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Utilizing PhET Simulator in Guided Inquiry Learning to Enhance Students Motivation and Science Learning Outcomes

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Abstract: This study aims to examine the differences in motivation and science learning outcomes between students who use the guided inquiry learning model assisted by PhET Simulation media and those who use conventional learning models. This research is a quasi-experimental study with a non-equivalent pretest-posttest control group design. The research population consisted of all eighth-grade students at SMP Negeri 4 Petang in the 2023/2024 academic year, totaling 75 students from three classes. Two classes (50 students) were selected as samples using a random sampling technique. Learning motivation data were collected through questionnaires, while learning outcome data were obtained through tests. The data were analyzed using descriptive statistical techniques and MANOVA analysis. The results showed: (1) there was a significant difference in learning motivation between students who used the guided inquiry model assisted by PhET Simulations and those who did not ($p=0.006<0.05$), (2) there was a significant difference in learning outcomes between the two groups ($p=0.000<0.05$), and (3) simultaneously, there were significant differences in both motivation and learning outcomes between students who used and did not use the PhET-assisted guided inquiry model ($p=0.000<0.05$).

Keywords: Guided inquiry learning; Motivation; PhET simulation; Science learning outcomes

Introduction

Science learning is learning to develop students' knowledge through natural phenomena that occur in real life (Inabuy et al., 2021). In essence, science involves processes, products, and attitudes (Vannilia et al., 2023). Science as a process, emphasizes the process of obtaining knowledge, especially natural science. Science as a product, emphasizes the results obtained in the scientific activity itself. Science as an attitude emphasizes more on efforts to equip, train, or instill positive values in students.

The purpose of science education emphasizes the understanding of the environment and the surrounding nature with its natural resources that need to be preserved and maintained in terms of biology, physics and chemistry (Abdullah et al., 2022). In line with these objectives, through science learning, students are also expected to demonstrate scientific behavior such as having curiosity, objectivity, honesty, and thoroughness towards everyday life (Sulistyo et al., 2023). Through this behavior, it is expected to be able to motivate students in the learning process in the classroom.

In reality, there are still educational problems in Indonesia that affect the achievement of the goals of improving the quality of education. One of the problems at the micro level is the low motivation of students who tend to be passive in the learning process (Kurniawati et al., 2022). Another fact shows that the average learning motivation of Indonesian students tends to be in the medium and low categories, which affects the learning

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outcomes of students (Sari et al., 2020). Those problems was also found at SMPN 4 Petang, Bali.

Based on observations related to the implementation of science learning carried out on February 12, 2024 at SMP Negeri 4 Petang, it was found that students did not play an active role in constructing their knowledge in the learning process. Another thing is the lack of interesting activities in the learning process. These reasons will certainly greatly affect students' motivation to participate in learning. The learning process will become boring so that it will affect students' motivation and learning outcomes (Adnyani et al., 2020).

Starting from this fact, it is necessary to seek the selection of a learning model that is able to make students more active, creative, critical thinking in seeking and finding their own solutions to problems given to them, and also a model that is able to meet the needs of each student (Wahida et al., 2022). Teachers are expected to be able to apply the right learning model according to the characteristics of science materials and students' conditions. One alternative to overcome this problem is to apply the guided inquiry learning model. Guided inquiry learning is an educational approach that emphasizes student-centered exploration under the guidance of a teacher, allowing learners to construct knowledge through investigation and problem-solving. This method enhances critical thinking, scientific process skills, and promotes independence, as it encourages students to engage deeply with content while following structured inquiry processes, such as formulating hypotheses and analyzing data. The teacher's role shifts to that of a facilitator, fostering collaboration and accountability in learning activities (Mazidah et al., 2023; Ningsih et al., 2022). Evidence suggests that this model can improve educational outcomes, including academic performance and scientific literacy (Masniah, 2021; I. S. Sari et al., 2021; Yulianti et al., 2021).

Research shows that without the support of appropriate learning tools or media, the effectiveness of this approach can be reduced, as students may not be able to fully explore the concepts being taught (Gormally et al., 2009; Pedaste et al., 2015). In addition, inadequate infrastructure hinders students' practical experience, making it difficult to apply the inquiry method optimally (Mazidah et al., 2023). The presence of assistive media, such as virtual modules or simulation-based laboratories, can increase the effectiveness of learning and overcome the lack of facilities so that students can still be actively involved in the learning process (Sari et al., 2021; Vannilia et al., 2023).

To address the learning challenges faced by schools with minimal laboratory facilities, the use of hands-on simulations such as PhET Simulator is very important. Research shows that directed inquiry learning models combined with virtual media such as PhET can improve students' learning outcomes in science even in the absence of adequate physical laboratory facilities (Susilawati et al., 2022). This simulation allows students to interact with science concepts in a practical and visual way, thus improving their concept understanding and scientific process skills (Ain et al., 2020; Syafriyanti, 2023). Thus, the application of such tools can help reduce learning barriers due to limited facilities and provide students with the opportunity to conduct independent exploration and experimentation in a more appropriate context (Sularso et al., 2017; Syafriyanti, 2023).

Although many studies have shown that guided inquiry learning models and the use of PhET simulators can improve student motivation and learning outcomes, there are some research gaps that need to be considered. First, there is still no study that specifically investigates the implementation of these two methods in the context of junior high school (SMP), which makes the generalization of results from implementation at the senior high school level less valid (Nugroho et al., 2021). Second, although the effectiveness of each method has been demonstrated separately, there is no systematic empirical evidence on the integration of these two approaches and their effects on students in junior high school (Ayuningtyas et al., 2017; Sulistianingrum et al., 2017). Third, PhET is widely used abroad, but its use in the context of the Indonesian science curriculum, especially in guided inquiry models, has not been extensively explored. Fourth, guided inquiry supported by visualizations from PhET can encourage students' analytical, evaluative, and synthesis skills. This gap indicates the need for further studies to explore how the combination of guided inquiry and PhET simulator can be effectively and efficiently implemented in junior high school classrooms.

Research on the effect of guided inquiry learning assisted by PhET simulator on students' science learning outcomes and motivation in junior high school is urgent. This is due to the need for a deeper understanding of how these two methods can complement each other to facilitate the improvement of learning outcomes and student motivation in the junior high school environment. This research is expected to contribute significantly to efforts to improve the quality of science education at the junior high school level by offering innovative and effective learning strategies, especially in school conditions with limited practicum facilities.

Method

The method of study that carried out was quantitative method. This study was a Quasi-Experimental study using non-equivalent control group design. This study was conducted on January until May

2024. The location of this study was in SMP Negeri 4 Petang, Bali. The samples of this study were obtained thru a random sampling technique. There were 50 students used as the samples of this study, of which students were the students of VIIIA and VIIIB at SMP Negeri 4 Petang in the academic year of 2023/2024. Data on student learning motivation were collected using a questionnaire, while data on student learning outcomes were collected using tests.

The data that has been collected must go through the data prerequisite test stage including the data normality test with Kolmogorov-Smirnov test, the data homogeneity test with Levens statistic, and the variance martrix test. Statistical analysis was done by examining the hypotheses using the MANOVA analysis, in which it was assisted by SPSS 23 program and the withdrawal of the conclusion was in the significance level of 5%. If the significance level was < 0.05, the Ho was rejected and the Ha was received. From the MANOVA results, there would be differences in the student's motivation and science learning outcomes between experiment and control group. Furthermore, it would be further test to ascertain the significance level of each mean values.

Result and Discussion

The variables measured in this study are learning motivation and differences in student science learning outcomes.

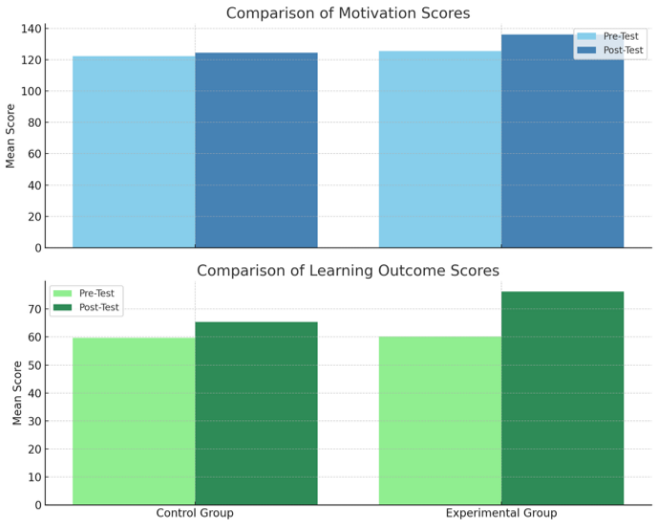

Figure 1. Data of motivation and learning outcome

Based on the data in figure 1, there was an significant increase of learning motivation in the experimental group. While in the control group, there was no significant increase in learning motivation. This shows that guided inquiry learning assisted by PhET simulator has a positive impact on increasing the learning motivation of SMPN 4 Petang students. Moreover, an significant increase in science learning outcomes occurred in the experimental group. While in the control group, there was no significant increase in learning outcomes. This shows that guided inquiry learning assisted by PhET simulator has a positive impact on improving the science learning outcomes of SMPN 4 Petang students.

Data Prerequisite Test

Based on the results of the analysis, motivation and learning outcomes data in both experimental and control classes have a sig value> 0.05. Thus, all research data are normally distributed.

Table 1. Summary of the Results of the Homogeneity Test of Variances

	Levene S.	df1	df2	Sig.
Learning Motivation	0.99	1	48	0.32
Learning Outcome	3.03	1	48	0.08

Table 2. Homogeneity Test Result

Treatment		Kolmogorov-Smirnova		
		Statistic	df	Sig.
Motivation	Guided Inquiry	0.10	25	0.20*
	Guided Inquiry Assisted by PhET Simulations Media	0.08	25	0.20*
Learning Outcomes	Guided Inquiry	0.13	25	0.20*
	Guided Inquiry Assisted by PhET Simulations Media	0.15	25	0.14

Based on the results of the analysis, motivation and learning outcomes data have a sig value> 0.05. Thus, all research data are homogeneous.

Table 3. Box's Test Equality Covariance Matrices

Box's M	F	df1	df2	Sig.
7.49	2.38	3	414720.00	0.06

The results of Box's M test of the simultaneous similarity of the variance-covariance matrix resulted in a significant number of 0.06 greater than the value of α = 0.05. This means that the variance matrix on the Learning Motivation and Science Learning Outcomes variables of students is homogeneous.

Hyphotetic Analyze

First Hypothesis Test Results Based on Tests of Between-Subjects Effects obtained an F-statistic of 8.19 and a sig. 0.00 < 0.05. Thus, the null hypothesis (Ho) is rejected and it can be concluded that there is a difference in learning motivation between groups of students who learn with the guided inquiry learning model supported by PhET Simulations media and groups of students who learn with the guided inquiry learning model. The mean

learning motivation of the groups of students who learn with the guided inquiry learning model supported by PhET Simulations media is 0.34 higher than the group of students who learn with the guided inquiry learning model, which is 0.02.

The results of the second hypothesis test based on the test of Between-Subjects Effects obtained an F-statistic of 29.75 and a sig. 0.00 < 0.05. Therefore, the null hypothesis (Ho) is rejected and it can be concluded that there are differences in students' science learning outcomes between groups of students who learn with the guided inquiry learning model supported by PhET Simulations media and groups of students who learn with the guided inquiry learning model. The mean science learning outcomes of the groups of students who learn with the guided inquiry learning model supported by PhET Simulations media is 0.40 higher than the group of students who learn with the guided inquiry learning model, which is 0.17.

Table 4. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	Sig.
Corrected Model	Learning Motivation	1.27a	1	1.27	0.00
	Learning Outcomes	0.65b	1	0.65	0.00
Intercept	Learning Motivation	1.70	1	1.70	0.02
	Learning Outcomes	4.19	1	4.19	0.00
Group	Learning Motivation	1.27	1	1.27	0.06
	Learning Outcomes	0.65	1	0.65	0.00
Error	Learning Motivation	7.48	48	0.15	
	Learning Outcomes	1.05	48	0.02	
Total	Learning Motivation	10.47	50		
	Learning Outcomes	5.90	50		
Corrected Total	Learning Motivation	8.76	49		
	Learning Outcomes	1.70	49		

The third hypothesis uses a multivariate test for statistical tests on testing the first hypothesis in this study. Based on the results of the multivariate test, the statistical value of F is equal to 17,36 and the significance value is 0.00 less than 0.05 for Pillai's trace, Wilk's lambda, Hotelling's trace, and Roy's greatest root. Thus, the null hypothesis (Ho) is rejected and it can be concluded that there are differences in students' learning motivation and science learning outcomes simultaneously between groups of students who learn with the guided inquiry learning model supported by PhET simulation media with groups of students who learn and guided inquiry learning model.

Table 5. Multivariate Tests Result

Effect		Value	F	Sig.
Intercept	Pillai's Trace	0.80	95.83[b]	0.00
	Wilks' Lambda	0.19	95.83[b]	0.00
	Hotelling's Trace	4.07	95.83[b]	0.00
	Roy's Largest Root	4.07	95.83[b]	0.00
Group	Pillai's Trace	0.42	17.36[b]	0.00
	Wilks' Lambda	0.57	17.36[b]	0.00
	Hotelling's Trace	0.73	17.36[b]	0.00
	Roy's Largest Root	0.73	17.36[b]	0.00

In order to determine the magnitude of the degree of difference in hypothesis testing, as a follow-up to the MANOVA technique, the significance test of the group mean value was carried out using the Tukey test. The Tukey test results show that the difference in the mean score of science learning outcomes between the guided inquiry learning group supported by PhET Simulations media and the guided inquiry learning group is 0.23, the calculated Q value of 6.12 is greater than Q table 2.92. Therefore, it can be concluded that at the significance level of 0.05, the mean value of students' science learning outcomes in the guided inquiry learning group assisted by PhET Simulations media and the guided inquiry learning group are significantly different.

Discussion

Guided inquiry learning model assisted by PhET Simulations media based on the findings of this study has a positive effect on increasing student learning motivation. The highest indicator of learning motivation in the experimental class is the indicator of future hopes and aspirations and the lowest indicator is the indicator of a conducive learning environment. While the highest indicator of learning motivation in the control class is the indicator of the desire and desire to succeed and the lowest indicator is the indicator of a conducive learning environment.

In line with the opinion of Sumadi et al. (2022) that motivated students are students who have hopes or goals to succeed in learning, have goals that must be achieved and provide future targets as a benchmark for learning. In addition, in learning the guided inquiry model assisted by PhET Simulations media encourages students to be active in finding facts and being able to display phenomena that are difficult to observe directly

(Prima et al., 2018). This makes it easier for students to communicate an idea from abstract to concrete in solving various physics problems (Amin, 2023).

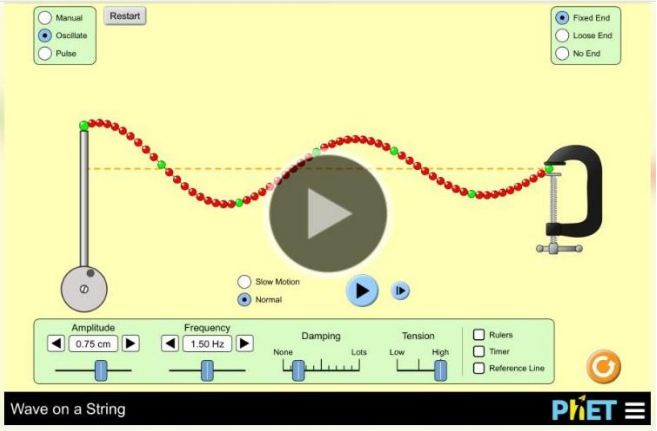

Figure 2. PhET simulator footage

This finding is in line with research conducted by Rahayu et al. (2020) explaining that the use of PhET Simulations media in science learning can increase student learning motivation. This is because learning through PhET Simulations media is more contextual and interesting, so students are more interested in exploring the material being taught. Through this interest, students can properly follow learning from the beginning of the learning stage, so that they can learn meaningfully and construct their own knowledge (Lusidawaty et al., 2020). The diverse and challenging student engagement activities in guided inquiry model learning assisted by PhET Simulations media are an advantage.

The guided inquiry learning model assisted by PhET Simulations media can also improve learning outcomes through activities that are more fun to see, read, digest and remember, and make the concept of material learned more real and easy to understand, besides that it can also make it easier for educators to deliver material so that the use of time becomes more efficient (Alvarez-Segura et al., 2022). Such conditions expect students to be more active and explore their abilities (Sarumaha et al., 2022; Susilawati et al., 2022).

The guided inquiry model assisted by PhET Simulations media invites students to explore their knowledge through experimental activities in learning. Experimental activities that can improve student learning outcomes are in the step of collecting data, students are directed to find concepts that aim for students to find their own material concepts (Hamidah, 2022). Wahyuningtyas et al. (2020) state the steps of guided inquiry aim for students to find their own concepts so that learning becomes more meaningful. Learning activities with the guided inquiry model assisted by PhET Simulations media are carried out in groups so that it requires students to communicate and interact. In the discussion process that occurs during learning, it can increase students' knowledge which is aligned in improving their learning outcomes (Nugroho et al., 2021; Sarumaha et al., 2022).

The guided inquiry learning model assisted by PhET Simulations media makes students interested and motivated to learn, while helping them understand the material better (Oke et al., 2023) Learning motivation has a positive influence on learning outcomes seen in learning activities that involve students (Nurfauzan et al., 2023; Yogi Fernando et al., 2024). By combining guided inquiry with the use of PhET Simulations media, this model creates an interactive, directed, and in-depth learning experience for students to understand scientific concepts. The guided inquiry learning model assisted by PhET Simulations media has an effect on increasing student motivation and learning outcomes theoretically and empirically. The guided inquiry learning model assisted by PhET Simulations media is superior to the guided inquiry learning model, because the contribution is given in the form of freedom in exploring information about the stages in designing to conclude in the investigation process, thus creating an interactive, directed, and in-depth learning experience for students to understand scientific concepts (Nugraha et al., 2023).

Conclusion

Based on the results of the research and discussion, it can be concluded that learning using the guided inquiry model assisted by PhT Simulations media can significantly improve student motivation and learning outcomes. This is because this model combines the advantages of the scientific approach with the support of interactive technology, thus enhancing motivation and learning outcomes.

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