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The Effect Of Guided Inquiry Learning Model Assisted by PhET Simulation On Student's Physics Concept Mastery Ability

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Abstract— *This study aims to determine the effect of implementing the guided inquiry learning model assisted by PhET simulations on students' physics concept mastery at SMAN 1 Kediri. This study employed a quasi-experimental method with a Nonequivalent Control Group Design. The population consisted of all Grade X students at SMAN 1 Kediri, totaling 181 students. The sample consisted of class X.1 as the control group and class X.3 as the experimental group. The research instrument was a multiple-choice test designed to measure students' physics concept mastery, which had met the requirements for validity, reliability, difficulty level, discrimination index, and distractor effectiveness. Data analysis was conducted using normality, homogeneity, and an Independent Samples t-test. The results showed an increase in the average physics concept mastery scores in both groups. In the experimental group, the average score increased from 30.75 on the pretest to 79.90 on the post-test, while in the control group, it increased from 31.67 to 59.33. The data were normally distributed and homogeneous. The Independent Samples t-test showed a Sig. (2-tailed) value of 0.000 (< 0.05), with a t-value of -4.812, indicating that H_0 was rejected and H_1 was accepted. These results indicate that the guided inquiry learning model assisted by PhET simulations has a significant effect on students' physics concept mastery.*
Keywords— *guided inquiry learning, PhET simulation, physics concept mastery*

1. Introduction

Physics is a branch of science that encompasses not only a body of knowledge but also a process of scientific thinking. The abstract nature of physics often causes the subject to be perceived as difficult by students [1]. Furthermore, the development of science and technology in the 21st century requires students not merely to memorize concepts and mathematical equations, but also to understand the relationships among concepts and apply them to solve various physics problems [2]. Therefore, physics learning needs to be directed toward developing students' physics concept mastery so that they can understand physical phenomena comprehensively and apply concepts in various situations [3].

Concept mastery refers to students' ability to understand concepts after participating in the learning process [4]. In physics learning, concept mastery involves the ability to understand, connect, and meaningfully apply basic physics ideas and principles. This ability is important because strong conceptual understanding can help students avoid misconceptions and solve physics problems logically [5]. However, students' physics concept mastery in Indonesia still faces various challenges. Learning that tends to be procedural and oriented toward memorizing mathematical formulas can make it difficult for students to visualize and understand physical phenomena conceptually [6]. Such conditions may prevent conceptual understanding from developing optimally and consequently affect students' ability to solve physics problems [7].

These problems were also identified based on interviews with a physics teacher and observations conducted during the School Field Introduction (PLP) program at SMAN 1 Kediri. Physics learning in the classroom sometimes still employs the lecture method and occasionally uses *collaborative learning*. Following the learning activities, students work on worksheets containing practice questions. Direct laboratory activities have not been implemented optimally because the school laboratory has been converted into a teachers' room, while some of the available laboratory equipment is no longer adequate. This condition limits students' opportunities to construct knowledge through direct investigation and experimental activities. Consequently, learning tends to emphasize problem solving and the use of formulas rather than developing a deeper conceptual understanding. This situation indicates the need for learning that provides students with opportunities to actively discover and construct concepts through investigative activities.

One alternative to address these problems is the implementation of a guided inquiry learning model assisted by PhET simulations.

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Guided inquiry provides students with opportunities to discover and construct concepts through an investigative process under the teacher's guidance, allowing learning activities to remain directed toward predetermined objectives [8]. Through the inquiry stages, students can observe phenomena, formulate problems, develop hypotheses, collect and analyze data, and draw conclusions based on the evidence obtained. This process enables students to participate actively in knowledge construction rather than simply receiving concepts directly from the teacher.

The implementation of guided inquiry can be strengthened through the use of PhET simulations as a learning medium. PhET simulations are computer-based learning media that provide interactive visualizations of various physical phenomena and concepts that are difficult to observe directly. The simulations enable students to conduct virtual experiments by manipulating variables and observing the resulting changes, allowing physics concepts to be learned in a more concrete and interactive manner [9]. Thus, PhET simulations can serve as a virtual laboratory, particularly when direct experimental activities are constrained by limited facilities and infrastructure. The use of PhET can also help students visualize abstract physics concepts and thereby support the development of concept mastery [10].

Integrating guided inquiry with PhET simulations has strong potential because both support student-centered learning. Guided inquiry provides systematic learning stages that direct students toward concept discovery, while PhET simulations provide a virtual experimental environment in which students can obtain data through exploration. The combination can provide a more interactive, contextual, and meaningful learning experience. Previous studies have indicated that guided inquiry assisted by PhET simulations has the potential to improve various student competencies, including scientific literacy, science process skills, and concept mastery [11]. Nevertheless, studies on the integration of this learning model and medium have largely focused on particular competencies and specific physics topics. Therefore, further research is needed to provide empirical evidence in different learning contexts.

These conditions indicate that the implementation of the guided inquiry learning model assisted by PhET simulations is relevant to the learning context at SMAN 1 Kediri. The limited availability of laboratory facilities and experimental equipment is an important consideration in selecting appropriate learning media. Therefore, PhET simulations can be utilized as a virtual laboratory that enables students to engage in more interactive inquiry activities, even when direct experiments cannot be conducted optimally. In addition, previous studies have widely investigated the implementation of PhET-assisted guided inquiry in relation to scientific literacy, science process skills, conceptual understanding, and critical thinking skills across various physics topics. This study contributes by examining the implementation of this model among Grade X students at SMAN 1 Kediri, with a focus on students' physics concept mastery in the topic of energy. Thus, this study is expected to provide empirical evidence regarding the implementation of PhET-assisted guided inquiry in a different school and subject-matter context, while also providing an alternative learning approach to address the limitations of direct experimental activities in schools.

2. Method

This study employed a quasi-experimental research design to investigate the effect of the guided inquiry learning model assisted by PhET simulations on students' physics concept mastery. A quasi-experimental design was selected because the researchers could not randomly assign individual students to different treatment groups. Instead, the study compared existing classes that had been established by the school [12].

The research used a Pretest-Posttest Non-Equivalent Control Group Design. Two existing classes were selected as the experimental and control groups. Both groups were administered a pretest before the learning intervention to determine their initial physics concept mastery. The experimental group received instruction using the guided inquiry learning model assisted by PhET simulations, whereas the control group received conventional instruction using the collaborative learning method. After the learning process was completed, both groups were administered a posttest to measure their physics concept mastery. The research design was adapted from [13] and is presented in Table 1.

Tabel 1. Pretest-Posttest Non-Equivalent Control Group Design

Group	Pretest	Treatment	PostTest
Experimental	O_1	X	O_2
Control	O_3		O_4

Note: X = guided inquiry learning model assisted by PhET simulations; O_1 and O_3 = pretest; O_2 and O_4 = posttest.

The study was conducted at SMAN 1 Kediri, West Lombok Regency, West Nusa Tenggara, Indonesia, on August 2026. The population consisted of all Grade X students in the 2026/2027 academic year. Based on school records, the population comprised 181 students distributed across six classes, namely X.1 (31 students), X.2 (30 students), X.3 (30 students), X.4 (31 students), X.5 (30 students), and X.6 (29 students).

The samples were selected using cluster random sampling, in which intact classes were randomly selected from the available classes rather than individual students. This technique was considered appropriate because the students had already been organized into classes and the classes had relatively similar characteristics. The use of cluster random sampling also facilitated the implementation of the experimental treatment in a natural classroom setting [14]. Based on the sampling procedure, class X.1 (31 students) was selected as the control group, while class X.3 (30 students) was selected as the experimental group.

The research instrument was a multiple-choice physics concept mastery test administered as a pretest and posttest. Before the treatment was administered, a pretest was conducted to determine the students' initial physics concept mastery. The average pretest score was 30.75 for the experimental group and 31.67 for the control group. An independent samples t-test was conducted to examine whether there was a significant difference in the students' initial abilities between the two groups. The results showed that there was no significant difference in the pretest scores between the experimental and control groups ($p > 0.05$), indicating that the two groups had comparable initial physics concept mastery before the treatment.

The instrument was developed to measure students' ability to understand and apply physics concepts. Before being used for data

collection, the instrument was subjected to validity, reliability, difficulty level, discrimination index, and distractor-function analyses. The collected data were subsequently analyzed using appropriate statistical procedures to determine differences in physics concept mastery between the experimental and control groups, but in this article will be focus to discuss about student's physics concept mastery.

The hypotheses of this study are : H_0: There is no effect of the guided inquiry learning model assisted by PhET simulations on the physics concept mastery of students at SMAN 1 Kediri and H_1: There is an effect of the guided inquiry learning model assisted by PhET simulations on the physics concept mastery of students at SMAN 1 Kediri.

3. Result and Discussion

This study was conducted at SMAN 1 Kediri during the first semester of the 2026/2027 academic year with the aim of determining the effect of the guided inquiry learning model assisted by PhET simulations on students' physics concept mastery. The study involved two sample classes, namely class X.1 as the control class and class X.3 as the experimental class. The test used was a multiple-choice test consisting of 10 items that had been tested for validity, reliability, item difficulty, discrimination index, and distractor effectiveness.

Based on the descriptive analysis, the mean pretest scores of both classes at cognitive levels C1–C6 were still relatively low. This was because the students had not yet received instruction on the material being tested. The students relied primarily on their prior knowledge when answering the test questions. The pretest data for both classes are presented in the following figure.

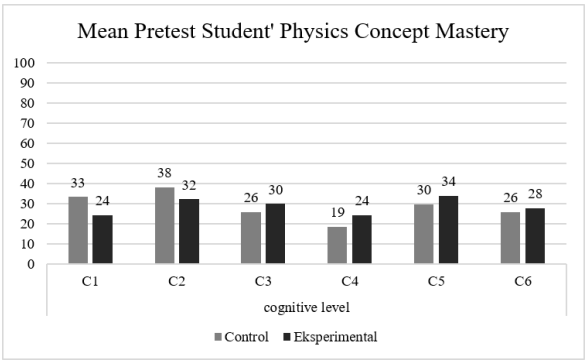


Fig 1. Pretest results

After the pretest was administered, the experimental class received the guided inquiry learning model, while the control class received the collaborative learning model. Following the learning process, a posttest was administered to determine the effect of the treatment on students' physics concept mastery. The mean posttest scores at cognitive levels C1–C6 for both classes are presented in the following figure.

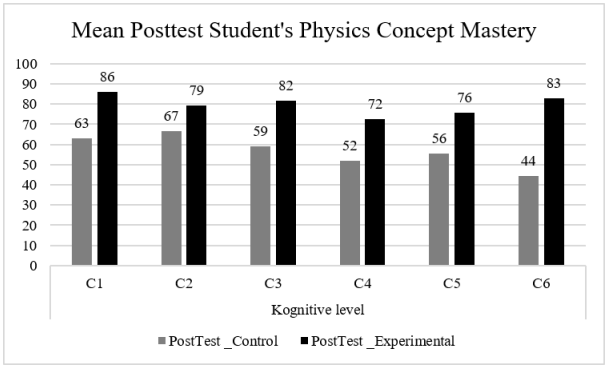


Fig 2. Posttest results

A comparison of the mean pretest and posttest scores for students' physics concept mastery in both classes is presented in Figure 3.

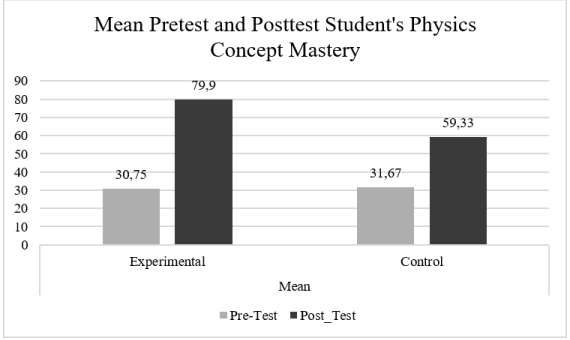


Fig 3. Mean pretest and posttest

Before conducting the hypothesis test, normality and homogeneity tests were performed. The results indicated that the pretest and posttest data from both classes were normally distributed and homogeneous. The results are presented in the following tables.

Table 2 Result of the normality test

Class	Test	$X_{hitung}{}^2$	$X_{tabel}{}^2$	Decision
Experimental	*Pre-Test*	30,35198	7,814728	Normal
	Post-Test	89,44781	7,814728	Normal
Control	*Pre-Test*	25,16113	7,814728	Normal
	Post-Test	45,84915	7,814728	Normal

Table 3 Result of the homogenity test

Nilai signifikansi	Taraf signifikansi	Kriteria
0,651	0,05	Homogen

The hypothesis was subsequently tested using the **Independent Samples t-test**. The results are presented in Table 4.

Tabel 4 Hasil uji independent sample t-test

Variable	t value	df	Sig. (2-tailed)	Decision
Physics concept mastery	-4.812	54	0,000	H_0 rejected and H_a accepted.

Based on Table 4, the significance value was 0.000 < 0.05; therefore, H_0 was rejected and H_a was accepted. Thus, it can be concluded that the guided inquiry learning model assisted by PhET simulations had an effect on students' physics concept mastery at SMAN 1 Kediri.

The effect of the guided inquiry learning model on students' physics concept mastery was also evident during the learning process. At the beginning of the lesson, students were given questions about energy to determine the extent of their prior knowledge. The results indicated that students had difficulty distinguishing between the concepts of energy, energy sources, and the utilization of energy. The learning process was then conducted using the guided inquiry learning model assisted by PhET simulations. At the end of the lesson, students were given the same questions as those presented at the beginning of the lesson to determine the extent to which the treatment affected their physics concept mastery. After the treatment, students demonstrated a better understanding of the concepts of energy, energy sources, and energy utilization.

According to [15], the guided inquiry learning model assisted by PhET simulations has a positive effect on students' conceptual understanding of physics. The use of PhET simulations during the inquiry process can help students visualize abstract concepts, thereby facilitating the development of conceptual understanding through systematic investigation activities. Their findings indicated that students who learned through the guided inquiry learning model assisted by PhET simulations achieved better conceptual understanding than students who received conventional instruction. Thus, there was a significant difference in physics concept mastery between students in the experimental and control classes following the implementation of the guided inquiry learning model assisted by PhET simulations.

During the learning process, the experimental class was taught using the guided inquiry learning model assisted by PhET simulations, while the control class was taught using the Collaborative Learning model. In the experimental class, PhET simulations were integrated into the inquiry stages to support students in observing phenomena, conducting virtual investigations, collecting data, and drawing conclusions. The interactive visualizations provided by PhET enabled students to explore energy concepts through virtual experiments, particularly concepts that were difficult to observe directly because of the limited availability of laboratory facilities.

The analysis showed an increase in students' physics concept mastery across cognitive levels C1–C6 in both groups. The experimental group showed an increase in the mean score from 30.75 on the pretest to 79.90 on the posttest, while the control group increased from 31.67 to 59.33. These results indicate that both groups experienced improvements in physics concept mastery, with a greater increase in the experimental group. The Independent Samples t-test further showed a significant difference in posttest physics concept mastery between the two groups (Sig. 2-tailed = 0.000 < 0.05). Therefore, the findings indicate that the guided inquiry learning model assisted by PhET simulations was associated with significantly different physics concept mastery outcomes compared with the Collaborative Learning model. Therefore, the *t*-test results confirmed that the implementation of the guided inquiry learning model assisted by PhET simulations had a positive effect and was more effective in improving students' physics concept mastery.

4. Conclusion

The results showed that the guided inquiry learning model assisted by PhET simulations had a significant positive effect on students' physics concept mastery. The experimental group achieved a higher mean posttest score (79.90) than the control group (59.33), with an improvement from 30.75 to 79.90 in the experimental group and from 31.67 to 59.33 in the control group. The Independent Samples t-test showed a significant difference between the two groups (t = -4.812, df = 54, Sig. 2-tailed = 0.000 < 0.05). These findings indicate that students who received guided inquiry learning assisted by PhET simulations achieved higher

physics concept mastery than those who received Collaborative Learning**.**

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