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Applying the PhET Simulation and Problem-Based Learning to Enhance Students' Problem-Solving Ability

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Abstract

The primary focus of physics instruction in schools is to improve students' problem-solving skills. This study aims to determine whether employing problem-based learning can enhance students' problem-solving skills. This study employs a quasi-experimental design with a non-equivalent control group. It was discovered that students' problem-solving skills remained deficient due to less collaborative and active learning. The study was carried out in classes XI A through XI D at MAN 1 Mataram. The researchers used purposive sampling, which resulted in XI C and XI D being designated as the experimental and control classes, respectively. The test used in the research data collection method consisted of ten questions. Pretest and posttest results are research data. N-Gain is used to evaluate the effectiveness of the learning process. According to the N-Gain results, the N-Gain of the experimental class was 0,66, whereas the control class was 0,48. Therefore, it can be said that using PhET simulations to facilitate problem-based learning is a good way to enhance problem-solving abilities. Compared to traditional learning, the use of the problem-based learning paradigm with PhET simulation is more successful.

Keywords: Problem Solving; Problem-Based Learning; Sound Waves.

INTRODUCTION

The demands of 21st-century education encourage the development of innovative learning approaches to prepare students for the global challenges of the future. These challenges require students to master 21st-century skills, not only for future careers but also for meaningful self-actualization in a world that is vastly different from that of the 20th century (Aktamış, 2024). Among the key skills that need to be developed are critical thinking, problem solving, creativity, and collaborative ability in addressing real-world problems (Fitriani et al., 2024; Nahar & Machado, 2025; Handajani et al., 2018; Tanjung & Mufit, 2023; Setiawati et al., 2020; Khoiri et al., 2021). Schools are essential for the development of these abilities. Educational institutions must cultivate learners who are not only knowledgeable but also responsible, independent, caring, and critical thinkers (OECD, 2023). Teachers, as key agents in this process, must adopt student-centered learning approaches and act as facilitators to ensure effective development of these essential competencies (Tandika, 2022). As such, promoting problem-solving in classrooms becomes a core priority for preparing students to face real-life challenges (Heldalia, 2025).

The ability to utilize information, comprehension, and abilities to solve problems and turn what was formerly difficult into something manageable is known as problem-solving (Kusaeri, 2019). In the educational setting, it entails motivating pupils to actively participate in the learning process while thinking critically, logically, and creatively (Kania, 2022). Effective problem-solving involves multiple competencies, including conceptual, technical, and methodological knowledge, as well as interdisciplinary thinking (Morgado et al., 2025). This skill is particularly vital in science subjects such as physics, which deals with abstract concepts like sound waves, requiring strong analytical and problem-solving abilities (Öztürk, 2023; Kiswanto, 2022).

Based on Polya (1973), there are four main markers of problem-solving abilities: (1) comprehending the issue, (2) formulating a strategy, (3) implementing the strategy, and (4) assessing the outcomes. However, observations in schools have revealed that students often show low problem-solving abilities, especially in physics. This is due to teacher-centered learning methods that focus on memorizing formulas rather than encouraging active exploration or collaborative work (Yunita et al., 2020; Fartina et al., 2021). As a result, creative teaching strategies are needed to motivate students to solve problems efficiently.

One such model is problem-based learning (PBL), which encourages students to solve real-life problems using scientific thinking processes. PBL is proven to develop higher-order thinking skills and conceptual understanding (Syamsidah & Suryani, 2018; Erviana et al., 2022; Firmansyah et al., 2022; Putri et al., 2023; Sadiah et al., 2024). To further enhance this model, integrating PhET simulations—interactive digital learning tools developed by the University of Colorado—can create more contextual and meaningful experiences. These simulations are accessible online and can help visualize complex physics concepts in an engaging, inquiry-based format (Rizaldi et al., 2020; Sylviani et al., 2020; Pranata & Seprianto, 2023; Ogi, 2024). Based on studies, students' interest and problem-solving abilities in physics can be enhanced significantly by integrating PBL with PhET simulations (Surahman et al., 2022; Liana et al., 2023).

The effectiveness of PBL and PhET simulations has been demonstrated separately in earlier research; however, little is known about how the PBL model and PhET simulations work together to enhance high school students' capacity to resolve physics issues. In particular, integrating these two approaches in the context of abstract physics topics, such as wave phenomena, still requires empirical exploration. This research aims to determine the efficacy of using PhET simulations in conjunction with a problem-based learning methodology to enhance problem-solving ability in solving physics problems. It is anticipated that the study will help instructors create learning experiences that are more skill-oriented, meaningful, and participatory. Furthermore, the results could be used as a guide for next studies and instructional strategies aimed at enhancing 21st-century skills, particularly in the area of scientific education.

MATERIALS AND METHODS

Time and Place

This research was conducted in the even semester of the 2024/2025 academic year, namely from February to March. The study was conducted between January and May 2025. The study was conducted at MAN 1 Mataram.

Research Design

As a quasi-experiment, this study includes control variables; however, not all of them can be completely controlled. Analyzing the effect of an independent variable on the dependent variable, this experimental investigation aims to determine how one variable influences another (Setyosari, 2020). The researcher employed a non-equivalent control group design with non-random sample selection. (Sugiyono, 2013).

Population and Sample

Classes XI A through XI D of MAN 1 Mataram, who were given physics materials, are the population of this research. The sample was selected by purposive sampling, which was based on predetermined standards (Furqon et al., 2024). As a result, the experimental class was XI C, comprising 34 students, and the control class was XI D, comprising 31 students. This study's variables comprise independent, dependent, and control factors (Herliandry, 2018). The problem-based learning paradigm is the independent variable in the study, while problem-solving skills are the dependent variable. Additionally, test tools, resources, instructional materials, and learning technologies are employed as control variables.

Research Instrument

The study's instrument included a student response questionnaire, an observation sheet, and a test of problem-solving skills.

Research Procedure

To determine the traits of learners and their degree of problem-solving ability, the study process begins with observation activities. The population and sample were established based on the findings of the observations. Additionally, a pretest was administered to students to assess their initial proficiency in problem-solving. Following that, the experimental group received a problem-based learning model aided with PhET simulation, whereas the control group received treatment using traditional learning methods. Students are given a posttest using the same instrument as the pretest once the learning process is over. The N-Gain computation was then used to examine the pretest and posttest results to determine the extent of improvement in the students' skills.

Data Analysis Techniques

The test instrument used in this study's data collection method consisted of ten essay questions. According to Arikunto (2013), a test instrument is a tool used to gauge how well pre-planned learning objectives, such as questions or exercises, are met. A problem-solving ability exam is used to evaluate students' problem-solving skills in line with the problem-solving skill indicators. According to Polya (1973), researchers employ four markers of problem-solving ability: comprehending the problem, formulating a solution strategy, executing the plan, and evaluating and interpreting the findings of the investigation.

To determine the efficacy or enhancement of students' problem-solving skills following treatment, the outcomes of the problem-solving ability test will be examined for N-Gain. The N-Gain equation that researchers utilize is as follows.

$$\langle g \rangle = \frac{S_{Posttest} - S_{Pretest}}{S_{Maksimal} - S_{pretest}}$$

Table 1. Criteria for <g> values

Mean	Guidelines
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$0 < g < 0.3$	Low
$g \leq 0$	Failed

(Hake, 1999).

RESULTS AND DISCUSSION

Result

Pretest and Posttest

In this study, a pretest was administered before the experimental class was introduced to a problem-based learning model supported by PhET simulation, while the control class received conventional teaching. Ten essay questions are used to assess problem-solving skills. Table 2 shows the pretest results.

Table 2. Pretest Result Data

Class	n	Maximum Value	Minimum Value	Mean
Experiment	34	20	1	9
Control	31	19	1	10

Based on Table 2, the experimental class has a total of 34 pupils, with the highest score being 20 and the lowest being 1. There are 31 pupils in the control class overall, with the best score being 19 and the lowest being 1. The control group averages ten points, while the experimental group averages nine more after obtaining the pretest results. Both classes received treatment and a posttest as the final assessment of learning (Nurmayani et al., 2018). Table 3 presents the study's post-test results.

Table 3. Posttest Result Data

Class	n	Maximum Value	Minimum Value	Mean
Experiment	34	83	53	69
Control	31	81	35	53

Table 3 illustrates the experimental class's findings, with an average of 69, a maximum value of 83, and a lowest value of 53. The control class, on the other hand, has an average of 53, a maximum of 81, and a low of 38.

The following graph illustrates the increase in scores for the two classes based on the pretest and posttest results.

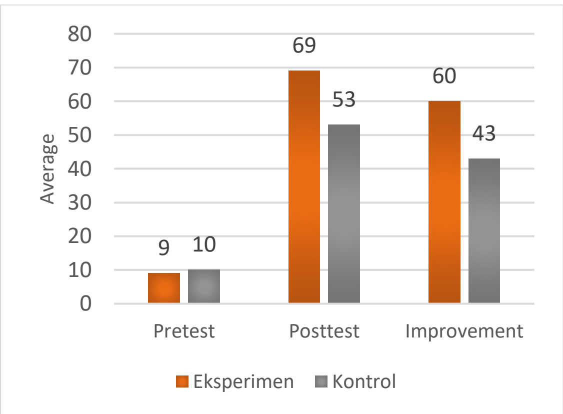

Figure 1. Graph of improvement in pretest-posttest results.

Figure 1 demonstrates that students in the experimental class solve more problems than those in the control group. The average problem-solving score of the experimental class increased by 60 points, from an average pretest score of 9 to an average posttest score of 69. In contrast, the control group's average problem-solving score increased by 43 points from an average pretest score of 10 to an average posttest score of 53.

N-Gain Result

The post-pre score is divided by the max-pre score to determine the N-Gain value. The effectiveness of learning conducted in experimental and control classes is assessed using N-Gain. Table 4 displays the N-Gain findings of this research on problem-solving.

Table 4. N-Gain Result

Class	Mean		
	Post-Pre	S.max-pre	N-Gain
Experiment	60	91	0,66
Control	43	90	0,48

According to Table 4, the experimental class is 0.48. N-Gain values for both classes fall into the medium range. A graph representing the N-Gain results is shown in Figure 2.

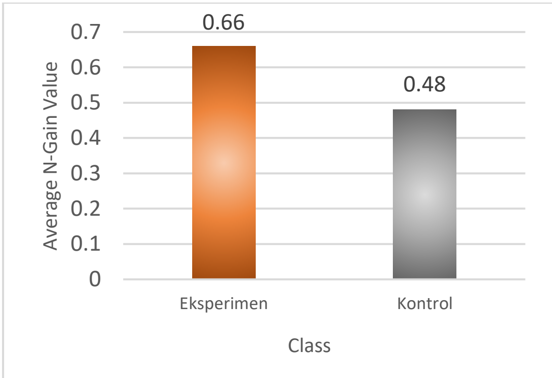

Figure 2. N-Gain Graph

Based on the N-Gain statistics, Figure 2 shows that the experimental class has more pupils than the control class. In the medium category, the experimental class's N-Gain score is 0.66. In the medium category, the control class's N-Gain is 0.48.

Discussion

This study aimed to assess the effectiveness of a problem-based learning strategy with PhET simulation help at MAN 1 Mataram. Ten essay questions served as the test instrument for this study. The experimental and control groups were formed using purposeful sampling in this investigation. While class XI D received traditional learning treatment, class XI C received treatment in the form of a problem-based learning paradigm assisted by PhET simulation. Both classes took a pretest before starting treatment. According to the pretest scores of the experimental and control classes, the problem-solving skills of students in the control group are generally superior to those in the experimental group.

Following the pretest, the control group received conventional teaching, whereas the experimental group was treated by adopting a problem-based learning model supported by PhET simulations. It was found that, on average, learners in the experimental class engaged in active communication and teamwork with others during the learning process. In contrast, only a small percentage of students in the control group did so. As a result, during the learning process, there was some variation in how the problem-solving abilities of the two classes developed. Following treatment, a posttest was administered to both classes. The posttest is the final test in research that aims to determine the value of a sample after it has been given specific treatments. The posttest results in the study are presented in Table 3. The experimental and control class posttest results show that the experimental class has better final problem-solving skills than the control class.

Compared to the experimental class, the control group's average score on the first problem-solving test was greater. In contrast, the experimental class's post-test average score was greater than that of the control class. These findings suggest that traditional teaching strategies, which often involve memorization and lecture-based instruction, may not be the most effective approach to developing students' problem-solving skills. Instead of encouraging students to think critically, actively, and reflectively, lecture techniques frequently concentrate on the passive transmission of information. As a result, it is possible that the control group's children will not show any significant improvement in their problem-solving abilities while learning. On the other hand, problem-based learning encourages students to be proactive and cooperative (Aprilianti et al., 2024), resulting in more significant improvements in problem-solving skills compared to the control group. As stated by Rizqi et al. (2020), problem-based learning is more effective in improving students' problem-solving skills than traditional learning methods.

One component of 21st-century thinking skills is problem-solving. Each learner possesses unique abilities that are necessary for problem-solving. Beyond simple comprehension and rote memory, problem-solving abilities enable pupils to grasp and apply knowledge at a deeper level. To encourage meaningful educational experiences and equip students for success in a changing environment, problem-solving skills must be developed in the classroom. Teachers can empower students to become autonomous learners, proficient problem solvers, and critical thinkers who can navigate the complex issues in their lives by placing a strong emphasis on developing problem-solving skills (Abdulaziz et al., 2024).

Students can actively address contextual problems using scientific techniques in the experimental class thanks to the use of problem-based learning supported by PhET simulation. Because students seek information to solve problems using scientific techniques, Apriliasari et al. (2019) argue that the development of problem-solving abilities occurs through a scientific process. This provides pupils with a fresh perspective that they may not have had previously, which enhances their comprehension and problem-solving skills in physics.

Using the N-Gain Test on Posttest and Pretest data, the efficacy and enhancement of using problem-based instructional methods supported by PhET simulations and traditional learning are evaluated. Based on the average N-Gain score for both classes, both the control and experimental groups had moderate N-Gain scores. However, the average N-Gain score was higher than that of the control class (Figure 2). This indicates that compared to the class that got traditional instruction, the class that was taught utilizing the problem-based learning approach with PhET simulation support saw a higher increase in value.

Iolanessa et al. (2020) state that problem-based learning effectively increased student problem-solving skills at a moderate level. Similar findings were made by Rusdiana (2019), who discovered that using PhET simulations in the classroom enhanced students' ability to solve physics problems using moderate criteria. PhET simulations and problem-based learning models work well together to enhance the caliber and outcomes of physics education. Therefore, an innovative technique to assist student in increasing their problem-solving skills is to use the PhET simulations combined with the problem-based learning approach. Nonetheless, the use of the problem-based learning paradigm, aided by a PhET simulation, turns out to be more effective than traditional learning. The research findings of Maharani et al. (2024), which found that the problem-based learning paradigm is more effective than traditional learning, are also in line with this.

CONCLUSION

It is clear from the previously discussed examples that using problem-based learning models, combined with the help of PhET simulations, helps students become more adept at solving problems. Although both are in the medium category, N-Gain results demonstrate that the experimental class students' problem-solving skills are superior to those of the control class. This suggests that using a problem-based learning approach with PhET simulation support enhances students' problem-solving skills more effectively than conventional instruction.

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