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Implementation of Problem-Based Learning Model Assisted by Augmented Reality to Improve Learning Outcomes of MAN 2 Tidore Kepulauan Class XI Students on Newton's Second Law

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ABSTRACT

This study aims to analyze the effect of the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) on improving the learning outcomes of grade XI students at MAN 2 Tikep in Newton's Law II material. The background of this research is based on the students' low understanding of the concepts of force and motion, particularly the application of Newton's Law II in daily life. The research method used is a quasi-experimental design with a nonequivalent control group design. The research subjects consisted of two classes: the experimental class, which received learning with the AR-based PBL model, and the control class, which used the PBL model with conventional media. Data were collected through learning outcome tests administered before and after the treatment (pretest and posttest). Data analysis was carried out using a t-test to determine the difference in learning outcomes between the two groups. The results showed that there was a significant difference between the learning outcomes of students in the experimental class and those in the control class. Students who participated in learning with the AR-based PBL model achieved higher average scores compared to students in the control class. Thus, the application of the AR-based PBL model has proven to be effective in improving student learning outcomes in Newton's Law II material.

KEYWORDS *Problem Based Learning, Augmented Reality, Learning Outcomes, Newton's Law II*

INTRODUCTION

Students' understanding of the basic concepts of physics, especially Newton's Law, remains a challenge in high school education. This is due to several factors, including the conventional learning approach, the limitations of interactive learning media, and the lack of connection between abstract concepts and real-life phenomena. Many students struggle to integrate theoretical understanding with practical application, which negatively impacts their learning outcomes and motivation towards physics subjects (Garzón & Acevedo, 2019; Ibáñez & Delgado-Kloos, 2018; Rasheed et al., 2020; Sailer et al., 2017; Zheng et al., 2016). Additionally, misconceptions about the concepts of force, motion, and causal relationships in Newton's Law are often not properly identified by educators. Therefore, innovative learning strategies are needed that can actively and contextually facilitate knowledge construction, such as the use of Augmented Reality (AR)-based media combined with the application of problem-based learning (PBL) models, to improve students' conceptual understanding in a comprehensive and sustainable manner (Cheng & Tsai, 2019; Howard et al., 2021; Lai & Bower, 2019; Makransky & Mayer, 2022; Schindler et al., 2017).

In line with the demands of 21st-century education, physics learning aims not only at mastering concepts but also at developing critical thinking, collaboration, creativity, and scientific communication skills. Problem-based learning supported by AR-based media can be a strategic solution to address these challenges. AR allows students to visualize abstract concepts, such as the interaction of force and motion in Newton's Law, in three-dimensional visual forms that are easier to understand. With the support of this technology, students can explore concepts independently or in groups, thus encouraging active participation, increasing learning motivation, and strengthening conceptual understanding in depth. Additionally, the integration of the problem-based learning model provides opportunities for students to analyze real problems, develop hypotheses, and formulate solutions based on logical and scientific thinking (Bond et al., 2020; Wu et al., 2013).

The AR-based problem-based learning (PBL) model is an innovative approach that integrates real-world problem-solving with interactive visual technology to enhance the quality of physics learning. In its implementation, PBL places students at the center of active learning, where they are confronted with contextual problems that encourage exploration, investigation, and decision-making, both independently and collaboratively (Framiswari & Anwar, 2024). When combined with AR, this model becomes even more effective because students can visualize physical objects and phenomena more vividly through an interactive three-dimensional display. This helps students build a more concrete understanding of abstract concepts that have been difficult to explain through text or static images. Moreover, the use of AR in the context of PBL also increases students' emotional and cognitive engagement, strengthens memory, and encourages critical and creative thinking skills. Thus, learning physics not only becomes more interesting and meaningful but also aligns with the development of 21st-century competencies.

This is in line with the results of research by Usman et al. (2024), which concluded that the physics problem-solving ability of grade XI students, after being taught with the problem-based learning model (PBL), was in the high category. The same conclusion was reached by Anwar et al. (2023), who found that the learning outcomes of students taught with the problem-based learning model using experimental methods were also in the high category.

The findings of Rachmayani & Setyasto (2025) also showed that AR-based problem-based learning has a direct relationship with the object studied, indicating that the use of problem-based learning models with AR not only increases students' interest in learning but also deepens their understanding of the material being taught. Furthermore, research by Sholikhah et al. (2023) concluded that the application of the AR media-based PBL model was effective in improving student learning outcomes. The use of the augmented reality (AR)-based problem-based learning model to improve student learning outcomes has been widely studied, including the application of technology. This approach provides opportunities for students to conduct experimental activities, thereby increasing their motivation and learning outcomes (Faria, 2024; Majid et al., 2023).

Assemblr Edu is an augmented reality-based application developed specifically to support educational needs, especially in the learning process. The app offers a variety of features, including classes, topics, scans, and user profiles. Augmented reality technology creates an interactive and fun learning experience, while expanding innovative teaching methods (Câmara Olim et al., 2024).

Moreover, augmented reality supports a constructivist approach to education, making students more active and participatory in learning. This aligns with previous research, such as Sholikhah et al. (2023). Additionally, other studies have shown that the application of the problem-based learning model has a positive influence on students' problem-solving abilities, with a significance value of <0.05 indicating that the alternative hypothesis (Ha) is accepted. Furthermore, the study also showed that students in the experimental class experienced a higher average increase compared to students in the control class (Setyaningsih & Rahman, 2022). Another study by Masruroh et al. (2023) showed that the use of AR-based learning media significantly improved students' understanding of concepts. In their study, AR was used for vibration, wave, and sound materials, and the results showed a marked improvement in students' ability to understand concepts. This improvement occurs because AR can display multimedia that clarifies abstract concepts, making the delivery of material more effective and directly impacting learning outcomes.

Technology in education continues to develop, offering many useful tools or media to increase the effectiveness of achieving learning goals. One of the technological products that can be used in education is Augmented Reality (AR). Along with the times, learning media also follow the development of existing technology, ranging from print, audio-visual, and computer technologies, to the combination of print and computer technologies. Currently, learning media combine print and computer technology, and AR technology has emerged as an innovative solution in this context. Augmented Reality (AR) is a technology used to integrate the virtual world with the real world in real time (Alfitriani et al., 2021).

The purpose of this study is to analyze the effect of the application of the Augmented Reality (AR)-based Problem-Based Learning (PBL) model in improving the learning outcomes of grade XI students of MAN 2 Tidore Islands on Newton's Law II material. This study aims to determine how learning models that utilize AR technology can improve students' conceptual understanding of force and motion materials, as well as the application of Newton's Law II in daily life.

The benefit of this research is that it contributes to the development of learning methods by integrating AR technology into the PBL model, which can increase students' active involvement and deepen their conceptual understanding of physics. Additionally, this study shows that the application of the AR-based PBL model significantly improves student learning outcomes, demonstrating that this model is effective in helping students master complex physics concepts. This research also provides practical insights for educators who want to implement innovative, technology-based learning solutions to improve the quality of physics teaching, especially at the secondary education level.

METHOD

This study is a quantitative research using the Pretest-Posttest Control Group Design (Listiani et al., 2024). The research was carried out at Madrasah Aliyah Negeri 2 Tidore Islands. The research subjects amounted to 40 students, consisting of 20 students in class XI-D as the experimental class and 20 students in class XI-E as the control class. The research instruments are in the form of test questions and student response questionnaires. The techniques used to obtain data are test and non-test techniques. The data from the research results were analyzed using inferential statistics, namely t-test and N-gain statistics.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$X = \frac{skor\ peroleh}{skor\ maksimum} = 100\% \ldots\ldots\ldots (1)$$

$$N\ Gain = \frac{(Skor\ Posttest\text{-}Skor\ Pretest)}{(Skor\ Maksimum\text{-}Skor\ Pretest)}$$

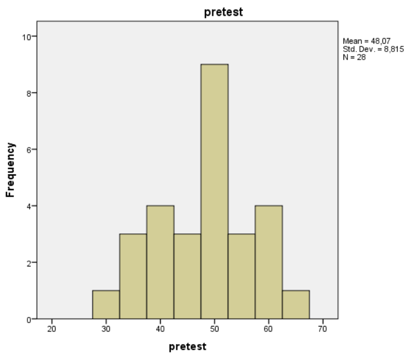
The data obtained from the student response questionnaire was analyzed using the Likert Scale to describe the level of student response to the application of Augmented Reality (AR)-based learning media in Physics learning activities, especially in Newton's Law II material (Aulia et al., 2023).

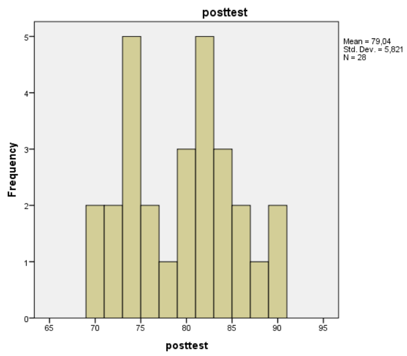
RESULT AND DISCUSSION

Based on the results of the experimental research carried out in Aliyah Negeri 2 Tidore Islands, with class IX-D as the experimental class and class IX-E as the control class, there are several aspects that are analyzed in the results and discussion section. These aspects include: pretest and posttest learning outcomes of students, pretest and posttest data normality tests in experimental and control classes, data homogeneity tests, hypothesis tests using t-tests, and N-Gain calculations for both classes.

The learning outcomes of science in this study are based on the pretest and posttest scores of the experimental class and the control class. The student learning outcomes are presented based on a comparison of the pretest and posttest results of the two classes.

The number of questions prepared was 10 items. After testing the instrument through validity and reliability tests, 8 questions were obtained that met the criteria and were suitable for use as pretest and posttest instruments in the experimental and control classes. The data on the pretest and posttest results are presented in Graph 1 and Graph 2.





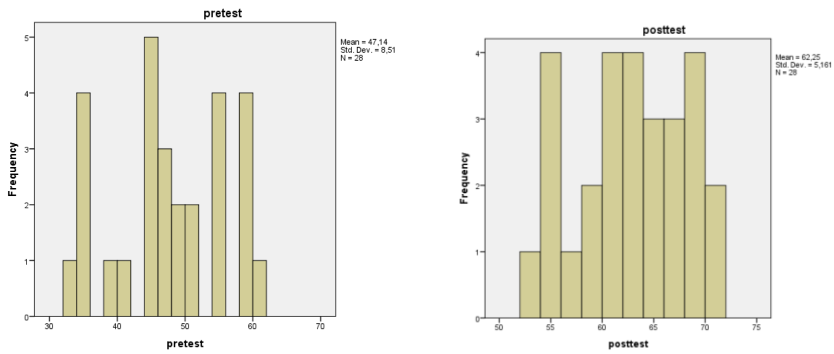


Figure 1. Distribution of Pretest and Posttest Scores for Experimental and Control Classes
Source: Research conducted at MAN 2 Tidore Kepulauan (2026)

Student learning outcomes at the beginning (pretest) and end (posttest) in the experimental class were higher than in the control class. From the data, it can be seen that the thinking ability of students in the experimental class during the pretest had a minimum score of 60, but by the time of the posttest, the minimum score increased to 90, showing a difference of 30 points. In contrast, in the control class, the pretest had a minimum score of 35, but by the posttest, the minimum score was 65, reflecting a difference of 25 points.

Based on the graph, it can be seen that during the pretest, before the implementation of the Augmented Reality (AR)-based PBL learning model, most students (56.67%) obtained scores below 56, which is classified in the very low category. Additionally, none of the students scored in the range of 80–100. After implementing learning using the AR-based PBL model, there was an increase in learning outcomes, with 8 students (37.5%) achieving scores in the range of 80–100 (very high category), while only a few students scored in the range of 45–54 (low category). Thus, it can be concluded that the application of the AR-based PBL learning model is effective in improving student learning outcomes. This indicates that the AR-based PBL approach is capable of encouraging a substantial improvement in overall student performance.

The results of the pretest in the control class showed that most students obtained scores in the low category, specifically between 54 and 40.75%, and none of the students achieved scores in the range of 80–100 (high or very high categories). After the learning session, the posttest results showed improvement, with 62.5% of students scoring between 65–79 (medium category), 34.38% scoring between 80–89 (high category), and only one student (3.13%) reaching the very high category. Despite the improvement, the achievement of student learning outcomes in the control class remains relatively limited. When compared to the experimental class that used the AR-based PBL learning model, the improvement in the control class is not as optimal. Therefore, it can be concluded that learning without the application of the AR-based PBL model is still less effective in improving overall student learning outcomes, whereas the application of the PBL model supported by AR media has proven to be more effective in fostering a more significant improvement in learning outcomes.

Before performing the hypothesis test, the data on student learning outcomes were first analyzed through a normality test and a homogeneity test. The results of these tests are presented in Table 1 and Table 2.

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

Classes		Kolmogorov-Smirnova		
		Statistic	df	Sig.
Experiments	Pretest	.966	28	.482
	Posttest	.945	28	.144
Controls	Pretest	.935	28	.081
	Posttest	.943	28	.129

Source: Data analysis conducted as part of the research study on the AR-based PBL model at MAN 2 Tidore Kepulauan (2026).

The results of the normality test using SPSS in both experimental and control class data showed a significance value greater than 0.05 (p > 0.05). Thus, it can be concluded that the data is distributed normally.

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

Classes			Living Statistic	df1	df2	Sig.
Experiment-Control	Pretest		.008	1	54	.929
	Postest	Based on Mean	.864	1	54	.357
Classes			Living Statistic	df1	df2	Sig.
Experiment-Control	Pretest		.008	1	54	.929
	Postest	Based on Mean	.864	1	54	.357

Source: Data analysis conducted as part of the research study on the AR-based PBL model at MAN 2 Tidore Kepulauan (2026)

The results of the homogeneity test using SPSS on the experimental and control class data showed a significance value greater than 0.05 (p > 0.05), so that the data was declared homogeneous. After the data on students' critical thinking ability meets the prerequisite test, then the N-Gain test and the difference test (t-test) are carried out. The N-Gain test is used to determine the effectiveness of the Augmented Reality (AR)-based PBL learning model 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	N-Gain	73,91	Quite Effective
Classes	% N-Gain	73,91 %	
Control	N-Gain	33,99	Ineffective

Class	% N-Gain	33,99 %

Source: Data analysis conducted as part of the research study on the AR-based PBL model at MAN 2 Tidore Kepulauan (2026)

The results of the study showed a significant improvement in student learning outcomes in the experimental class, with an increase of 73.92%, classified as quite effective. These findings demonstrate that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) has a positive impact on improving student learning outcomes, particularly in Newton's Law II material. This improvement reflects the success of a learning strategy that not only emphasizes knowledge transfer but also develops higher cognitive abilities such as analysis, evaluation, and reflection. In contrast, the control class, which did not use AR-based PBL teaching materials, saw an increase of only 33.99%, placing it in the less effective category. This indicates that conventional learning approaches, which are teacher-centered and lack active student involvement, have not been able to optimally support the improvement of learning outcomes.

The effectiveness of the PBL learning model is closely linked to the role of Augmented Reality (AR), which can present material visually, interactively, and accessibly. The presence of AR encourages student involvement both independently and collaboratively, while enriching learning resources that align with the demands of 21st-century learning. Therefore, the application of the AR-based PBL model not only increases learning outcomes quantitatively but also positively impacts the quality of the learning process. This model fosters students' critical thinking skills, engagement, and reflective attitudes in understanding scientific concepts.

The results of a study conducted by Masruroh et al. (2023) also show that the use of AR-based learning media significantly improves students' understanding of concepts. AR, when used in learning Newton's Law II, motion kinetics, and other topics, has been proven to improve students' concept comprehension, collaboration skills, and communication. This aligns with the principles of the PBL model, which emphasizes the importance of interaction in the learning process. Through the use of technology, students not only act as recipients of information but also as creators of knowledge. Furthermore, research by Rachmayani and Setyasto (2025) revealed that problem-based learning with the help of AR has a direct relationship with the object studied. Thus, the use of AR-based PBL models not only increases students' interest in learning but also deepens their understanding of the subject matter. This increase is significant, particularly in the context of physics learning, which is often considered difficult by students. Therefore, the combination of PBL models and AR technology can be an effective solution to overcome challenges in physics learning.

The results of the analysis using SPSS showed a very significant difference between the experimental class and the control class, with an increase of 44.56 in the experimental class compared to 20.84 in the control class. These findings indicate that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) has proven to be quite effective in improving students' critical thinking skills. This can be seen from the increase in the number of students with high scores after learning and the decrease in the number of students with low scores. The application of the PBL model combined with digital technology, such as AR, creates a more interactive, systematic learning process and significantly supports the development of critical thinking skills.

Augmented Reality (AR) itself is a technology that combines virtual elements with the real world simultaneously (Alfitriani, Maula, & Hadiapurwa, 2021). Based on the results of this study, it can be concluded that the AR-based PBL model is not only effective in improving critical thinking skills but also able to create a more engaging and enjoyable learning atmosphere. This model provides students with the opportunity to take an active role in the learning process, enabling them to understand physics concepts more deeply. Similar results were also reported by (Rahman & Prabowo, 2025), who showed that the application of the PBL model helped students better understand the material and increased their interest and motivation in learning.

The application of the Problem-Based Learning (PBL) model, which includes stages such as problem identification, investigation, discussion, and reflection, provides a systematic and structured learning approach. This model encourages students to think critically and actively because it places them at the center of the learning process (student-centered learning). In PBL-based learning, students do not merely receive information passively; instead, they are trained to think, discuss, and find solutions to the problems they encounter. This process not only hones their analytical skills but also fosters a deeper curiosity about the material being studied.

In the Observe stage, students make systematic observations by recording and analyzing the data they obtain. This stage plays an important role in helping students understand the relationship between theory and practice. In the Explain stage, students are given the opportunity to explain the results of their observations. For example, in learning Newton's Second Law concepts, students can explain the relationship between the speed of motion and the acceleration of an object. At this stage, students' communication and argumentation skills are tested, as they are required to present ideas and explanations logically and clearly—an important skill in the development of critical thinking.

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	3,574	.064	15,511	54	.000	30,964	1,996
	Equal variances not assumed			15,511	46,788	.000	30,964	1,996

Source: Data analysis conducted as part of the research study on the AR-based PBL model at MAN 2 Tidore Kepulauan (2026)

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	6.659	.013	8.032	54	.000	15.107	1.881
	Equal variances not assumed			8.032	44.459	.000	15.107	1.881

Source: Data analysis conducted as part of the research study on the AR-based PBL model at MAN 2 Tidore Kepulauan (2026)

The results showed a significant improvement in the learning outcomes of students who participated in learning with the Augmented Reality (AR)-based PBL model compared to the control class. The average post-test score in the experimental class reached 90, while in the control class, it was only 64.86. Statistical analysis showed that the difference was significant, with a p-value of 0.005 (< 0.05), indicating that the application of the AR-based PBL model has a positive effect on student learning outcomes. These findings confirm that the use of AR-based PBL models makes a significant contribution to improving learning outcomes. Through this model, students are encouraged to actively participate in the learning process, such as predicting phenomena, making direct observations, explaining findings, elaborating on knowledge, writing down results of understanding, and reflecting and evaluating. The exploratory and reflective learning cycle greatly supports the development of high-level thinking skills, especially critical thinking.

In addition, AR's role as a supporting medium strengthens the effectiveness of learning by providing structured access to information, interactive material visualization, and wider collaboration opportunities. Through this technological assistance, students can learn independently, access materials at any time, and receive direct feedback from teachers and peers. The integration of AR technology with constructivist approaches in the PBL model creates a learning experience that is more meaningful, contextual, and relevant to modern learning needs.

The significant difference in the average scores between the experimental group (79.04) and the control group (48.07), accompanied by a statistically significant value (p = 0.000), suggests that this approach is not only effective but also has the potential to be applied more widely in learning activities. Various previous studies also support this finding, showing that the application of the Problem-Based Learning (PBL) model based on Augmented Reality (AR) is able to improve student learning outcomes. The use of AR technology provides opportunities for students to conduct experiments directly, which increases learning motivation while strengthening their understanding of concepts (Faria, 2024; Majid et al., 2023).

In addition, the application of Augmented Reality (AR) technology supports a constructivist approach in education, encouraging students to be more active and participate in the learning process. This synergy between AR and a constructivist approach is in line with the research findings of Sholikhah et al. (2023), which show that the integration of technology in learning can increase student engagement. Other research also revealed that the application of the Problem-Based Learning model has a positive influence on students' problem-solving abilities, with a significance value of <0.05, meaning that alternative hypotheses (Ha) are accepted (Rahman et al., 2025). Rahman and his colleagues emphasized the importance of integrating digital learning tools into certain learning models to improve engagement, critical thinking skills, and independent learning. In this context, the use of AR helps students visualize abstract concepts, such as the interaction between force and motion in Newton's Law, into a more concrete and easy-to-understand three-dimensional form.

Through this technological support, students can explore concepts independently or collaboratively, thereby increasing active participation, learning motivation, and deepening their conceptual understanding. Furthermore, the application of the Problem-Based Learning (PBL) model provides opportunities for students to analyze real problems, formulate hypotheses, and create solutions based on logical thinking and scientific approaches. This combination of AR and PBL makes the learning process more meaningful, contextual, and relevant.

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 impact on improving student learning outcomes in physics, especially in Newton's Law II material. The average post-test score in the experimental class was 86.56, which was significantly higher compared to the control class, which obtained an average of 70.31. The results of the statistical test, with a significance value ($p = 0.005 < 0.05$), further confirm that this learning model is effective and worthy of being applied more widely. Learning models that integrate the PBL approach have been proven to increase students' active involvement through systematic learning stages and encourage the development of higher-level thinking skills.

Additionally, the use of AR media strengthens the effectiveness of the learning process by presenting interactive, structured, and collaborative materials. This technology also allows students to learn independently and receive direct feedback, making the learning experience more immersive and meaningful. It is recommended that the AR-based PBL learning model be implemented more widely across various subjects to enhance students' learning outcomes and engagement. Teachers should be provided with additional training on how to integrate AR technologies into their teaching to optimize the benefits of this approach.

Further research is needed to assess the long-term effects of AR-based PBL on students' retention of knowledge and its effectiveness in other subjects. Additionally, schools are encouraged to invest in AR learning media and technologies, as they have the potential to improve students' conceptual understanding and critical thinking skills.

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