JPPIPA 9(11) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Investigation of Problem-Based Learning (PBL) on Physics Education Technology (PhET) Simulation in Improving Student Learning Outcomes in Acid-Base Material

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Received: July 28, 2023
Revised: October 1, 2023
Accepted: November 25, 2023
Published: November 30, 2023

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DOI: 10.29303/jppipa.v9i11.4820

Abstract: This study aimed to ascertain how well the problem-based learning model and physics education technology (PhET) simulation improved student learning outcomes in acid-base materials. The research method used was a quasi-experiment with a non-equivalent control group design. Data collection techniques were used in this study by providing test instruments in the form of multiple-choice questions, pretests and posttests, and observation sheets of teacher and student activities. The findings revealed that students taught using the PBL model with PhET simulation achieved an average learning outcome score of 79.29, while those taught using the PBL model alone obtained an average score of 73.97. The calculated average N-gain of 0.70 (categorized as medium) indicates that the PBL model with PhET simulation significantly contributed to enhancing student learning outcomes. This study demonstrates that integrating the PBL model with PhET simulation is an effective approach for improving student learning outcomes in the context of acid-base materials. The results highlight the importance of experiential, inquiry-based approaches combined with technology in enhancing student engagement and understanding. Further research could explore the long-term effects of implementing this instructional approach and investigate its impact on broader aspects of student learning in science education.

Keywords: Acid; Base; PhET; Problem-based learning; Learning outcomes;

Introduction

The 2013 curriculum is a new government policy in the field of education that is expected to be able to answer the challenges and problems that will be faced by the Indonesian people in the future. The 2013 curriculum demands that in the implementation of learning, students are free to think about understanding problems, build problem-solving strategies, and submit ideas freely and openly (Bebasari et al., 2022; Retnawati et al., 2018). One method that emphasizes process and work is experimentation and practicum activities. In school, a subject that is closely related to practicum is chemistry. Chemistry is an important subject for students because it can improve their thinking skills and stimulate creative thinking (Rahmawati et al., 2019; Wan et al., 2023). It's just that, in reality, many students still experience difficulties when learning chemistry. The fact that chemistry is an abstract and difficult concept that necessitates a thorough understanding causes students' difficulties in understanding chemistry (Sozbilir, 2004; Rahmawati et al., 2022). Chemistry is a field of study that students prefer to avoid because it is considered a difficult and boring subject by most students (Sanjiwani et al., 2020; Cardellini, 2012). Some of the difficulties students experience in learning chemistry are caused by students not knowing how to learn, having difficulty connecting concepts, and requiring the ability to utilize logic, mathematics, and language skills (Zakiyah et al., 2018; Priliyanti et al., 2021; Gultom et al., 2023; Inayah, 2023).

How to Cite:
Haetami, A., Zulvita, N., Dahlan, Maysara, Marhadi, M. A., & Santoso, T. (2023). Investigation of Problem-Based Learning (PBL) on Physics Education Technology (PhET) Simulation in Improving Student Learning Outcomes in Acid-Base Material. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9738–9748. https://doi.org/10.29303/jppipa.v9i11.4820

Based on the results of initial observations at Senior High School 1 Siompu, it was found that in teaching, the teacher uses the project-based learning model; it's just that in practice, some students need to become more familiar with real problems. They are used to solving problems after seeing examples of questions from the teacher. As a result, students feel they need more time to solve problems, and they play a lot in class. Other information obtained from the Chemistry Teacher at Senior High School 1 Siompu is that chemistry lessons are difficult to understand, especially material on abstract concepts that require memorization and skills such as acid-base material. Students' difficulties in understanding acid-base concepts can be seen from the low student learning outcomes. The average value of students' daily test evaluation results in 2019/2020 was 66.04.

Furthermore, the average value for the 2020–2021 school year is 68.15. This value does not meet the school's KKM (Minimum Completeness Criteria) score of 75. Based on the problems described, it is necessary to make efforts to solve them. The steps that can be taken include applying learning media and practicum activities. With these activities, students will be happy and easily accept the concept of the discussed material. So learning is not only about concepts; a scientific process is applied in practical activities. The reasons for the importance of doing a practicum are: it can foster learning motivation, improve basic skills in experimenting, become a means of learning in a scientific approach, help smooth understanding of subject matter, and illustrate a chemical concept (Zulyusri et al., 2023; Sakdimah & Dewata, 2018; Alshaikh, 2023; Hulyadi et al., 2023).

Learning media are needed to help carry out learning activities and improve student learning outcomes (Widodo, 2018; Kao et al., 2023). Learning media is a factor that supports the success of the learning process in schools because it can help the process of conveying information from teachers to students or vice versa (Liliana et al., 2020; Sukariasih et al., 2022; Khairunnisa et al., 2020). Today's increasingly developing technology requires teachers to use technology to create and develop instructional media according to their progress (Kossybayeva et al., 2022; Maussumbayev et al., 2022). Education 4.0 (Education 4.0) is a general term education experts use to describe various ways of physically integrating technology into learning. One of the media that teachers can use as a tool is PhET simulation media (McKagan et al., 2008; Paje et al., 2021; Banda & Nzabahimana, 2021).

Physics Education Technology (PhET) is an interactive application regarding research-based physical phenomena that can be used free of charge. The PhET application, or virtual laboratory, was developed by a team from the University of Colorado in the United States (Moore et al., 2014; Perkins et al., 2012; Anderson & Barnet, 2013). PhET applications are used to assist students in understanding virtual concepts. PhET applications can clarify concepts using graphics and intuitive controls (Perkins et al., 2012; McKagan et al., 2008). According to research by Riku (2021), there was an improvement in student learning outcomes after using the Discovery Learning learning model with PhET (Physics Education Technology) media simulations in chemistry subjects with the material Molecular Forms in class X_{IPA} Senior High School 1 Wolowa in the odd semester of the 2019/2020 academic year.

Given the ongoing evolution of education, it is crucial to investigate inventive instructional approaches that improve student learning results and foster a more profound comprehension of intricate ideas. The primary focus of this study is to enhance student achievement in acid-base materials through integrating problem-based learning (PBL) and physics education technology (PhET) simulation. Science education equips the upcoming generation to address intricate global concerns. To comprehend physics topics, students must actively participate in efficient learning strategies that foster problem-solving, analytical thinking, and the tangible implementation of acquired knowledge. Problem-based learning (PBL) is a technique that has garnered considerable interest. Problem-based learning (PBL) is an instructional approach that focuses on the student and is centered on solving real-life problems. Within the framework of physics, students engage in active exploration and problem-solving as they tackle significant issues or scenarios offered to them in PBL. Research has demonstrated that problem-based learning (PBL) is effective in improving conceptual comprehension, fostering critical thinking abilities, and enhancing student retention in the field of physics education.

Conversely, the progress of educational technology has created fresh prospects in physics teaching. The Physics Education Technology (PhET) Simulation is a physics learning tool that enables students to engage with interactive simulation models. PhET simulations have demonstrated efficacy in enhancing the grasp of intricate physics ideas and enhancing students' visual perception.

Acid-base materials are a significant subject in the physics curriculum and are frequently seen as difficult for students to comprehend. Hence, it is imperative to examine the integration of PBL with PhET simulations to optimize student learning results in this domain. The study aims to ascertain the efficacy of problem-based learning (PBL) and PhET simulations in facilitating students' understanding of acid-base materials. The study aims to determine the effectiveness of PhET simulations in enhancing students' comprehension of ideas. This will be achieved by comparing a group of students who were taught using the problem-based learning (PBL) model with the integration of PhET simulations to another group who were trained using the PBL model alone.

Furthermore, the study will investigate the change in students' learning outcomes abilities after engaging in problem-based learning (PBL) and learning through PhET simulations. Proficiency in cognitive skills, such as deductive reasoning, and assessment, is important for comprehending physics principles profoundly and implementing them in practical scenarios. The research findings will offer useful insights to educational practitioners and physics teachers, aiding them in the development and execution of impactful learning experiences. Suppose the study demonstrates that incorporating PhET simulations into problem-based learning (PBL) enhances students' understanding of acid-base materials. In that case, this approach can be more frequently employed.

Based on the considerations and needs description, the researcher is interested in studying the influence of the PheT-based problem-based learning model on chemistry lessons at school. The study is expected to become an interactive simulation platform that allows students to be actively involved in virtual experiments regarding the concept of acids and bases. By experiencing themselves and observing the effect of changing certain parameters, students can better understand the phenomena underlying acid-base reactions. In addition, with the PheT, students face problem scenarios relevant to everyday life or the surrounding environment. By using PhET to explore the concept of acids and bases in the context of real problems, students can more easily understand and associate theory with its real-life applications. Thus, technology such as PhET can increase student involvement in learning. Interesting and fun interactive simulations can make students more enthusiastic about understanding the concept of acids and bases and reduce boredom in learning.

Method

This research was carried out in the 2022–2023 school year for students of class XI at MIPA Senior High School 1, Siompu. The research method used in this study was a quasi-experimental design with a non-equivalent control group. The following is a non-equivalent control group design (Table 1).

Table 1. Non-equivalent control group design

O_1	X	O_2
O_3	Y	O_4

Where: O_1 = Pretest for experimental class, O_3 = Pretest for control class, X = PBL learning model assisted by PhET Simulation, Y = PBL learning model, O_2 = Posttest for experimental class, O_4 = Posttest for control class.

The population in this study was all students of class XI MIPA, which consisted of 2 classes with 29 students in MIPA 1 and 28 in MIPA 2, so the total number was 75. The two classes also served as samples, where class XI MIPA 1 was the experimental class and class MIPA 2 was the control class. In this study, the instrument used to collect data was a learning achievement test in the form of pretest and posttest multiple-choice questions and observation sheets of teacher and student activities. Step-by-step research procedure for the investigation of Problem-Based Learning (PBL) on Physics Education Technology (PhET) Simulation in Improving Student Learning Outcomes in Acid-Base Material:

Identify the Research Objectives; Clearly define the study's objectives, such as assessing the effectiveness of PBL integrated with PhET simulation in improving student learning outcomes in acid-base materials. Design the Research Study; a. Quasi-Experimental Design: Select a quasi-experimental design with a non-equivalent control group to compare the effectiveness of the intervention. Assign one group to the experimental condition (PBL + PhET) and the other to the control condition (PBL-only).

Participant Selection; a. Identify and select the participants who will participate in the study, such as high school physics students from a specific grade level or class. b. Ensure that participants are randomly assigned to the experimental and control groups to minimize potential confounding variables. Develop Pretest Assessment; a. Design and validate a pretest assessment that evaluates students' baseline knowledge and understanding of acid-base materials. b. The pretest should cover relevant conceptual areas and align with the desired learning outcomes.

Implement the PBL + PhET Intervention; a. Design PBL Lesson Plan: Develop a detailed PBL lesson plan integrating PhET simulations specifically targeting acid-base materials. b. Provide students in the experimental group with the PBL lesson plan, guiding them through the problem-solving process using PhET simulations. c. The control group should receive a similar PBL lesson plan without the integration of PhET simulations. Implement Posttest Assessment; a. Develop a posttest assessment that aligns with the learning objectives and measures students' understanding of acid-base materials after the intervention. b. Administer the posttest evaluation to both the experimental and control groups.

Collect Additional Data; a. Teacher and Student Activities: Observe and record teacher and student activities during the PBL + PhET intervention. Use observation sheets that document student engagement, collaboration, and critical thinking skills displayed. Analyze the Data; a. Quantitative Analysis: Utilize appropriate statistical methods to analyze the pretest and posttest scores, calculating the average scores and comparing the learning outcomes between the experimental and control groups. b. Qualitative Analysis: Conduct qualitative analysis of the teacher and student activities observed during the intervention to identify patterns, themes, and insights related to the effectiveness of the PBL + PhET approach.

Interpret and discuss; the Findings a. Interpret the quantitative and qualitative findings, comparing the learning outcomes between the two groups. b. Discuss the implications and significance of the results, considering previous research and theoretical frameworks. c. Reflect on the limitations of the study and suggest areas for future research.

Report and conclude; a. Compile the research findings, analysis, and discussion into a comprehensive account. b. Summarize the key findings, contributions, and implications of the study. c. Conclude the research report with recommendations for educators and policymakers regarding integrating PBL and PhET simulation in acid-base material instruction.

The data analysis phase begins with distributing the average value of student learning outcomes, calculating the standard deviation, calculating N-gain, and determining the percentage of student learning activity and teacher teaching. The categorization of the gain index values obtained is then processed to determine the N-gain index level, as shown in Table 2.

Table 2. N-gain criteria

N-gain index	Interpretation
N-gain > 0.70	High
0,30 ≤ N-gain ≤ 0.70	Medium
N-gain < 0.3	Low

The analysis of the observation sheet to determine student learning activities and teacher teaching in the classroom was analyzed using percentage analysis, which is interpreted in Table 3. The percentage of quality in the implementation of learning is obtained by using equation (1).

$$P\% = \frac{\text{Total scores of observations}}{\text{Maximum total score}} \times 100\% \quad (1)$$

Where, P = Percentage of the quality of learning implementation

Table 3. Interpretation of the quality of learning implementation

Percentage of the quality of learning implementation	Criteria
0% - 20%	Very less
21% - 40%	Not enough
41% - 60%	Currently
61% - 80%	Good
81% - 100%	Very good

Result and Discussion

Student learning outcomes

The learning outcomes of students in the experimental class who were taught the PBL model assisted by PhET Simulation and the control class with the PBL model are shown in Table 4.

Table 4. Data on student learning outcomes in the control and experimental classes

Parameter	Experiment		Control	
	Pretest	Posttest	Pretest	Posttest
The number of students	28	28	29	29
Minimum Value	15	60	15	55
Maximum Value	45	95	50	90
Means	31.79	79.29	34.83	73.97
Mode	30	75	35	80
Median	30	80	35	75
Standard Deviation	8.74	9.20	9.68	9.76

Table 4 shows that the control and experimental classes had equally low abilities before being given treatment; this indicates that students with initial abilities about the material to be taught still need to improve. However, after being given different treatments, namely by applying the problem-based learning model to the control class and the PhET Simulation-assisted problem-based learning model to the experimental class, the average learning outcomes in both classes increased, but the increase in learning outcomes in the experimental class was higher than the control class. This increase is related to the media used. The difference in improving student learning outcomes between the control class and the experimental class can be seen in Figure 1.

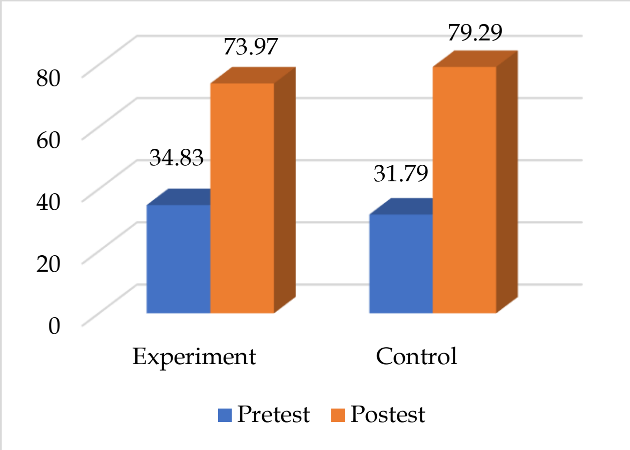

Figure 1. Graph of student learning outcomes in the control class and experimental class

Figure 1 shows that the average student learning outcomes in the experimental class are higher than in the control class. Since the media used (PhET Simulation) was the cause of this increase, it is clear that using PhET Simulation for virtual practicums effectively improves learning outcomes because it can accommodate all learning styles, including auditory, visual, and kinesthetic. This research also aligns with De Jong et al. (2013) and Koretsky et al. (2008), which show that a virtual laboratory likened to an interactive environment can improve learning outcomes.

Figure 1 shows that the control group experienced an increase in the average score from the pretest (31.79) to the posttest (79.29). This indicates a positive change in understanding of the material or students' skills after participating in the program or learning. Meanwhile, it can be observed that the experimental class group also experienced an increase in the average score from the pretest (34.83) to the post-test (73.97). Even though the post-test scores were not as large as those in the control class, positive changes in scores indicated that the intervention or treatment given to the experimental class had a positive impact on students' understanding or skills.

Table 5. Categorization of student learning outcomes on acid-base material

Mastery Level	Completeness	Experiment				Control			
		Pretest		Posttest		Pretest		Posttest	
		F	%	F	%	F	%	F	%
0> x <75	Not complete	28	100	6	21	29	100	12	41
75> x <100	complete	0	0	22	79	0	0	17	59
Total		28	100	28	100	29	100	29	100

According to Table 4, where the school set the KKM (Minimum Completeness Criteria) score at 75, 41% of students in the control class and 21% in the experimental class did not experience completeness. This is due to the PBL learning model, a student-centered learning model in which students must know the subject matter before learning activities occur. According to Wulandari (2021) and Irwansyah (2021), one of the drawbacks of the PBL learning model is that students need to be interested in or believe that the problems studied are easy to solve, so they are hesitant to try. The need for researchers to have more ability to encourage students to solve problems is also one reason for students' reduced interest in solving the given problems. Another factor that causes the learning process to be less than optimal is the allocation of time. For example, when determining the pH of a solution, students seem to be in a hurry to work on the questions given because the time in the learning process is insufficient. Hence, they are less focused on participating in learning. The standard deviation of the data shows the distribution of student learning outcomes. From the study results, the pretest standard deviation was smaller than the post-test standard deviation in both classes. This shows that students' initial abilities are relatively the same. While the post-test scores have increased because of students' different abilities in receiving lessons, even though the PBL learning model is applied, some students still need help understanding the material. As in teaching and learning activities, some students are active, less active, or not active in learning.

Student & teacher learning activities

Data on student learning activities of Senior High School 1 Siompu obtained from observation results can be seen in Table 6.

Tabel 6. Description of observation results of student learning activities

Observation	Student activity			Average (%)	Criteria
	Meeting 1	Meeting 2	Meeting 3		
Control class	88	89	90	89	Very good
Experiment class	89	90	93	91	Very good

From Table 6, it was found that the data from observations of student activities from the first meeting to the third meeting continued to increase. Students were still adjusting to the learning media model at the first meeting. At the second meeting, student activity increased to 89 in the control class and 90 in the experimental class; it was 90 in the control class at the third meeting and 93 in the experimental class. Based on the analysis of the results of observations of student involvement, the achievement of all aspects observed in the control class was 89 and in the experimental class was 91, and each was in the very good category. The value of the learning activities of the experimental class students was greater than that of the control class because student activities influenced the learning process taking place with the help of PhET Simulation. The results of observing teacher activity during the learning process can be seen in Table 7.

Table 7. Description of teacher activity observation results

Observation	Teacher activity			Average (%)	Criteria
	Meet 1	Meet 2	Meet 3		
Control	84	88	90	87	Very good
Experiment	85	90	93	89	Very good

From the first meeting to the third meeting, both the control class and the experimental class experienced an increase. This increase occurs because the teacher has begun to adjust to the conditions of the students during the learning process and has been able to guide the students in their learning (Table 7). The average value of teacher activity is 87 for the control class and 89 for the experimental class, which is in the very good category. The activities of students and teachers in the learning process determine the learning outcomes obtained. The learning outcomes in the experimental class were higher than those in the control class because, apart from the learning model, they were also due to the influence of student and teacher activities in the learning process. The teacher has direct control over all teaching and learning activities in the classroom. Therefore, teachers must be more creative in observing various problems during the process (Haetami, 2022; Fredagsvik, 2023). A teacher's success in the learning process can be seen in achieving learning objectives. One achievement of learning objectives is that students can understand the material the teacher presents. How students perceive the teaching and learning process is key to successfully achieving educational goals. Students who study will certainly experience a change in knowledge, understanding, skills, values, and attitudes. Teachers, as people who are considered to have the ability to transfer knowledge to students, are expected to be able to carry out tasks professionally according to the discipline they have (Dimkpa, 2015; Girvan et al., 2016; Jeschke et al., 2021)

The effectiveness of learning models

The effectiveness of the PhET Simulation-assisted problem-based learning model based on the N-gain value in the experimental and control class can be seen in Table 8.

Table 8. N-gain student learning outcomes

Interval	Control		Experiment	
	Total student	Percentage	Total student	Percentage
N-Gain <0.30	0	0	0	0
0.30 ≤ N-gain ≤ 0.70	22	75.86	15	55
N-Gain >0.70	7	24.13	50	90
Average		0.60		0.70
Classification		Medium		Medium

Table 8 shows no students have average learning outcomes in the N-Gain range below 0.3. However, there were 22 students in the control class and 18 students in the experimental class whose average learning outcomes were in the N-gain range below 0.7, and 7 students in the control class and 10 students in the experimental class whose average learning outcomes were in the N-gain range above 0.7. At the same time, the average N-Gain value is 0.60 in the control class and 0.70 in the experimental class, with moderate classification in the second class. This illustrates that the PhET Simulation-assisted PBL learning model is effective for the learning process because it can improve student learning outcomes. When learning to use the PhET Simulation-assisted PBL model, students focus on solving problems and are problem-oriented. Educators present problems, ask questions, and argue. Students play an active role in learning because this model focuses on student activity.

This learning model will encourage students to dare to do something, and students will try to understand the material in the learning process.

With the help of the PhET Simulation, students can easily carry out practicums using only a laptop or Android (Budiarti & Lumbu, 2021; Prayoga et al., 2023). So the characteristics of learning using the PBL model assisted by PhET Simulation have compatibility and mutually support one another. Easy-to-understand learning stages are necessary for the application of learning so that students are not burdened with complicated steps but can focus on the learning process to improve student learning outcomes in acid-base material. So that the average N-gain value of the experimental class's student learning outcomes is greater than that of the control class.

Normality test

The results of the normality test for student learning outcomes data can be seen in Table 9.

Table 9. Normality test result

	Control class		Experiment class	
	Pretest	Posttest	Pretest	Posttest
Total student	29	29	28	28
Mean	34.83	73.97	31.79	79.29
Sig.	0.200	0.119	0.200	0.145

Table 9 shows that the results of the normality test for the average value of the data on student learning outcomes for both classes obtained a significance value for the pretest scores for the control and experimental classes, namely 0.200, while the posttest scores for the control class and the experimental class, respectively, were 0.119 and 0.145. The significance value is greater than 0.05. Thus, it can be concluded that Ho is accepted, which means that the average value of the learning outcomes data for the two classes is normally distributed.

Homogeneity test

The results of the average homogeneity test of student learning outcomes in the experimental class and control class can be seen in Table 10.

Table 10. Homogeneity result test

Source date	Sig.	Information
The average value of learning outcomes	0.683	Homogeneity

Table 10 shows that the significance value for the homogeneity test of the average data value on student learning outcomes between the experimental and control classes was 0.683. The significance value is greater than 0.05, so it can be concluded that Ho is accepted, which means that the variances of the two samples are homogeneous.

Hypothesis Test

The results of hypothesis testing of student learning outcomes data can be seen in Table 11.

Table 11. Hypothesis result test

Source date	T	Df	Sig. (2-tailed)	Information
The average value of learning outcomes	-2.116	55	0.039	H_a accepted

Table 11 shows that the significance value (2-tailed) is 0.05, so it can be concluded that H_o is rejected. H_a indicates a significant difference between the average scores of students taught using the problem-based learning model with PhET Simulation and the average value of learning outcomes taught using the problem-based learning model. The average learning outcomes of students using the PhET Simulation-assisted Problem-based learning model was greater than those taught with the Problem-based learning model. This shows that the PhET Simulation media in the Problem-based learning model improves student learning outcomes. This is due to several factors. First, with the problem-based learning model assisted by PhET Simulation, students are motivated to learn so they can solve problems given by the teacher. Second, the learning process of using the problem-based learning model assisted by PhET Simulation makes lessons more attractive to students because they can learn by exploring concepts. This is in line with the research by Putri & Jatmiko (2018) and Kurniasih et al. (2018) that there was a significant increase in the results of students' generic abilities in fluid dynamic learning in the experimental class using the application of the Problem-Based Learning (PBL) learning model with the help of PhET Simulation media compared to the control class using conventional models, as evidenced by the average score N-gain.

The use of PheT (Physics Education Technology) in learning acid-base material is an approach that can potentially improve student learning outcomes innovatively and effectively (Firmayanto et al., 2021; Ulhaq et al., 2023). PhET technology provides interactive simulation facilities that allow students to experience virtual experiments, understand concepts in depth, and relate them to applications in everyday life (Salame & Makki, 2021; Wijaya & Widodo, 2021). With PheT, students can actively learn, increasing their involvement and enthusiasm in understanding acid-base material (Srivastava et al., 2020; Puspitasari & Mufit, 2021). Students' critical thinking and problem-solving abilities can also develop through the exploration of concepts that involve interactive activities that have an impact on improving student learning outcomes (Batuyong & Antonio, 2018; Halim et al., 2021)

The PhET (Physics Education Technology)-based Problem-Based Learning (PBL) model is an innovative and effective learning approach for improving student learning outcomes in acid-base materials. Using PhET, students can experience interactive experiments, a deeper understanding of concepts, and practical experiences without attending a physical laboratory in person (Penn & Ramnarain, 2019; Moore & Perkins, 2018). Through the PBL model, students are invited to be actively involved in solving real problems relevant to the concept of acids and bases, enabling them to associate theory with applications in everyday life. In addition, this approach also develops students' critical and collaborative thinking skills in analyzing information and finding solutions together. Increased student engagement, interaction with PhET technology, and a focus on a deep understanding of acid-base material will positively impact their learning outcomes. Thus, PhET-based PBL is an effective learning approach to ensure students gain a solid understanding and can better apply acid-base concepts in real life. By continuing to apply innovative learning methods like this, we can improve the quality of education and prepare students to become knowledgeable and competent individuals.

Conclusion

Based on the results of the data analysis, it can be concluded that the learning outcomes of students taught with the PhET Simulation-assisted PBL learning model in class XI MIPA 1 Senior High School 1 Siompu in acid-base material have increased and are better compared to the learning outcomes of students in class XI MIPA 2 who are taught using the model learning problem-based learning. The average value of the pre-test for class XI MIPA 1, namely 31.79, and the average value of the post-test, namely 79.29, were the same, while the average pre-test for class XI MIPA 2 was 34.83. The post-test was 73.97, indicating that the average N-gain of student learning outcomes is 0.70 (moderate category), which indicates that the problem-based learning model with PhET Simulation's assistance effectively improves student learning outcomes. Thus, it can be concluded that the PhET Simulation in the problem-based learning model affects improving student learning outcomes in acid-base material, as indicated by the differences in learning outcomes between the experimental class and the control class, where the experimental class student learning outcomes are higher than student learning outcomes in the control class.

Acknowledgments

The author would like to thank Mr. La Ode Muhamad Asfid, S.Pd., the principal of Senior High School 1 Siompu, and Mr. Albar, S.Pd., a chemistry teacher who has helped in the smooth running of the research process.

Author Contributions

Aceng Haetami: validation, funding, supervision, writing-original preparation; Nina Zulvita: formal analysis, methodology, investigation, Dahlan: visualitation, investigation, conceptualization; Maysara: visualitation; M. Alim Marhadi: visualitation, editing; Tri Santoso: editing, data curation

Funding

This research received no external funding

Conflicts of Interest

The authors declare no conflict of interest.

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