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The Effectiveness of Utilizing PhET in Increasing the Comprehension of Physics Concepts

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Abstract

This research assessed the effectiveness of using PhET media to increase the comprehension of physics concepts among eleventh-grade students at SMA Negeri 2 Makassar. This research design was a true experiment, specifically a pretest-posttest control group design. The population comprised all students of XI Science at SMA Negeri 2 Makassar, with a total of three classes. The sampling method utilized was random sampling, and collecting data entailed a test. The test consisted of a pre-test conducted before the learning phase and a post-test administered after the completion of the learning activities. The indicators for assessing the comprehension of the concepts were based on Bloom's Taxonomy, specifically Translation, Interpretation, and Extrapolation. The comprehensive analysis of the data revealed that the students' comprehension of physics concepts increased more effectively through the use of PhET simulation media. These findings suggest a significant positive effect of incorporating PhET simulation media in physics learning on student outcomes. The N gain score indicates an increase in students' comprehension of the material, demonstrating an increased ability to apply physics concepts following the implementation of PhET simulation media in the learning process. Implementing PhET simulations in physics education yields a positive impact in terms of increasing comprehension of physics concepts. Additionally, the utilization of PhET simulations facilitates the attainment of educational objectives by both teachers and students. Moreover, PhET simulations have the potential to streamline the learning process in classes, which previously necessitated an abundance of materials and instruments for experimentation. In other terms, PhET serves as an effective learning medium.

Keywords: concept comprehension; effectiveness; media; PhET

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INTRODUCTION

Physics education is a scientific field that utilizes physics or science as a means for the development of students. As a result, physics education can equip students to incorporate physics and the humanities with continuously evolving technology, thereby facilitating a balance between their culture and daily lives. If physics learning is not interesting or innovative,

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students will have difficulty understanding physics concepts. Students will struggle to comprehend physics concepts if the learning environment is uninteresting and repetitive. This is because physics is a scientific discipline that demands scientific skills, process skills, and the ability to understand concepts (Gaigher et al., 2007). The choice of media is critical for increasing students' comprehension of concepts.

The integration of advanced simulations significantly simplifies and elucidates the instruction of complex physics topics that are challenging to convey. In addition, simulations can facilitate the comprehension of experiments that present challenges in a conventional laboratory environment or are difficult for students to comprehend. As a result, physics courses evolve into engaging and immersive experiences, influencing students' perceptions of physics and bolstering their confidence. Modern computer simulations facilitate the comprehension of physics concepts and provide students with practical skills in virtual environments, replicating experiences typically gained in physical laboratories (Bozkurt & Ilik, 2010; Laseinde & Dada, 2023).

The observations conducted at SMA Negeri 2 Makassar showed that printed books and e-books were teachers' most commonly used instructional media to address material-related questions. Practical instruments were scarce in the laboratory, which hindered the regular implementation of hands-on learning experiences. As a result, students' comprehension of physics concepts was impeded, and their comprehension may not have been deemed at its peak. Additionally, a notable number of students perceived physics as a challenging and uninteresting subject, as evidenced by their lack of enthusiasm for this particular academic discipline. Students who take physics subjects only range from 100 to 120 students and are divided into three classes. Meanwhile, students who took biology specialization are totaled eight classes or around 300 students. Based on this discrepancy, it can be inferred that students continue to perceive physics learning as monotonous and unpleasant. Therefore, it is essential to utilize media that can contribute to the eradication of this stigma.

Physics is a science that requires scientific skills, process skills, and the ability to understand concepts. Therefore, media selection is very important to increase students' comprehension of ideas. To deeply understand many physical phenomena, simulations or direct experiments are necessary. For example, mechanical wave material needs simulations. With visualization aid, abstract concepts that are more accessible via IT and communication-based media can be described. PhET (Physical Education and Technology) Simulation media consists of various simulations, so it is anticipated that it can increase students' comprehension of problems or abstract material that is challenging to grasp.

PhET simulation media comprises diverse simulations, potentially increasing students' comprehension of abstract or challenging material. The objective is to promote understanding of complex problems. Moreover, the utilization of PhET simulations is designed to generate increased enthusiasm for learning physics, thereby providing students with a more pleasurable and less repetitive experience. Functioning as a form of computational media, PhET presents animated simulations in physics, biology, and various scientific fields through blogs or websites. Notably, PhET provides theoretical simulations and interactive experiments, actively involving users in learning. This interactive nature allows users to select specific activities within an experiment. Consequently, PhET serves not only to increase students'

comprehension of concepts but also to increase their skills in the scientific process (Bandoy & Pulido, 2016; Ekawati et al., 2020).

Incorporating simulation media is anticipated to significantly increase students' comprehension of physics concepts. PhET simulations play an important role in fostering understanding by enabling students to formulate scientific predictions and articulate explanations for various phenomena based on more valid scientific principles. Observation and reflection activities assisted by PhET simulations have been widely used in learning physics concepts. PhET simulation delivers massiveness using graphics and controls such as clicks, drags, rulers, and buttons. In addition, PhET simulations provide measuring instruments such as rulers to enhance students' quantitative exploration. The measurement outcomes will be presented in real-time in order to illustrate the causal connection between the experimental parameters (Banda & Nzabahimana, 2021;Finkelstein et al., 2005; Wieman et al., 2010). Therefore, to obtain good results, students must be able to develop their thinking skills.

Understanding the concept is the process of acquiring a comprehensive comprehension of a concept or an abstract mental image that enables one to categorize an object or an event (Elisa et al., 2017; Kokkonen et al., 2022). According to Subhan et al. (2020), understanding is comprised of three elements: 1) Understanding of translation; 2) The ability to understand concepts expressed in a manner distinct from the initial statements known; and 3) The ability to translate the relationship that exists in a symbol, illustration 2) Ability to Interpret, the ability to understand material or concepts that are recorded, changed, or arranged in other forms. 3) Extrapolation Understanding is the ability to predict current trends based on certain data by conveying the consequences and implications of the conditions described.

Comprehending the concept can also be interpreted as mastery of learning material. Students not only know the concept but are also capable of articulating it to facilitate comprehension and subsequent application. According to Kartika (2018), comprehension encompasses the capacity to communicate and interpret information and the capability to furnish additional innovative examples, descriptions, and explanations without losing the essence of what is conveyed. Nevertheless, the concept is an internal composition of the mind, thoughts, ideas, or comprehension.

Learning effectiveness can be interpreted as measuring the success of achieving learning objectives or accuracy in managing situations. In addition, Rohmawati (2015) stated that learning effectiveness pertains to the degree of success that the interaction process between teachers and students attains in order to accomplish educational objectives. Subhan et al. (2020) define learning effectiveness as effective teaching behavior in which teachers can provide students with new experiences through specific approaches and strategies to achieve learning objectives. Furthermore, learning effectiveness may also be operationalized as accuracy in managing situations or as one of the quality standards of education (Fathurrahman et al., 2019)

The research conducted by Susilawati et al. (2022) showed that significant improvements in indicators were observed in the experimental class. These improvements were attributed to the engaging learning activities facilitated by using PhET simulation media. The capacity of this media to stimulate students and foster enthusiasm for the learning process was identified as a key factor contributing to the observed increase. Moreover, the substantial increase in indicators was linked to PhET

simulation media's role as an alternative medium, presenting visually captivating elements during the learning process. This, in turn, enhanced students' interest and active participation in their educational experience, aligning with findings from Defianti et al.'s (2021) research. In conjunction with their tangible and practical implications, the inclusion of these engaging exercises distinguishes PhET simulation media from conventional educational media.

Similar research conducted by Usiana et al. (2016) revealed that incorporating PhET simulation learning media in physics education improved students' comprehension of concepts, particularly in modern physics courses. Another study by Rizaldi et al. (2020a) explored using PhET simulation in the learning process, yielding positive outcomes. The research demonstrated that PhET simulation media is valuable for teachers and students, especially when integrated with the inquiry learning model. The media was found to be highly effective in elucidating abstract physics concepts, boasting an attractive interface. However, a notable limitation highlighted was the reliance on the availability of computer units for successful implementation in schools.

METHOD

The research was quantitative using the True-Experiment method (Kothari, 2004). The research carried out employed an experimental method involving two groups: (1) the control group or the group that used conventional learning media and (2) the experimental group or the group that used PhET simulation media. The research was carried out at SMAN 2 Makassar. The research was conducted in semester 2 of the 2022/2023 school year. The sampling technique in this research was a simple random sampling technique by taking a group of samples from the population at random of the 3 classes. Two classes were selected: Class XI Physics 2 as the control class and Class 3 as the experimental class. The data collection technique used by the researcher was administering a test consisting of a pre-test before the lesson and a post-test after the lesson to determine the extent to which the students' conceptual comprehension increased before and after the implementation of the PhET simulation learning media. The instrument used in this research tested the ability to understand physics concepts through 25 multiple-choice questions. Researchers prepared the questions used in this research, which were assessed through item validity and expert validity stages. Based on the expert validity results from the two validators, the instrument was valid with a score above 0.75. For the item validity results in this study, point biserial validity was used, and two invalid question items were obtained from a total of 25 question items. According to Bloom, the indicator of conceptual understanding is translation, namely the ability to translate or change data from one form to another. Interpretation is the ability to conclude data; extrapolation is the ability to predict or suspect further data from previous data sets. Furthermore, the research data were analyzed and processed using a normalized gain score. The categorization of the ability to understand physics concepts in terms of the N-Gain value can be seen in Table 1 (Meltzer, 2002).

Table 1 Normalized gain level category

Value	Category
$g < 0.30$	Low
$0.30 \leq g < 0.70$	Medium
$g \geq 0.70$	High

RESULTS AND DISCUSSION

Descriptive statistical analysis was used to describe or summarize the results of SMA Negeri 2 Makassar experimental and control class students' comprehension of the physical concept of mechanical waves. According to the descriptive statistical analysis results of the physics

concept comprehension of Class 11, Physics 2, the control class, used conventional learning media for learning. Physics 3, of Class 11, as the experimental class, used PhET simulated learning media for concept comprehension. The results are consistent with Table 2.

Table 2 Statistics of pre-test and post-test scores of students' concept comprehension

Descriptive Statistic	Statistic Value			
	Experiment Class		Control Class	
	Pre-test	Post-test	Pre-test	Post-test
Number of Samples	25	25	25	25
Ideal Score	25	25	25	25
Highest Score	11	24	10	21
Lowest Score	4	13	3	8
Average Score	7.6	19.8	5.84	12.6
Median	8	21	6	13
Modus	8	23	8	15
Standard Deviation	2.18	3.32	2.08	3.23

The results of the pre-test and post-test comprehension of physics concepts for students in class XI Physics 2 (control class) and XI Physics 3 (experimental class) are presented in Table 4.1. Based on the results of calculating the pre-test and post-test scores in the experimental and control classes, the data obtained is presented in Table 4.1. The results revealed that the pre-test in the experimental class had the lowest score of 4 and the highest score of 11. Meanwhile, the post-test results in the experimental class have the lowest score of 13 and the highest score of 24. The acquisition of pre-test scores for students' ability to understand physics concepts in class XI Physics 2 (control class) and class XI Physics 3 (Experimental Class) SMA Negeri 2 Makassar is categorized into five scales, namely very low, low, medium, high and very high. The results of categorization are displayed in Table 3.

Table 3 Categorization of physics concept comprehension scores of control class and experiment class

Percentage Score Interval			Category	Pre-test score frequency	
				Control	Experiment
1	-	5	Very Low	11	5
6	-	10	Low	14	16
11	-	15	Medium	0	4
16	-	20	High	0	0
21	-	25	Very High	0	0
Total				25	25

The analysis of the pre-test score categorization of students' comprehension of physics concepts in the experimental class and the control class showed thatmostf students' physics concept comprehension were still in the low category. Meanwhile, if the acquisition of post-test scores on students' physics concepts comprehension in class XI Physics 2 (control class) and class XI Physics 3 (Experimental Class) SMA Negeri 2 Makassar is categorized into five scales, namely very low, low, medium, high and very high, the results can be seen in Table 4.

Table 4 Categorization of physics concept comprehension scores of control class and experiment class students

Percentage Score Interval			Category	Post-test Score Frequency	
				Control	Experiment
1	-	5	Very Low	0	0
6	-	10	Low	8	0
11	-	15	Medium	14	4
16	-	20	High	2	8
21	-	25	Very High	1	13
		Total		25	25

The post-test score categorization analysis of students' comprehension of physics concepts shows that most students' ability to understand physics concepts in the control class is still in the moderate category. As for the post-test scores, most students in the experimental class were in the very high category.

PhET simulation media is effective in increasing students' comprehension of physics concepts if the minimum normalized average gain is in the moderate category or more than 0.30.

The analysis for the gain test on the results of understanding the physics concepts of control class students can be seen in Table 5.

Table 5 Control class n-gain frequency distribution

Category	Frequency	Percentage (%)
Low	10	40
Medium	14	56
High	1	4
Total	**25**	**100**

The data in Table 5 yielded the N-Gain Score for the physics concept comprehension in class XI Physics 2 in the medium category.

The analysis for the gain test on the results of understanding the physics concepts of experimental class students can be seen in Table 6

Table 6 Experimental class n-gain frequency distribution

Category	Frequency	%
Low	3	12
Medium	6	24
High	16	64
Total	**25**	**100**

The data in Table 6 yielded the N-Gain Score for comprehending physics concepts in class XI Physics 3 in the high category. The N-Gain frequency distribution diagram for the control and experimental classes is presented in Figure 1.

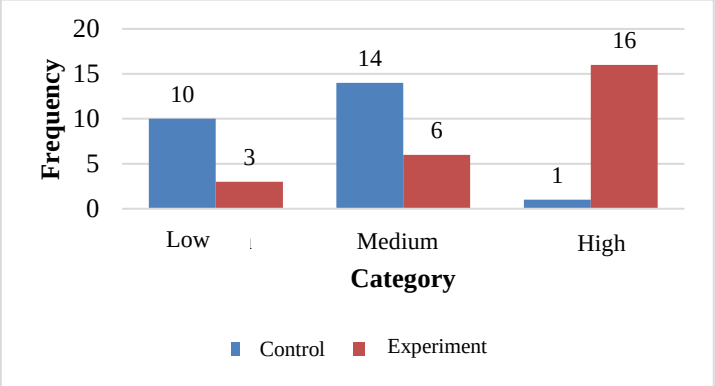

Figure 1 N-Gain frequency distribution diagram for experiment class and control class

The results of the descriptive analysis in Table 2 show that the average value of the experimental class is higher than the average value of the control class. The pre-test average score obtained in the experimental class was 7.6 while the average score of student learning outcomes in the control class was 5.84. The post-test average score obtained in the experimental class was 19.8 while the average score of student learning outcomes in the control class was 12.6. The difference in the average value obtained was due to differences in the treatment of the two sample classes in that study. In addition, there are differences in the standard deviation values. The experimental group obtains a lower standard deviation than the control group. The standard deviation value for the pre-test in the experimental group is 2.18 while the control class is 2.08. The experimental group's standard deviation value for the post-test is 3.32 while the control class is 3.23. This means that the deviation of the data in the experimental group treated with simulated media was less than that of the control group, which utilized conventional media.

In a study conducted by Azhar et al. (2020), two classes were compared, with the first class adopting traditional teaching methods and the second class utilizing interactive simulation techniques. Following data collection from the study sample, the findings revealed a significant impact associated with using interactive simulation methods, particularly in teaching various scientific topics, with a specific emphasis on physics across different school stages.

Inferential statistical analysis was carried out to strengthen the descriptive statistical analysis results. Descriptively and statistically, using PhET simulation media as a teaching medium significantly influences the students' comprehension of physics concepts according to the average value and N-Gain score, in which the experimental class is higher than the control group. The truth of the hypothesis is proven through hypothesis testing. Overall, this shows that using PhET simulation teaching media effectively increases students' comprehension of physics concepts compared to conventional teaching media. This is supported by research (Chang, 2017; Morgan & Moore, 2016) showing that after using PhET simulation, the students have an increased understanding of physics problems than before using PhET simulation.

The results of the independent sample test showed that the Two-sided p-significance value is at a significance level of 0.001 <0.05, meaning that H0 is rejected and H1 is accepted. It can be concluded that there is a difference between the comprehension of physics concepts by students in the experimental class and the control class. Based on the results of statistical tests to determine the effectiveness of using PhET simulation media, it can be interpreted that using PhET simulation media is effective in increasing students' comprehension of physics concepts. This is supported by research results of other researchers, which showed that there were significant differences in pre-test and post-test means scores for the experimental group that used PhET simulation to improve students' learning outcomes in physics (Najib et al., 2022; Rizaldi et al., 2020).

The results of the N-Gain test analysis in Table 5 indicate the N-Gain score in the control class. The data show the increase in N-Gain in the control class in the medium category, meaning that using conventional media in the control class is good enough to increase students' comprehension of physics concepts. The results of the N-Gain test analysis in Table 6 show the N-Gain score in the experimental class. The data show that the increase in N-Gain in the experimental class is in the high category, meaning that using PhET

simulation media applied in the experimental class is very good for increasing students' comprehension of physics concepts. This is supported by research (Saudelli et al., 2021) showing that the student studies physics concepts more effectively when using PhET simulations. In addition, students reacted positively to a question, indicating that they used PhETS outside of class for homework and fun. Students noted that they used PhET to assist them in doing the assignments.

The differences in the increase in students' understanding of physics concepts in terms of the N-Gain Score in the control class show that the understanding of physics concepts increased by a percentage of 35% in the control class while the increase in understanding of physics concepts in the experimental class had a percentage of 70%. Based on the results of the overall analysis of the data obtained, using PhET simulation media is more effective in improving students' comprehension of physics concepts. These results indicate that the use of PhET simulation media in physics learning has a significant impact on improving student learning outcomes. The N gain score also indicates that students have increased their comprehension of the material being taught and can apply physics concepts better after applying PhET simulation media in learning. PhET is an application that simulates real-world laboratory experiments and enables students to perform practical work easily using a smartphone or computer so students can gain a deeper understanding of physics (McKagan et al., 2008).

This is further reinforced by the fact that the learning process has been carried out face-to-face directly between the teacher and students to improve student learning outcomes on mechanical wave material using PhET simulation teaching media. This is also because students engage in direct communication with their peers through discussions and explanations of learning material in a face-to-face setting, which allows them to observe and listen to the material. As a result, their learning experience is enhanced, as the learning process incorporates multiple senses. PhETs can represent the essentially dynamic nature of Physics concepts, and the learning can develop intuitively (Kubricht et al., 2017; Tallant, 2013)

Astutik et al. (2017) state that the experience level in E. Dale's pyramid is based on how many senses are involved. The more senses involved, the more concrete the learning is and the greater the benefits of learning. E. Dale's Pyramid of Experience, where individual learning styles are based on how information is presented, is similar to using PhET to simulate a learning environment where students read, listen to, and see images in the form of images relevant to the learning content provided about the material. Cuadros et al. (2015) also state that the study, which involved a contextualized task utilizing a virtual laboratory, yielded results that such activities offer substantial support for an active learning environment. In this context, students are deeply involved and focused on actively completing the assignment.

Numerous comparable studies have provided additional evidence supporting the effectiveness of utilizing PhET simulation media. These studies indicated that the mean scores of students in experimental classes, where simulated instructional media like PhET was employed, surpassed the average scores of students in control classes taught through traditional instructional methods. The students in the experimental group, benefiting from the use of Interactive Science Simulation or PhET, demonstrated higher academic achievement compared to their counterparts in the control group. In summary, the implementation of PhET

contributed to an increase in students' academic performance at Suan Sunandha Rajabhat University. (Chan et al., 2021; Krobthong, 2015; Srisawasdi & Kroothkeaw, 2014). In a study conducted by (İnce et al., 2015), the pre-test results revealed significant misconceptions among students in each group regarding electromagnetic and magnetic fields. However, the post-test outcomes demonstrated that students instructed through the IUVIRLAB virtual physics laboratory exhibited substantially higher scores than their pre-test performances. This suggests that using the IUVIRLAB virtual physics laboratory effectively prevented the identified misconceptions. As a result, employing virtual laboratory-based learning media can be deemed effective in averting misconceptions in physics education, indicating an increase in students' comprehension of physics concepts.

The findings from the study conducted by Sarabando et al. (2014) indicate that incorporating the computer simulation "Weight and mass" significantly contributed to students' comprehension of physics concepts related to weight and mass, whether used independently or in conjunction with hands-on activities. Students using the computer simulation achieved higher total gains ranging from approximately 40% to 58%, whereas those relying solely on experimental activities exhibited total gains from 20% to 37%. This underscores the importance of the teacher's role in effectively implementing computer simulations. It is essential to acknowledge that the gains observed in this study are reasonably significant, considering the acknowledged challenges associated with learning these concepts.

PhET simulations are more effective in reducing misconceptions among students than teaching aids for electrical circuit materials. The reduction in misconceptions can be attributed to the characteristics of PhET simulations, which can present microscopic and abstract phenomena in a more tangible form compared to the teaching aids. For example, when explaining the brightness difference in a light bulb when the resistance value (resistor) is altered, teaching aids cannot demonstrate the flow of charges within each component in these circuits. This issue can make it challenging for students to construct concepts due to uncertainty about the concepts taught (Rizaldi et al., 2020).

CONCLUSION

PhET simulation media in class XI Physics 3 SMA Negeri 2 Makassar effectively increases students' comprehension of physics concepts. The N-Gain value in the control class is 0.35 in the medium category while the N-Gain value in the experimental class is 0.70 in the high category. This indicates that the concept's comprehension level varies significantly between the two classes.

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