhile, in the control class the minimum pretest score of 16 increased to 27 in the posttest, with a difference of 11 points, and the maximum score increased from 37 to 48, with the same difference of 11 points. Before the hypothesis test was carried out, the data on student learning outcomes was first analyzed using the normality test and the homogeneity test. The results of the two tests are presented in Table 1 and Table 2.

Table 1. Results of Data Normality Test for Experimental Class and Control Class

Classes		Shapiro-Wilk		
		Statistic	df	Sig.
Experiments	Pretest	.954	26	.286
	Posttest	.938	26	.121
Controls	Pretest	.950	26	.231
	Posttest	.956	26	.322

Source: Author's own research (2025)

The results of the normality test conducted using the SPSS device on the experimental and control class data showed a significance value greater than 0.05 ($p > 0.05$). Thus, the data can be declared to be normally distributed.

Table 2. Data Homogeneity Test Results of Experimental Class and Control Class Data

Classes			Living Statistic	df1	df2	Sig.
Experiment-Control	Pretest		1.625	1	50	.208
	Postest	Based on Mean	2.305	1	50	.135

Source: Author's own research (2025)

The results of the homogeneity test using the SPSS device in the experimental and control class data showed a significance value greater than 0.05 ($p > 0.05$), so that the data could be declared homogeneous. After the data of the students' learning outcomes met the assumptions of normality and homogeneity, then the analysis was carried out using *the N-Gain test* and the difference test (*t-test*). The *N-Gain* test is used to measure the level of effectiveness of the application of the *Problem Based Learning* (PBL) learning model based *on Augmented Reality* (AR) in improving student learning outcomes. The results of the N-Gain test analysis are presented in Table 3.

Table 3. N-Gain Test Analysis Results

N-Gain Test (Pretest-Posttest)			Conclusion
Experimental Classes	N-Gain	73.3505	Quite Effective
	% N-Gain	73,35 %	
Control Class	N-Gain	24.5765	Ineffective
	% N-Gain	24,58 %	

Source: Author's own research (2025)

Based on the results of the analysis, the increase in learning outcomes in the experimental class reached 73.35%, which is classified as quite effective. These findings show that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) has a positive influence on improving student learning outcomes, especially in the Regular Straight Motion (GLB) material. The improvement reflects the effectiveness of learning strategies that not only emphasize knowledge transfer but also develop high-level cognitive skills, such as analysis, evaluation, and reflection. In contrast, the control class, which did not apply the learning model, only increased by 24.58%, which falls into the ineffective category. This condition indicates that the conventional learning approach, centered on educators and lacking active student involvement, has not been able to make an optimal contribution to improving learning outcomes.

The effectiveness of the Problem-Based Learning (PBL) model cannot be separated from the role of Augmented Reality (AR), which is able to present material visually, interactively, and in an easily accessible manner. This technology supports student engagement both independently and collaboratively, as well as enriching learning resources that meet the demands of 21st-century skills. Therefore, the application of the AR-based PBL model not only contributes to improving learning outcomes quantitatively but also enhances the quality of the learning process, especially in fostering the ability to think critically, actively, and reflectively in understanding physics concepts.

The findings of this study are in line with the results obtained by Qotrunnada et al. (2025), which show that the application of Problem-Based Learning (PBL) assisted by Augmented Reality (AR) media is effective in improving student learning outcomes. This is consistent with PBL principles that emphasize active student participation, contextual problem-solving, and meaningful learning. Through the integration of technology, students not only play the role of information receivers but also as creators of knowledge. Additionally, Sholikhah et al. (2023) stated that the application of AR-based PBL increased learning effectiveness, where students in the experimental class achieved learning outcomes that exceeded the Minimum Completeness Criteria (KKM), compared to control classes that still used the lecture method. This shows that learning becomes more interactive, interesting, and meaningful, especially in the context of physics learning, which is often considered difficult by students. Thus, the combination of PBL models and AR technology can be an effective learning strategy in addressing the challenges of physics learning in the digital era.

The data from the research results was then analyzed by an independent sample t-test. The test results are shown in table 4

Table 4. Results of independent sample t-test experimental class data

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Experimental Classes	Equal variances assumed	.090	.765	17.732	50	.000	32.462	1.831
	Equal variances not assumed			17.732	49.723	.000	32.462	1.831

Source: Author's own research (2025)

Table 5. Test results independent sample t-test data class Control

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Control Class	Equal variances assumed	.044	.834	7.673	50	.000	11.231	1.464
	Equal variances not assumed			7.673	49.804	.000	11.231	1.464

Source: Author's own research (2025)

The results of the study showed a significant improvement in student learning outcomes through the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) compared to the control class. The average final test score in the experimental class was 62.46, while the control class only obtained 40.23. Based on the results of statistical analysis, the difference was statistically significant, with a p-value of < 0.05 ($0.005 < 0.05$), confirming that the use of AR-based PBL has a positive impact on improving student learning outcomes.

These findings show that the application of the Problem-Based Learning (PBL) model combined with Augmented Reality (AR) media contributes significantly to improving student learning outcomes. Through this approach, students are encouraged to actively engage in the learning process, identify and analyze relevant problems, collaborate to find solutions, and present their findings with the guidance of educators (Kesumawati & Riza, 2025). The learning cycle that emphasizes reflection and exploration plays an important role in improving students' understanding of concepts and overall learning outcomes. In addition, the role of AR as supporting media strengthens the effectiveness of learning by presenting interactive visualizations of abstract concepts, thereby helping students understand the material in a more in-depth and engaging way.

This is in line with the research of (Ningrum et al., 2025), which states that the application of the PBL model is not only effective in improving learning outcomes but also increases student involvement during the learning process, reflected in active participation in discussions, the ability to identify problems, and increased activeness in presentations in each cycle. With the support of this technology, students have the opportunity to learn independently, access learning resources whenever needed, and receive direct feedback from teachers and peers. The integration of Augmented Reality (AR) technology with the Problem-Based Learning (PBL) model makes the learning process more meaningful, contextual, and relevant to the learning needs in the digital era.

The application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) can be recommended as an innovative learning strategy that can significantly improve student learning outcomes. These findings are consistent with the results of research by (Kusumawati & Riza, 2025), which revealed that the application of the PBL model is effective in facilitating the understanding of physics concepts through an active, contextual learning process that focuses on solving real problems.

The significant difference in average scores between the experimental class (62.46) and the control class (40.23), accompanied by a statistically significant value ($p = 0.005$), suggests that the applied approach is not only effective but also has the potential to be implemented more widely in various learning contexts. Based on the results of the analysis using SPSS, a very significant difference was obtained between the experimental class and the control class, with the experimental class improving by 32.46 points and the control class improving by 11.23 points.

These results show that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) has proven to be effective in improving student learning outcomes. This effectiveness can be seen in the increase in the number of students who achieved high scores after learning, as well as the decrease in the number of students with low scores. The integration of PBL models with AR-based digital media creates a more interactive, directed, and meaningful learning process, significantly impacting the improvement of learning outcomes. This model also provides space for students to actively participate in the learning process, which positively influences their understanding of physics concepts in a more in-depth way.

In line with these results, Lana and Ismail (2021) stated that the application of Problem-Based Learning (PBL) to business materials and energy is effective in improving students' understanding of concepts and learning outcomes through learning activities that focus on active and collaborative problem-solving. Furthermore, (Ahmad et al., 2022) emphasized that the use of Augmented Reality (AR)-based learning media, accessible through digital devices such as smartphones and laptops, has been proven to increase students' interest in learning and understanding concepts, while providing an interactive, interesting, and fun learning experience.

The application of the Problem-Based Learning (PBL) model in the learning process provides a structured and systematic approach. This model not only focuses on developing critical thinking skills but also emphasizes the active participation of students during learning activities. In the early stages of learning, students are encouraged to identify and formulate problems related to the phenomenon of object motion in their environment, such as estimating the travel time of vehicles moving at a constant speed. This activity serves to train students' analytical skills while fostering curiosity about the basic concept of Regular Straight Motion (GLB). Next, students carry out simple observations or experiments to collect data on the distance and travel time of a moving object. Through this activity, students learn to connect theory with practice directly, so their conceptual understanding becomes more meaningful.

After the data is obtained, students discuss and interpret their observations, relating them to the concept of speed and the graph of the relationship between distance and time. This stage is an important forum for practicing scientific communication skills and logical argumentation, as students must present ideas and explanations based on empirical data. In addition, the PBL model fosters learning independence, where students are encouraged to seek out and utilize various relevant learning resources to strengthen their understanding of the concepts learned. Thus, the classroom atmosphere becomes more active, collaborative, and conducive because students do not just receive information from the teacher but also play a direct role in discovering and building their own knowledge about the concept of Regular Straight Motion.

Research conducted by Istni et al. (2025) revealed that the use of technology in the learning process not only contributes to improving student learning outcomes but also strengthens their involvement during learning activities. In line with that, Rahman et al. (2025) emphasized the importance of integrating digital learning tools into certain learning models as an effort to increase student active participation, develop critical thinking skills, and encourage independent learning. In this context, the application of Augmented Reality (AR) as a learning medium is becoming increasingly relevant and strategic. This technology has the ability to combine real environments with two- and three-dimensional virtual objects interactively and in real-time, providing students with opportunities to interact directly with learning materials. These interactions create an immersive, contextual, and engaging learning experience, which ultimately positively impacts students' understanding of concepts and engagement in learning.

The application of this model is able to create a more structured, interactive, and effective learning process, significantly improving student learning outcomes. This finding aligns with the results of Suswati's (2021) research, which states that Problem-Based Learning (PBL) has a close relationship with improving student learning outcomes. The model emphasizes the active involvement of students in the process of finding and solving problems independently, strengthening conceptual understanding while increasing learning outcomes in a meaningful way. The significant difference in results between the experimental and control classes is empirical evidence of the effectiveness of the application of Augmented Reality (AR)-assisted Problem-Based Learning in the learning process. Through an engaging approach and the appropriate use of media, students are encouraged to participate more deeply in learning activities, making the learning experience more meaningful and contextual. Therefore, educators need to continue to innovate in developing teaching materials based on creative and relevant learning models, ensuring that students are optimally prepared to face future challenges. In line with the views of Maryani et al. (2022), quality education plays an important role in shaping a generation that excels academically and has the ability to think critically, creatively, and adaptively to various life challenges.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) has a significant influence on improving student learning outcomes in physics, particularly in the Regular Straight Motion (GLB) material. The average test score of the experimental class, 62.46, showed a significantly higher result compared to the control class, which obtained 40.23. Additionally, the results of the N-Gain calculation showed that the experimental class reached 73.35%, classified as quite effective, while the control class only reached 24.58%, categorized as less effective. The statistical test results, showing a significance value of $p = 0.005$ (< 0.05), further confirm that this learning model is effective and feasible to be applied more widely in the context of physics learning.

This difference confirms that the Augmented Reality-based Problem-Based Learning model is more effective in improving student learning outcomes compared to conventional methods. The PBL model, enhanced by AR, has proven to increase student active involvement through systematic learning stages that focus on contextual problem-solving. The integration of AR media in this model plays a crucial role in enriching the learning process by presenting interactive, structured, and collaborative materials. In addition, the model provides an opportunity for students to learn independently through realistic three-dimensional visual experiences, as well as allowing them to receive direct feedback from interactions with virtual objects presented during the learning process.

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