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The Effect Of The Problem Based Learning Model Integrated With Virtual Lab On Students' Learning Outcomes In Dynamic Electricity Material

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Abstract

The Effect of Problem Based Learning Model Integrated with Virtual Lab on Student Learning Outcomes in Dynamic Electricity Material. Thesis. Science Education Study Program, Postgraduate Program, Manado State University.This study aims to determine the effect of the Problem-based learning (PBL) model, the use of Virtual Lab, and the integration of PBL and Virtual Lab models on student learning outcomes in dynamic electricity material. The study was conducted at SMK Negeri 1 Langowan using a quantitative approach with a quasi-experimental method. The study sample consisted of four treatment groups, namely the control class, PBL class, Virtual Lab class, and PBL class integrated with Virtual Lab. Learning outcome data were obtained through multiple-choice tests that have met the validity and reliability criteria. Data analysis was carried out using descriptive statistics, normality tests, homogeneity tests, one-way ANOVA tests, and Tukey's advanced tests at a significance level of 0.05. The results of the study showed that all data were normally distributed and homogeneous. The average posttest score in the control class was 69.50, the PBL class was 80.50, the Virtual Lab class was 81.50, and the PBL integrated Virtual Lab class was 86.75. The results of the ANOVA test showed a significant difference between the treatment groups (Sig. = 0.000 < 0.05). The results of the Tukey further test showed that the PBL, Virtual Lab, and integration models provided higher learning outcomes than conventional learning. In addition, the PBL integrated Virtual Lab class obtained the highest learning outcomes and was significantly different from the PBL class and the Virtual Lab class. It was concluded that the Problem-based learning model integrated with Virtual Lab had a positive and significant effect on student learning outcomes in dynamic electricity material, so it could be used as an effective learning alternative to improve student learning outcomes.

1. INTRODUCTION

Education is a crucial factor in improving the quality of human resources. In the era of globalization and rapid technological development, education is required to produce students who not only possess knowledge but also critical, creative, collaborative, and communicative thinking skills. In this context, science learning, particularly physics, plays a strategic role because it directly relates to natural phenomena and rapidly evolving technology. Physics not only teaches formulas but also trains students to think logically, systematically, and analytically in solving everyday problems. However, learning in schools is often still oriented towards mastering formulas and theoretical concepts.

One of the fundamental physics materials that is often considered difficult by students is dynamic electricity. Based on the results of preliminary survey data conducted at State Vocational School 1 Langowan, it was found that the average value of students' daily tests on dynamic electricity material was still below the Minimum Completion Criteria (KKM), where out of a total of 25 students who achieved learning completion, only 12 people (48%). There are still many students whose average score has not reached the Minimum Completion Criteria (KKM) set by the school, which is 75. This low learning outcome is caused by several factors, including: learning that is still teacher-centered with lecture methods and formula recording, lack of experimental or practicum activities, and minimal use of interactive learning media.

Field conditions indicate that school laboratories are often inadequate. Practical tools such as ammeters, voltmeters, resistors, connecting cables, and circuit boards are often damaged, limited in quantity, or even unavailable. Furthermore, dynamic electricity labs carry safety risks such as short circuits, electric shocks, or even fires if procedures are not followed correctly. Consequently, many teachers choose not to conduct labs and rely solely on verbal explanations and practice problems.

In fact, based on the constructivist theory pioneered by Piaget and Vygotsky, knowledge is more easily understood, remembered, and applied if students construct it themselves through exploration, experimentation, social interaction, and problem-solving. Students learn better when they are actively involved in the learning process, rather than simply passive recipients of information. Therefore, a learning model is needed that can activate students, integrate theory with practice, and provide authentic and contextual learning experiences. One model considered most appropriate is Problem-based Learning (PBL).

The PBL model is a learning model that uses real-world problems as a context for students to learn to think critically, solve problems, and acquire essential knowledge and skills. According to Arends, PBL is a student-centered learning model with the following characteristics: (1) posing authentic problems, (2) focusing on interdisciplinary connections, (3) conducting authentic investigations, (4) producing real products or works, and (5) collaborating in groups. In PBL, students work in small groups, identifying problems, formulating hypotheses, seeking information, conducting investigations, and presenting solutions. This model has been proven effective in various studies to improve conceptual understanding, higher-order thinking skills, and overall student learning outcomes.

However, the implementation of PBL on dynamic electricity in Indonesian schools still faces a serious obstacle, namely the limited tools and materials for investigation. In PBL syntax, after students identify a problem and formulate a hypothesis, they need to conduct experiments or observations to test the hypothesis. Without adequate laboratory tools, this investigation stage is suboptimal and may even be skipped. As a result, the essence of PBL itself is lost. An innovative solution to overcome this problem is to utilize virtual lab technology.

*Virtual lab*A virtual lab is a computer-based simulation environment that allows students to conduct virtual experiments, similar to real-life laboratory experiments, complete with interactive tools and materials. One of the most popular, free, and easily accessible examples of virtual labs is PhET Interactive Simulations. In the Circuit Construction Kit (DC) simulation, students can assemble various electrical components such as batteries, resistors, lamps, switches, ammeters, and voltmeters on a computer or laptop screen. They can change resistance and voltage values, observe electron flow in animations, and read measurement results in real time without fear of errors, short circuits, or equipment damage.

The integration of the PBL model with a virtual lab is an ideal and innovative synergy. PBL provides a pedagogical framework that emphasizes authentic problem-solving, group work, and active learning, while the virtual lab provides tools or media for conducting investigations and experiments that have been the main obstacles. Based on the description, the use of PBL and virtual lab integration is seen as a relevant solution to overcome the problems of learning dynamic electricity. Therefore, it is necessary to conduct research to determine "The Effect of the Problem-Based Learning (PBL) Model Integrated with a Virtual Lab on Student Learning Outcomes in Dynamic Electricity Material"

2. THEORITICAL REVIEW

2.1 Problem-based learning

*Problem-based learning*is a learning model that trains and develops the ability to solve problems that are oriented towards authentic problems from students' actual lives, to stimulate high-level thinking skills (Shoimin, 2014). Then Dutch (1994) as quoted by Amir (2009) stated that problem-based learning is an instructional method that challenges students to "learn to learn," working together in groups to find solutions to real problems.

The most important characteristic of the problem-based learning model is that problems are presented at the beginning of the lesson. According to Tan (Amir, 2009), some characteristics of the problem-based learning process include:

1)... Problems are used as a starting point for learning.
2)... The problems used are real-world problems presented in a floating manner.
3)... Problems typically require multiple perspectives. Solutions require students to use and derive concepts from previously taught disciplines or cross-disciplinary approaches to other fields.
4)... Problems challenge students to learn in new learning areas.
5)... Highly prioritize self-directed learning
6)... Utilize a variety of knowledge sources, not just one source.
7)... Collaborative, communicative, and cooperative learning. Students work in groups, interact, teach each other (peer teaching), and give presentations.

2.1 VirtualLaboratory (Virtual Lab)

According to Elmoazen et al. (2023), a virtual lab is a technology-based environment that enables digital experiments, including 2D/3D simulations, to study and solve experimental problems. According to Stark (2017), a virtual lab is a computer program in which users can interact with experiments through a computer interface.

2.2.......The Nature of Learning Outcomes

According to Sudjana (2017), learning outcomes are behavioral changes that encompass the cognitive, affective, and psychomotor domains resulting from teaching and learning interactions. Meanwhile, Bloom (in Anderson & Krathwohl, 2015) defines learning outcomes as the achievement of learning objectives measured through thinking skills, attitudes, and skills.

Learning outcomes are classified into three main domains, namely:

1....**Cognitive Domain**– Related to intellectual abilities, including: remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6) (Anderson & Krathwohl, 2015).
2....**Affective Domain**– Relating to attitudes, values, and emotions, such as accepting, responding, appreciating, organizing, and internalizing values.
3....**Psychomotor Domain**– Relating to physical skills and movement, such as

Learning outcomes do not stand alone, but are influenced by internal and external factors (Slameto, 2015):

1. **Internal factors**: intelligence, interests, motivation, talents, and physical condition.

2. **External factors**: family environment, school environment (teachers, facilities, curriculum), and community environment.

This research will focus on the use of learning models and learning media as variables that are suspected of influencing learning outcomes.

2.3.Relevant Research

1.... Supriyadi et al. (2022)

Title: Implementation of Problem Based Learning (PBL) Model Assisted by Virtual Laboratory Media to Improve Physics Learning Outcomes in Dynamic Electricity Material.

Focus: Virtual lab + PBL, learning outcomes

Results: The implementation of PBL syntax with virtual laboratory digital practicum successfully boosted students' learning activities. The classical mastery of knowledge competencies (cognitive learning outcomes) of students on the topic of Dynamic Electricity increased drastically after the action cycle was given.

2....Febby Damayanti et al. (2024)

Title: The Effect of PBL-Based Virtual Lab Learning Media on Critical Thinking Skills and Learning Outcomes of Excretory System Material

Focus: Virtual lab + PBL critical thinking & learning outcomes

Results: The use of Virtual Lab learning media based on Problem Based Learning has a significant effect on thinking skills in the excretory system material.

3....Luthfianingrum, N., & Sumarna, S. (2023)

Title: The Effect of Virtual Lab-Assisted PBL Learning Model on Learning Motivation and Concept Understanding

Focus: PBL virtual lab, learning motivation, conceptual understanding

Results: The PBL + virtual lab model has been proven to be effective in increasing students' learning motivation and conceptual understanding.

4....*Eva Rolita Harianja & Karya Sinulingga (2023)*

Title: The Effect of Problem Based Learning (PBL) Model Using PhET Media on High School Students' Learning Outcomes

Focus: Virtual lab + PBL, learning outcomes

Results: There is an influence of the Problem Based Learning (PBL) model using PhET media on student learning outcomes in the Temperature and Heat material in class XI of high school.

5....Research by Adha, LZ, & Yanto (2025)

Research Title: The influence of OLabs virtual lab learning media with the Problem-based learning model on student learning outcomes

Focus: Virtual lab + PBL & learning outcomes

Results: The use of a virtual lab with a Problem Based Learning (PBL) model has been proven to significantly improve student learning outcomes in the human digestive and respiratory systems.

2.4.Framework of thinking

Figure 2.1 Framework of Thinking

INITIAL CONDITIONS (PR
TEACHER (Learning Process): ▪....Teacher-centered learning, lecture method. ▪....Focus on memorizing theoretical formulas/c

meaning.

- ....Dynamic electricity practicums are ra lab equipment, as well as safety risks (

STUDENTS:

- ....Students tend to be passive in the learr
- ....Students are less motivated to learn.

LEARNING OUTCOMES:

- ....Low learning outcomes in Dynamic E
- ....The average student score is still belov
- ....Classical completion is very low

FINAL CONDITION (OUTPUT)

IMPROVING LEARNING OUTCOMES & ACTIVITIES

- ....Students are more active and motivated through circuit simulations.
- ....Abstract visualization of electric current becomes easy to understand.
- ....Significant improvement in dynamic electrical cognitive scores
- ....The aver value exceeds the KKM (>75)
- ....Classical completion increased.

GIVEN TREATMENT

Problem Based Learning (PBL) Model Assisted by Virtual Lab Media (PhET Simulations)

Learning Steps:

1. ....Problem Orientation: Observing real dynamic electrical problems
2. ....Learning Organization: Forming small groups, formulating hypotheses
3. ....Investigation (Virtual Lab): Conducting experimental simulations through PhET Simulation to collect data and test hypotheses independently/in groups.
4. ....Results Development: Compiling group reports & work presentations.
5. ....Evaluation: Analyze & evaluate concept solutions.

2.5.Research Hypothesis

The use of the PBL model, virtual lab, and PBL and virtual lab interactions have an impact on improving student learning outcomes in dynamic electricity. From this description, the following hypothesis can be formulated:

1....PBL model learning

H_0 : There is no influence in the use of PBL model strategy on improving student learning outcomes in the dynamic electricity material.

H_1: There is an influence in the use of the PBL model on improving student learning outcomes in the dynamic electricity material.

2....Virtual lab learning

H_0: There is no influence in the use of virtual labs on improving student learning outcomes in the Dynamic Electricity material.

H_1: There is an influence in the use of virtual labs on improving student learning outcomes in the material Dynamic electricity.

3....Interaction learning using PBL and Virtual Lab models

H_0: There is no influence in the use of PBL and Virtual Lab model interactions on improving student learning outcomes in the Dynamic Electricity material.

H_1: There is an influence in the use of PBL and Virtual Lab model interactions on improving the learning outcomes of class X students on the dynamic electricity material at State Vocational School 1 Langowan

3. RESEARCH METHODS

This study employed a quantitative approach with a Quasi-Experimental Design. The design used was a Pretest-Posttest Nonequivalent Control Group Design involving four study groups. The visual form of this research design is as follows:

Table 3.1 Research Design

Class	*Pretest*	Treat	*Posttest*
Experiment	X_1	X	Y_3
Control	X_2	X	Y_4

Information:

- X_1 = Initial test or before treatment (pretest) in the experimental class
- X_2 = Final test (posttest) in the experimental class
- Y_3 = Initial test or before treatment (pretest) in the control class
- Y_4 = Final test (posttest) in the control class
- X = Learning treatment

The research was conducted in the computer laboratory of SMK Negeri 1 Langowan, Minahasa Regency, North Sulawesi Province in the even semester of the 2025/2026 academic year, for three months (January-March). The population in this study were grade X students at SMK Negeri 1 Langowan which consisted of 4 classes, while sampling was carried out using Purposive Sampling or Cluster Random Sampling techniques, so that 4 classes were selected that had equivalent characteristics and initial academic abilities.

Independent Variable: Learning model consisting of 4 levels of treatment: conventional model (), PBL model (), Virtual Lab media (), and integrated PBL model Virtual Lab (), Dependent Variable: Student learning outcomes on dynamic electricity material$X_0 X_1 X_2 X_3$

The research design uses a 2x2 factorial

P_0= without PBL

P_1= with PBL model

V_0= without virtual lab

V_1= with virtual lab

Table 3.2 Research Design

Treat	V_0	V_1
P_0	P_0V_0	P_0V_1
P_1	P_1V_0	P_1V_1

Note:

P_0V_0= Control Class

P_1V_0= with PBL Model

P_0V_1= with Virtual Lab

P_1V_1= Virtual Lab integrated model

The test sheet instrument is used to measure student learning outcomes, each using a written test instrument in the form of 20 multiple-choice questions that are tested for validity and reliability and produce 20 multiple-choice items that are valid and reliable and arranged based on their indicators. This instrument is given to students in the pretest activity, namely before the treatment and posttest activities, namely after the treatment. Before being given to students, the instrument must be tested through validity and reliability tests. Testing the validity of the question items uses the SPSS program for Windows.

Research data was collected through three main stages:

1. Preparation Stage: Preparing learning devices (Teaching Modules), preparing test instruments, and conducting instrument validation tests.
2. Implementation Stage:
   - Give a pretest to the entire group.
   - Carry out the learning process according to the treatment of each group
   - Give a final test (posttest) with the same instrument.
3. Final Stage: Tabulate the pretest and posttest score data for analysis.

Data analysis begins with descriptive statistics to present data in the form of average values (mean), highest value, lowest value, and standard deviation of each treatment group. Next, Normality and Homogeneity Tests are carried out as Prerequisite Analysis Tests. Hypothesis testing is carried out using parametric statistics, namely the One-Way ANOVA Test (One Way Analysis of Variance) at a significance level (= 0.05). For further testing, a Post Hoc Test is used to compare the average between groups in pairs to determine which group produces the highest learning outcomes significantly (proving superiority (over (, (, and $(,\alpha X_3)X_1)X_2)X_0)$

4. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Learning Syntax Implementation Results Data

The data on the implementation of the learning syntax results were obtained from filling out the observation sheet by the Science subject teacher on Ohm's law and electrical circuit material on the learning activity process in the classroom. The results obtained in the implementation of the syntax are explained as follows; Implementation in PBL, namely problem orientation, organizing, guiding, presenting results, and analyzing reached a result of 91.7% which shows that the syntax has been implemented effectively and efficiently in improving student learning outcomes. The results obtained in several syntaxes can be seen in table 4.1.

Table 3.1 Results of PBL Syntax Implementation

Syntax	Real Score/Max Score	Implementation Value	Criteria

Orientation	11/12	91.7%	Very good
Organizing	11/12	91.7%	Very good
Guidance	11/12	91.7%	Very good
Presentation of Results	11/12	91.7%	Very good
Evaluation	11/12	91.7%	Very good
Average	**55/60**	91.7%	**Very good**

3.1.2 Instrument Test Results

Measurement of learning outcomes using test instruments that have previously been tested for validity and reliability using SPSS, which is described as follows.

a. Validity Test Results

Instrument validity testing can be done by correlating each question item with the total score. The results can be seen in Table 4.2 and for more details, see Appendix 4, page 84.

Table 3.2. Validity Test Results

Question Items	Sig Value	Conclusion
1	0.004	Valid
2	0.019	Valid
3	0.011	Valid
4	0.009	Valid
5	0.015	Valid
6	0.008	Valid
7	0.020	Valid
8	0.003	Valid
9	0.020	Valid
10	0.005	Valid
11	0.008	Valid
12	0.019	Valid
13	0.008	Valid
14	0.008	Valid
15	0.015	Valid
16	0.019	Valid
17	0.003	Valid
18	0.015	Valid
19	0.007	Valid
20	0.011	Valid

Based on Table 4.2, it shows that all 20 test items are declared valid with a sig. value of <0.05.

b. Reliability Test Results

Based on the validity of the questions obtained, the next test is the reliability test and the results can be seen in table 4.3.

Table 4.3. Reliability Test Results

Cronbach's Alpha Based on Standardized Items	**Number of Question Items**	**Category**
0.886	20	Very high

Table 4.3 shows that all test items are reliable, with a Cronbach's Alpha Based on Standardized Items value of 0.885. This result falls into the very high reliability category, with a value range of 0.80-1.00.

c. Difficulty Level Test Results

Table 3.4. Difficulty Level Test Results

Question Items	Mean	Classification of Difficulty Levels
1	0.60	Currently
2	0.40	Currently
3	0.30	Difficult
4	0.60	Currently
5	0.30	Difficult
6	0.45	Currently
7	0.55	Currently
8	0.50	Currently
9	0.60	Currently
10	0.35	Currently
11	0.40	Currently
12	0.45	Currently
13	0.45	Currently
14	0.45	Currently
15	0.45	Currently
16	0.40	Currently
17	0.30	Difficult
18	0.40	Currently
19	0.35	Currently
20	0.25	Difficult

Based on the results of the difficulty level test in table 4.4 above, it can be seen that the difficulty index of the questions varies. The results of the difficulty level test on the instrument have a difficulty level of questions in the difficult category totaling 7 items and a difficulty level in the medium category totaling 16 items.

d. Differential Power Test Results

Table 3.5. Results of Differential Power Test

Question Items	***Corrected Item-Total Correlation***	**Classification of Differential Power**
1	0.547	Good
2	0.448	Good
3	0.494	Good
4	0.505	Good
5	0.472	Good
6	0.508	Good
7	0.445	Good
8	0.575	Good
9	0.444	Good
10	0.540	Good
11	0.509	Good
12	0.447	Good
13	0.508	Good
14	0.508	Good
15	0.467	Good
16	0.448	Good
17	0.582	Good
18	0.468	Good
19	0.519	Good
20	0.499	Good

Based on the results of the discriminatory power test in table 4.5 above, it can be seen that 20 questions were declared to have good discriminatory power, namely with a discriminatory power index between 0.40-0.69.

3.1.3 Learning Outcome Data

Learning outcome data was obtained from pretest and posttest scores in each class which can be seen in table 4.6.

Table 3.6 Average Pretest and Posttest Scores of Learning Outcomes

Class	*Pretest*		*Posttest*	
	Mean	Std. Dev	Mean	Std.
Control Class	43.00	8,176	69.50	7,4
PBL Class	47.00	7,847	80.50	5,3
Virtual Lab Class	45.50	7,763	81.50	5,6
PBL Class Integrated Virtual Lab	46.00	8,522	86.75	5,4

Based on table 4.6 above, the average pretest and posttest scores for each class show an increase in each class. The increase in the PBL class was 71.28%, the virtual lab class was 79.12%, the PBL integrated virtual lab class was 88.59%, and the control class was 61.63%. The highest increase was found in the PBL integrated virtual lab class, namely 88.59%, and the class with the lowest increase was the control class, with an increase of 61.63%.

3.1.4 Prerequisite Test Results

a. Normality Test

The results of the normality test on the pretest and posttest data of student learning outcomes can be seen in detail in Appendix 7, page 88. Decision making in this normality test is based on a sig value > 0.05 which states that the data is normally distributed and the summary results can be seen in Table 4.7.

Table 4.7. Summary of Normality Test Results

Class	Sig Value		Conclusion
	Pretest	*Posttest*	
Control Class	0.449	0.192	Normal
PBL Class	0.336	0.128	Normal
Virtual Lab Class	0.359	0.117	Normal
PBL Class Integrated Virtual Lab	0.352	0.108	Normal

b. Homogeneity Test

The results of the homogeneity test on the pretest and posttest data of student learning outcomes can be seen in Appendix 8, page 93. Decision making in this homogeneity test is based on a sig value > 0.05 which states that the data is normally distributed and the summary results can be seen in Table 4.8.

Table 4.8. Summary of Homogeneity Test Results

Class	Sig Value	
Pretest	0.982	I
Posttest	0.261	I

3.1.5 Hypothesis Testing

The learning outcome hypothesis testing was conducted using an independent samples test, detailed in Appendix 9 on page 94. A summary of the test results can be seen in Table 4.9.

Table 4.9. Summary of Hypothesis Test Results (ANOVA)

ANOVA

Posttest Results			
	Sum of Squares	df	M Sq
Between Groups	3150,938	3	10
Within Groups	2758,750	76	3
Total	5909,688	79	

More details in appendix 9, page 94

Based on Table 4.9 above, there is a significant difference in learning outcomes with a sig. value of 0.000 < 0.05. This indicates that there is an influence of the treatment in the PBL class, the Virtual Lab class, and the PBL class integrated with Virtual Lab. Then, to determine the use of the treatment that has the most influence on student learning outcomes, further post hoc tests were conducted, namely the Tukey test, the results of which can be seen in Table 4.10.

3.2 Discussion

3.2.1 The Influence of PBL Strategy on Learning Outcomes

The results of the study indicate that the use of the Problem-Based Learning (PBL) model has a positive influence on student learning outcomes in dynamic electricity material. This is evident from the average posttest score of students in the PBL class of 80.50, higher than the control class which only obtained an average of 69.50. The average difference of 11.00 points indicates that the application of the PBL model is able to improve students' understanding of dynamic electricity concepts.

This improvement in learning outcomes occurred because the PBL model provided students with opportunities to actively participate in the learning process through identifying problems, formulating hypotheses, seeking information, conducting investigations, and developing solutions to the problems presented. Through this process, students not only received information from the teacher but also constructed their own knowledge based on the learning experiences gained during the course. This finding aligns with constructivism theory, which states that knowledge is more meaningful when constructed by students themselves through active learning experiences.

In dynamic electricity, students are confronted with various contextual problems related to the use of electrical circuits in everyday life. This encourages critical thinking and connects physics concepts to real-world situations. These activities enable students to gain a deeper understanding than conventional, teacher-centered learning.

The results of Tukey's further test showed a significance value of 0.000 (<0.05) between the control class and the PBL class (average difference -11.000). A significance value smaller than 0.05 indicates that there is a significant difference in learning outcomes between students who learn using the Problem-based learning (PBL) model and students who learn using conventional learning. Thus, H_0 which states that there is no effect of using the PBL model on improving student learning outcomes on dynamic electricity material is rejected, while H_1 which states that there is an effect of using the PBL model on improving student learning outcomes on dynamic electricity material is accepted.

The results of this study are also supported by Suminarsih's (2020) research which found that the application of the Problem Based Learning (PBL) model was able to improve students' physics learning outcomes in dynamic electricity material. Similar findings were reported by Soge, Elizabeth, and Mole (2026) which showed that there were differences in student learning outcomes using the PBL learning model and the conventional model. Posttest data showed that student learning outcomes in the experimental class using the PBL model were higher than those in the control class using the conventional model. Based on the results of the hypothesis test, the t-count (8.53) value was obtained > t-table (2.042), so it was concluded that the application of the PBL learning model in static fluid material had an effect on the learning outcomes of students at St. Maria Rubit High School. In addition, research by Gani et al. (2024) showed that the use of the Problem Based Learning learning model in the inheritance of traits material at SMP Negeri 8 SATAP Tondano had an effect on student learning outcomes and could increase student learning activities with an active category. These findings strengthen the results of this study that the application of the PBL model had a positive impact on improving student learning outcomes.

3.2.2 The Influence of Virtual Labs on Student Learning Outcomes

The results of the study showed that the use of Virtual Laboratory had a positive impact on student learning outcomes. This was demonstrated by the average posttest score of 81.50 for the Virtual Lab class, which was higher than the 69.50 for the control class. Learning outcomes in the Virtual Lab class increased by 79.12%, compared to only 61.63% in the control class.

The Virtual Lab provides a more engaging and interactive learning experience because students can directly simulate dynamic electrical experiments using the PhET Circuit Construction Kit application. Through these simulations, students can visually observe electric current flow, voltage changes, and the effect of resistance on current strength. These visualizations help students grasp abstract concepts that are difficult to directly observe in conventional learning.

Furthermore, the use of Virtual Labs overcomes the limitations of existing laboratory facilities in schools. Students can conduct experiments repeatedly without worrying about equipment damage or safety risks such as short circuits and electric shocks. This provides students with broader opportunities to explore dynamic electricity concepts independently. This aligns with the theory of Elmoazen et al. (2023), which states that virtual laboratories allow students to conduct digital experiments in a safe and flexible environment, making the learning process more effective and efficient.

The Tukey test results showed a significance value of 0.000 (<0.05) between the control class and the Virtual Lab class (average difference -12,000). A significance value smaller than 0.05 indicates that there is a significant difference in learning outcomes between students who learn using the virtual lab and students who learn using conventional learning. Thus, (H_0) which states that there is no effect of the use of the Virtual Lab on improving student learning outcomes in the dynamic electricity material is rejected, while (H_1) which states that there is an effect of the use of the Virtual Lab on improving student learning outcomes in the dynamic electricity material is accepted. Thus, it can be concluded that the use of the Virtual Lab has a positive and significant effect on improving student learning outcomes in the dynamic electricity material.

This research is supported by several previous studies, such as Wijaya et al. (2025) who found that virtual laboratories have a positive impact on student learning outcomes. The study showed that the use of virtual laboratories can improve conceptual understanding, critical thinking skills, and student learning outcomes. These results are also in line with the findings of Ulfia and Wahyuni (2025) regarding the effectiveness of PhET simulations in visualizing scientific phenomena that are difficult to observe directly to boost learning outcomes. Furthermore, the urgency of utilizing digital media and simulations underlies the argument of Wola, Rungkat, Harinda (2023) who emphasized that the success of the science learning process is highly dependent on strengthening practical activities and students' science process skills.

This research is supported by several previous studies. Wijaya et al. (2025) found that virtual laboratories positively impact student learning outcomes, while also positively impacting student learning motivation, science process skills, and thinking skills in science learning. Similar results were also reported by Ulfia and Wahyuni (2025), who showed that technology-based interactive learning methods, such as PhET, can positively contribute to student learning outcomes. Furthermore, Wola et al. (2023) emphasized that the success of science learning is highly dependent on strengthening students' practical activities and science process skills. These findings reinforce the findings of this study that the use of virtual laboratories can support a more effective learning process, thereby impacting student learning outcomes.

3.2.3 The Influence of the Integrated PBL Model with Virtual Lab

The results showed that the integration of the Problem-Based Learning model with the Virtual Laboratory model provided the highest learning outcomes compared to the other groups. The average posttest score for students in the PBL class integrated with the Virtual Lab reached 86.75, representing an 88.59% increase. This score was higher than the PBL class (80.50), the Virtual Lab class (81.50), and the control class (69.50).

The advantage of this integrated model lies in the complementary nature of the two approaches. The PBL model provides a problem-solving-oriented learning framework, while the Virtual Lab provides a platform for interactive investigations and experiments. During the learning process, students not only engage in discussions to solve problems but also test their hypotheses through virtual simulations.

The integration of the two PBL and virtual lab models also increased student engagement during learning. Observations of syntax implementation showed that all PBL stages were implemented very well, with a 91.7% success rate. This indicates that students were actively involved in problem-orientation, group organization, investigation, presentation of results, and learning evaluation.

The Tukey test results showed a significance value of 0.000 (<0.05) between the control class and the class that implemented the interaction of Problem-based learning (PBL) and Virtual Lab models. A significance value smaller than 0.05 indicates that there is a significant difference in learning outcomes between the two groups. Therefore, the null hypothesis (H_0) which states that there is no effect of using the interaction of PBL and Virtual Lab models on improving student learning outcomes in dynamic electricity material is rejected, while (H_1) which states that there is an effect of using the interaction of PBL and Virtual Lab models on improving student learning outcomes in dynamic electricity material is accepted. Thus, it can be concluded that the interaction of Problem-based learning (PBL) and Virtual Lab models has a positive and significant effect on improving student learning outcomes in dynamic electricity material. These findings indicate that the combination of problem-based learning and the use of virtual laboratories can create a more effective learning experience than conventional learning.

. The results of this study are supported by a number of previous studies, one of which is Suminarsih's (2020) study which showed that the application of the PBL model assisted by a virtual laboratory on dynamic electricity material was able to significantly improve learning outcomes because the combination of problem solving and virtual experiments effectively boosted students' conceptual understanding and learning activities. In line with these findings, Damayanti et al. (2024) found that the use of a PBL-based Virtual Lab had a significant impact on student learning outcomes by increasing their engagement during the learning process. This positive impact is reinforced by the study of Adha and Yanto (2025) which confirmed that the integration of the Virtual Lab with the PBL model resulted in higher learning outcomes compared to conventional learning, because students had a golden opportunity to conduct investigations and

3.2.4 Differences in Effectiveness Between Treatment Groups

The ANOVA test results showed a significance value of 0.000 (<0.05), indicating a significant difference in learning outcomes between the treatment groups. Therefore, a further Tukey test was conducted to determine which group had the highest effectiveness.

The results of the Tukey test show that:

1. The PBL class was significantly different from the control class (Sig. = 0.000).

2. The Virtual Lab class was significantly different from the control class (Sig. = 0.000).
3. The PBL and Virtual Lab Interaction Class was significantly different from the control class (Sig. = 0.000).
4. The PBL class was not significantly different from the Virtual Lab class (Sig. = 0.953).
5. The PBL and Virtual Lab Interaction Class was significantly different from the PBL class (Sig. = 0.008).
6. The PBL and Virtual Lab Interaction Class was significantly different from the Virtual Lab class (Sig. = 0.036).

These findings indicate that using PBL and Virtual Labs separately has relatively equal effectiveness in improving student learning outcomes. However, when the two approaches are combined in a single learning process, student learning outcomes improve significantly and achieve the highest scores.

This demonstrates a synergistic effect between the PBL and Virtual Lab models. PBL plays a role in developing critical thinking and problem-solving skills, while Virtual Lab strengthens conceptual understanding through visualization and virtual experiments. The combination of the two results in more meaningful learning, thus optimally improving student learning outcomes.

5. CONCLUSION AND SUGGESTIONS

4.1 Conclusion

The use of the Problem Based Learning (PBL) model has a positive and significant effect on student learning outcomes in dynamic electricity. This is indicated by the average posttest score of the PBL class of 80.50, which is higher than the control class of 69.50. The Tukey test results show a significance value of 0.000 (<0.05), so H_0 is rejected and H_1 is accepted.

The use of Virtual Lab has a positive and significant effect on student learning outcomes in dynamic electricity. The average posttest score of the Virtual Lab class reached 81.50, higher than the control class which obtained an average of 69.50. The results of the Tukey test showed a significance value of 0.000 (<0.05), so H_0 was rejected and H_1 was accepted. The use of Virtual Lab helps students understand the abstract concepts of dynamic electricity through interactive simulations, thereby improving conceptual understanding and learning outcomes more effectively in improving student conceptual understanding and learning outcomes.

The Problem Based Learning (PBL) model integrated with Virtual Lab has a positive and significant effect on student learning outcomes in dynamic electricity. The PBL class integrated with Virtual Lab obtained the highest average posttest score of 86.75 with a percentage increase of 88.59%. The Tukey test results showed that the PBL class integrated with Virtual Lab was significantly different from the PBL class (Sig. = 0.008) and the Virtual Lab class (Sig. = 0.036). Therefore, H_0 is rejected and H_1 is accepted. The integration of PBL and Virtual Lab has proven to be the most effective learning approach because it is able to combine problem-solving activities with interactive virtual experiments, thereby optimally increasing student engagement, conceptual understanding, and learning outcomes

4.2 Suggestion

The suggestions that can be given in this research are as follows:

1. The use of the integrated PBL learning strategy Virtual Lab can be applied to other materials and classes at other levels, so that it can give rise to a variety of research models as a contribution to scientific knowledge.
2. Teachers are advised to implement a problem-based learning (PBL) model integrated with a virtual lab in their learning process, particularly for abstract physics materials that require practical work, such as dynamic electricity. This model can improve student engagement, critical thinking skills, and learning outcomes by making learning more interactive and student-centered. Teachers are also expected to effectively manage learning so that students can collaborate, discuss, and solve problems optimally.
3. Future researchers are advised to expand this research to other science subjects or at different educational levels to obtain broader results. Furthermore, further research could include other variables such as learning motivation, critical thinking skills, creativity, or science process skills to further explore the impact of the virtual lab-integrated PBL model.

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