JSEP (Journal of Science Education and Practice) p-ISSN 2548-950X
Volume 7, Number 2, 2023 e -ISSN 2549-7170

EFFECTIVENESS OF DEEP PHET INTERACTIVE SIMULATION IMPROVING UNDERSTANDING OF THE CONCEPT OF MATERIAL CHANGE

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Abstract: This research aims to evaluate the effectiveness of using PhET interactive simulations in increasing students' understanding of the concept of chemical material changes, by applying the Discovery Learning learning model. The research method applied was quantitative with a quasi-experimental design using Nonequivalent Control Group Design, involving two groups of 10th grade students at Madrasah Aliyah, Bogor Regency. The results of the Paired T-Test analysis in the experimental group showed a score of 0.000 which was smaller than 0.05, indicating a significant difference between the pretest and posttest scores. This illustrates the positive impact of using PhET simulations on improving student understanding. The results of the N-Gain analysis show an average value of 0.5, indicating that there is effectiveness in the learning process. The conclusion of this research is that there is an increase in students' understanding of the concept of material change, and the use of PhET in the learning process has proven to be effective.

Keywords: PhET, interactive simulation, understanding concepts, material changes.

INTRODUCTION

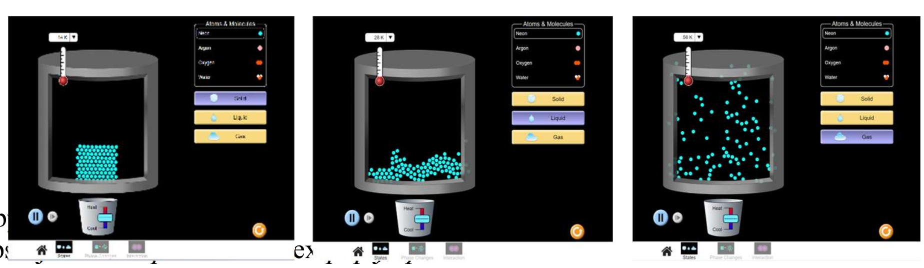
Education is an important milestone in the development of society and individuals. In an era that continues to develop with the support of technological advances, the field of education is also experiencing transformation with various learning innovations. One innovation that is gaining increasing attention is the use of technology in learning, especially through interactive simulations. Interactive simulations not only provide real visualization of scientific concepts, but also increase student engagement in learning, trigger curiosity, and help students build deeper understanding (Benninga et al., 2003; Khoiri et al., 2021; Thabiea et al., 2022).

Chemistry as a branch of natural science has a very important role in explaining the phenomena of changes in matter in nature. The concept of material change is the main basis for understanding various processes such as chemical reactions, physical changes, and the transformation of matter from one form to another. However, this concept is often considered complex material and difficult for students to understand (Ohn-Sabatello, 2020). Chemistry learning that only focuses on the lecture model in conveying theory and mathematical calculations can reduce students' interest and enthusiasm in studying this concept.

This is where innovative and interesting learning approaches for students are important (Engelberger et al., 2021; Gandhi et al., 2020). PhET presents itself as an attractive and effective solution to overcome this challenge. PhET is a collection of interactive simulations developed by *University of Colorado Boulder*. PhET provides access to realistic, easy-to-use simulations in a variety of subjects such as physics, chemistry, biology, mathematics, and earth sciences. This simulation provides a virtual experience for students to run experiments, observe the results instantly and easily understand the basic concepts.

PhET's use of interactive simulations in learning has produced a number of significant positive impacts. As research conducted by Salame & Makki, (2021) shows that PhET as a whole has a positive impact on students' attitudes and perceptions of the learning process. Students tend to be more enthusiastic and enthusiastic in facing lessons using PhET, because this tool allows them to learn through active exploration (Thabiea et al., 2022). One of the main advantages of PhET is its ability to bridge the gap between theory and practice. By offering in-depth simulation exploration, PhET allows students to experience chemistry, physics, and other science concepts in a real-world way, which in turn contributes to increased understanding of the subject matter (Ndihokubwayo et al., 2020; Saudelli et al., 2021).

The PhET application displays animated molecules in solid, liquid and gas form. (1) In the solid phase, the molecules form an ordered structure and are tightly bound to each other. They vibrate but have a relatively fixed position, illustrating the cohesive nature of solid matter. (2) In the liquid phase, the molecules have greater freedom of movement compared to the solid phase. They are still linked together, but not as tightly as in the solid phase. (3) The gas phase is characterized by the free and disordered movement of the molecules. They have kinetic energy large enough that they can move freely in space. This animation creates a visual representation of how gas molecules collide and move without fixed structural boundaries, creating the dispersion and compressibility properties of gaseous matter, which can be seen more clearly in Figure 1 below



(1) (2) (3)

Figure 1. Animation images of solid particle form (1), liquid particle form (2) and gas particles form (3)

Other research also shows that the use of PhET in learning can result in increased understanding of subject matter. Students who engage in the use of PhET tend to have a deeper understanding of complex scientific concepts (Ashraf Ali Bani Yassin, 2022; Gilbert et al., 2020). Apart from being a tool that improves understanding, PhET also helps in developing students' creative thinking abilities. The use of PhET in research-based learning has proven it self to be an effective tool in honing students' critical and creative thinking skills (Chotimah & Festiyed, 2021; Li et al., 2022). In the context of chemistry learning, PhET has helped make learning more effective and meaningful. Students feel more engaged in lessons, and their motivation increases. They feel challenged and want to continue learning more when using PhET simulations in the classroom (Mweene & Muzaza, 2020; Qin et al., 2021; Rahmawati et al., 2022).

Despite many positive impacts, the use of PhET in learning also faces several challenges. Several studies have noted that in virtual physics learning situations, the use of PhET can have a negative impact on students' attitudes toward physics inquiry learning fisika (Ng & Chua, 2023). This shows the importance of a careful approach in integrating technologies such as PhET in the learning process. In addition, research results show that teachers' knowledge, pedagogical reasoning, and the decisions taken by them in integrating PhET are closely related and influence student learning outcomes (Gong et al., 2023). This emphasizes the importance of adequate teacher training in optimizing the use of PhET in the classroom.

PhET's use of interactive simulations has proven it self to be an effective way to keep students active, highly motivated, and challenged in the learning process. Students tend to be more engaged in learning when they have access to tools like PhET that allow them to directly participate in experiments and simulations (Mallari, 2020; Ohn-Sabatello, 2020; Rodrigues et al., 2020). In the ever-evolving world of education, PhET has brought about significant changes in the way we approach scientific learning. With a thoughtful approach and appropriate training for educators, PhET has great potential to continuously improve the quality of education and help students become active, creative and passionate learners. All of this creates a more effective and meaningful learning experience.

This research aims to evaluate the effectiveness of using PhET interactive simulations in increasing students' understanding of the concept of chemical material changes. The focus of this research is on grade 10 students, where the concept of changes in matter is an important basis in understanding chemistry further. The lack of student involvement in conventional chemistry learning and their difficulties in understanding the concept of changes in matter are the main motivation for this research, besides that most of the research is only descriptive and does not utilize experimental designs to measure the effectiveness of interactive simulations. The learning model used in this research is Discovery Learning, which invites students to learn through independent exploration and direct experience, in line with the spirit of PhET interactive simulations.

METHOD

This research uses a quantitative approach with a quasi-experimental design. The type of design used is*Nonequivalent Control Group Design*, which compared an experimental group that used PhET simulation with a control group that did not use simulation (Borg & Gall, 2007; Gall et al., 2003). The research participants consisted of two groups of class X students at Madrasah Aliyah, Bogor Regency. The experimental group consists of 30 students who will use the learning model *Discovery learning* with the help of PhET simulations, while the control group consists of 30 students who will take part in learning with the model *discovery learning* only without using PhET simulation.

Table 1. Comparison of chemistry learning experiences between the control group and the experimental group

Control Group	Experimental Group
Students are given chemistry lessons using the discovery learning model	Students are given chemistry lessons using the discovery learning model
Students watch a video about material changes	Students carry out experimental activities to change material through PhET Interactive Simulation

The simulation used is related to the concept of changes in matter in chemistry lessons. This simulation includes virtual experiments that allow students to observe changes in matter in various situations based on both temperature and pressure changes (Chang, 2005).

Table 2. Research design

Class	PreTest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_1	-	O_2

The material used in this research is material about the concept of changes in chemical materials in accordance with the class 10 curriculum (Brady et al., 2014; Keenan, 1999; Petrucci, 2011). The instruments used in this research consisted of a pretest and posttest in the form of multiple choice questions and open questions to measure students' understanding of the concept of material change (Creswell, 2003). Pretest and posttest data will be analyzed using Paired T-Test analysis to measure significant changes in increasing student understanding in both groups (Fraenkel, 2012; Sugiyono, 2011). Apart from that, an N-Gain analysis was also carried out to determine the effectiveness of PhET in increasing students' understanding of concepts. The effectiveness criteria use the criteria table developed by Hake which is in table 3.

Table 3. N-Gain Criterion (Hake, 1999)

N-Gain Index	Interpretation
G < 0,7	Tall
0,70 > g > 0,30	Currently
G > 0,30	Low

RESULTS AND DISCUSSION

The research results of increasing understanding of this concept were obtained from analysis of pretest and posttest scores in the form of essay questions. Pretest questions are given at the beginning of learning before learning chemistry about material changes. In the learning process students are given a PhET learning link as a learning medium for material changes in the form of an interactive application as well as a bridge between the gap between theory and practice. After learning is complete, posttest questions are given to determine learning outcomes. The pretest and posttest results were tested using inferential statistics in the form of Normality test, Paired T-Test, Homogeneity, Independent T-Test and N-Gain.

A. Normality test

The Normality Test is calculated using the SPSS 16 application to determine whether the data is normally distributed or not, the results of which are presented in table 4.

Table 4. Tests of Normality

Kelas		Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	Df	Sig.
Hasil Belajar	Pretest Kelas Eksperimen	.153	30	.071	.960	30	.301
	Posttest Kelas Eksperimen	.144	30	.200	.945	30	.126
	Pretest Kelas Kontrol	.148	30	.090	.968	30	.488
	Posttest Kelas Kontrol	.151	30	.077	.945	30	.121

The results of the pretest and posttest calculations for the experimental class were 0.301 and 0.126 and the pretest and posttest results for the control class were 0.488 and 0.121, all of which had values greater than 0.05, meaning the sample was said to be normally distributed. So the next test uses parametric statistics.

B. Paired T-Test

The Paired T-Test was carried out to determine whether there was a difference in the averages of two paired samples.

Table 5. Paired Samples Tests

Paired	Paired Difference 95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
	Lower	Upper			
Pretest Kelas Eksperimen – Posttest Kelas Eksperimen	-31.422	-21.378	-10.752	29	.000

The results of the paired T-Test calculation in the experimental class resulted in a significance value of 0.000, which is smaller than 0.05, so that there was a significant change between the initial assessment and the final assessment after being given treatment.

C. Homogeneity Test

This test is carried out to ensure that the population to be measured is homogeneous, not much different in diversity. The calculations are still carried out the same using SPSS 16.

Table 6. Test of Homogeneity of Variances

		Levene Statistic	Df1	Df2	Sig.
Hasil Belajar	Based on Mean	.171	1	58	.681
	Based on Median	.337	1	58	.564
	Based on Media and with adjusted df	.337	1	57.724	.564
	Based on trimmed mean	.207	1	58	.651

The results of the homogeneity test calculation obtained a significant result of 0.681, which is greater than 0.05, meaning that the population has the same or homogeneous variance.

D. **Independent T-Test**

The Independent T-Test Analysis Test was carried out to determine whether there was a difference in the average student learning outcomes between the experimental class posttest scores and the control class posttest scores.

Table 7. Analisis Independent T-Test

		Levene's Test for Equakity of Variances		t-test for Equality of Means		
		f	Sig.	t	df	Sig. (2-tailed)
Hasil Belajar	Equal variance assumed	6.830	.011	5.303	58	.000
	Equal variance not assumed			5.303	52.441	.000

The calculation results of the Independent T-Test Analysis showed that the significance value was 0.000, which was smaller than 0.05, meaning that there was a significant difference between the average value of the experimental class and the value of the control class.

E. N-Gain Test

The N-Gain test was carried out to see how effective the treatment was in increasing students' conceptual understanding of the material provided by the teacher. From the N-Gain analysis, the data obtained are shown in table 8.

Table 8. N-Gain Achievement

Kelas				Statistic	Std. Error
NGain_Score	1	Mean		.5055	.03129
		95% Confidence Interval for Mean	Lower Bound	.4425	
			Upper Bound	.5695	

	5% Trimmed Mean	.5151
	Median	.5527
	Variance	.029
	Std. Deviation	.17139

The results of the N-Gain analysis obtained a mean or average value of 0.5055, which means that the effectiveness of increasing students' conceptual understanding scores regarding material changes in chemistry lessons is in the medium category. However, the findings of this study indicate that the use of PhET interactive simulations significantly increases students' understanding of the concept of chemical changes in matter. This is in accordance with previous research, that PhET simulations are able to provide an immersive and realistic visual experience, allowing students to run virtual experiments, observe the results, and understand scientific concepts better (Casa-Coila et al., 2023; Mahtari et al., 2020; Yunzal & Casinillo, 2020).

The main advantage of PhET simulation is its ability to make conceptual abstractions more concrete and observable. This helps students to overcome obstacles in understanding difficult and complex concepts. Additionally, these simulations also provide the ability to repeat experiments or change certain parameters to see how it affects the results. This is something that is difficult to achieve in conventional learning.

CONCLUSION

Based on the results of research data analysis, it can be concluded that the use of PhET interactive simulations can increase students' understanding of concepts in chemistry lessons regarding Changes in Matter, but the effectiveness of the improvement is less effective. Students who were involved in learning using PhET experienced a higher increase in understanding compared to students who did not use this simulation. Therefore, the integration of simulation technology such as PhET can be an invaluable tool in improving the quality of chemistry learning in the classroom.

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