

EFFECT OF PHET-ASSISTED WONDERING, EXPLORING, AND EXPLAINING MODEL ON STUDENTS' COGNITIVE OUTCOMES IN GLOBAL WARMING

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Abstract. A preliminary study at SMA Negeri 9 Tasikmalaya revealed that students' low activity and engagement during the learning process contributed to poor learning outcomes. This was evident from the average score of students' daily tests, which was 62, below the Minimum Mastery Criteria (MMC) of 75, thus categorized as low. This study aims to examine the effect of the Wondering, Exploring, Explaining (WEE) learning model assisted by PhET on students' cognitive learning outcomes in the topic of global warming among tenth-grade students at SMA Negeri 9 Tasikmalaya in the 2023/2024 academic year. The study employed a quasi-experimental method with a non-equivalent control group design across nine tenth-grade classes. The sample was determined through purposive sampling, with class X-3 assigned as the experimental group and class X-9 as the control group. Cognitive learning outcomes were measured using an essay test consisting of nine items covering cognitive levels C2, C3, and C4. Hypothesis testing using the t-test at a significance level ($\alpha=0.05$) showed that $t_{\text{count}} > t_{\text{tabl}}$, namely $11,5 > 1,67$, indicating that H_a was accepted and H_0 is rejected. It can thus be concluded that the WEE learning model assisted by PhET significantly influenced students' cognitive learning outcomes on the topic of global warming. The findings of this study imply that the WEE learning model assisted by PhET can serve as an effective instructional strategy for teachers to enhance student engagement and learning outcomes and may provide a reference for further research in the development of innovative learning models.

Keywords: cognitive learning outcomes, global warming, PhET, WEE Model

INTRODUCTION

Education plays an important role in improving the quality of learning, which is not only oriented towards mastery of the material but also toward the development of critical, creative, and collaborative thinking skills. According to Halean et al., (2021), education is a process of shaping knowledge, skills, and habits from generation to generation that continues throughout life. Therefore, effective learning requires active engagement between educators and learners so that students can learn optimally (Ubabuddin, 2019).

In the context of contemporary learning, active student participation has become a primary necessity to address the challenges of scientific and technological development. The Merdeka Curriculum aims to improve the quality of learning through a student-centered approach, encouraging teachers to create a learning environment that is educational, enjoyable, and simultaneously challenging (Wahyuni et al., 2023). However, the implementation of this policy still faces various obstacles in the field, both in terms of teacher understanding and student engagement.

Students' learning success is reflected in their ability to relate the material to everyday life, which impacts academic achievement. One important aspect is cognitive ability, which includes critical thinking, problem-solving, and reasoning.

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This ability affects other skills, such as motor skills, communication, social interaction, and emotional control (Zahara et al., 2023). Therefore, the development of cognitive abilities becomes an important indicator of learning success and students' future.

Teachers are required to innovate in selecting learning models or strategies that are capable of optimizing students' cognitive abilities. Such innovation is important so that students not only understand the material but are also trained in critical thinking, problem-solving, and logical reasoning. With the implementation of the right strategies, the learning process can be more meaningful and encourage active student engagement (Novita et al., 2023).

The implementation of the Independent Curriculum at SMA Negeri 9 Tasikmalaya has not been carried out optimally. The physics learning process still uses a one-way lecture method, so students are less actively involved. This condition causes students to have difficulty understanding the material and achieving low learning outcomes. Observational results show that many students have not met the Minimum Mastery Criteria (MMC), especially on the topic of global warming, with an average score of 57 out of the MMC standard of 75. This situation emphasizes the need for a more interactive and meaningful learning approach.

The Wondering, Exploring, Explaining (WEE) learning model can be one of the solutions applied to improve the quality of learning. This model falls under the cooperative learning approach, which encourages students to ask questions, conduct explorations, and explain the concepts they have learned (Anderson, 2013). Research conducted by Ningsih et al., (2023) and Safitri, (2023) shows that the WEE model is effective in enhancing students' conceptual understanding and reasoning skills, especially when combined with other learning strategies such as Student Active Learning (SAL) and Question Student Have (QSH).

Technological advances also enable the use of media such as virtual labs to support learning. One example is PhET, an interactive simulation media that allows students to understand abstract physics concepts visually. Research by Subiki et al., (2022) shows that the use of PhET has a positive impact on student learning outcomes. This simulation is very helpful for schools that do not yet have complete laboratory facilities.

The topic of global warming is relevant to students' daily lives and is a global issue that requires a critical understanding of environmental phenomena (Septaria et al., 2019). The WEE model, which emphasizes asking, exploring, and explaining activities, is very suitable for the characteristics of this material because it encourages active student involvement in discovering concepts (Anderson, 2013). In addition, the use of PhET interactive simulations helps visualize abstract concepts, such as the effects of greenhouse gases, making learning more concrete and meaningful (Subiki et al., 2022). Thus, the implementation of the PhET-assisted WEE model is relevant to enhancing students' cognitive understanding of global warming topics.

METHOD

The research method used is a quasi-experiment with a non-equivalent control group design, where the experimental and control groups are not selected randomly (Sugiyono, 2013). The population of this study includes all 10th-grade students of SMA Negeri 9 Tasikmalaya, totaling nine classes. The research sample was determined using a purposive sampling technique, namely, class X-3 as the experimental group and class X-9 as the control group.

In the experimental class, the WEE (Wondering, Exploring, Explaining) learning model assisted by PhET was applied, while in the control class, the Direct Instruction model was implemented. The research design is shown in Table 1.

Table 1. Research design

Group	Pretest	Treatment	Posttest
Experiment	O1	X	O2
Control	O3	–	O4

Description:

O1 = pretest of the experimental class

O2 = posttest of the experimental class

O3 = pretest of the control class

O4 = posttest of the control class

X = treatment (implementation of the WEE model assisted by PhET)

The learning stages used in each class are as follows:

Table 2. Learning stages

Experimental Class (WEE assisted by PhET):	Control Class (Direct Instruction):
1. Wondering: students are encouraged to ask questions and develop curiosity about the phenomenon of global warming.	1. Establishing objectives and orientation: the teacher explains the learning objectives and prepares the students.
2. Exploring: students conduct exploration through PhET simulations to understand the effects of greenhouse gases.	2. Demonstrating knowledge or skills: the teacher delivers the material through lectures, direct explanations, or demonstrations.
3. Explaining: students present the results of their exploration, engage in discussions, and explain the concepts they have learned.	3. Guided practice: the teacher provides structured exercises with direct guidance.
	4. Checking understanding and providing feedback: the teacher asks questions about concepts to ensure student comprehension.
	5. Providing advanced exercises and applications: students work on problems or assignments to reinforce their understanding of the material.

Data collection was conducted through cognitive ability tests in the form of 9 essay questions, representing three indicators: understanding, applying, and analyzing. To clarify the distribution of questions for each indicator, the grid of the cognitive ability test instrument is presented Table 3.

Table 3. Test instrument blueprint for cognitive ability

Subtopic	Question Indicators	Cognitive Aspect		
		C2	C3	C4
Greenhouse effect	Students can identify how the formation process of CO ₂ gas occurs.	1		
Greenhouse effect	Students can identify the consequences of the increasing CO ₂ gas in the atmosphere.	2		
Global warming	Students can identify the causes of global warming.	3		
Global warming	Students can conceptualize the occurrence of global warming after being presented with images related to average Earth's surface temperature data.		4	

Subtopic	Question Indicators	Cognitive Aspect		
		C2	C3	C4
Greenhouse effect	Students can conceptualize the process of the greenhouse effect after being presented with images of the greenhouse effect.		5	
The impact of global warming	Can students mention the factors that cause the increase in global warming?		6	
The impact of global warming	Students can analyze the impact of global warming and its effects on life and the environment.			7
Increase in Earth's temperature	Students can analyze the temperature in a greenhouse room.			8
Solutions to address global warming	Students can provide suggestions and opinions on what should be done to reduce global warming.			9
Number of Questions			9	

The instrument was validated by three validators who are experts in the field of physics education and learning evaluation. The validity test results using the Aiken's V formula showed an average score of 0.90, indicating that the instrument falls into the very valid category (Azwar, 2012). Reliability testing using the Cronbach Alpha formula yielded a value of 0.80, which means the instrument has very high consistency. (Arikunto, 2013). The test scores obtained were then interpreted based on the criteria in Table 4.

Table 4. Interpretation of learning outcomes

Reliability Coefficient	Category
0.80 – 1.00	Very High
0.60 – 0.79	Tall
0.40 – 0.59	Currently
0.20 – 0.39	Low
0.00 – 0.19	Very Low

Prerequisite tests include a normality test using the Chi-Square (Arikunto, 2013) and a homogeneity test using the Fisher (Sugiyono, 2017). The normality test is used to determine the data distribution. while the homogeneity test ensures the equality of variances between groups. The results showed that the data were normally distributed and homogeneous. so the hypothesis test was conducted using the t-test to determine the difference in means between the experimental and control classes (Arikunto, 2013). Calculations were carried out using equation 1.

$$t_{count} = \frac{\bar{X}_1 - \bar{X}_2}{SDG \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

RESULTS AND DISCUSSION

Based on the research results with the implementation of the Wondering Exploring Explaining (WEE) model in the experimental class and direct learning in the control class. the results show that the average student scores in the experimental class are higher compared to the control class. This indicates that the students' cognitive learning outcomes in the experimental class are better. In addition, the variance and standard deviation in the control class are greater. which means that the score distribution in the control class is wider compared to the experimental class. Thus, the posttest results show that the learning applied in the experimental class is

able to achieve more optimal outcomes. The posttest data can be seen as presented in Table 5.

Table 5. Posttest data on cognitive ability

Statistics	Experiment	Control
N	35	35
Ideal Score	45	45
Highest Score	43	35
Lowest Score	33	25
Average	39.73	31.16
Standard Deviation	3.05	3.19
Variance	9.32	10.17

Before hypothesis testing, the researchers conducted prerequisite tests in the form of normality and homogeneity tests. The normality test was carried out using the chi-square formula to evaluate whether the data were normally distributed. The results of the normality test are presented in Table 6.

Table 6. Results of data normality test

Class	Data	X^2_{count}	X^2_{table}	Description
Experiment	Pretest	5.16	12.8	Data is normally distributed
	Posttest	6.11	12.8	Data is normally distributed
Control	Pretest	6.32	12.8	Data is normally distributed
	Posttest	6.63	12.8	Data is normally distributed

Based on Table 6, this results indicate all pretest and posttest data, both in the experimental and control classes, have values X^2_{count} smaller than X^2_{table} , so that all data are normally distributed. Therefore, It can be concluded that all data groups are taken from a population that is normally distributed. The next prerequisite test is the homogeneity test to determine whether the data have the same variance. The testing is carried out using Fisher's test, and the results are presented in Table 7.

Table 7. Results of homogeneity test

Data	F_{count}	F_{table}	Description	Conclusion
Posttest Score (Experimental-Control)	11.09	1.77	H_0 is accepted	Both variances are homogeneous

Based on Table 7, both variances are considered homogeneous if $F_{count} < F_{table}$. Since this condition is met, the data are declared homogeneous. After it is determined that the data are normally distributed and homogeneous. The next step is to conduct a hypothesis test using the t-test, the results of which are presented in Table 8.

Table 8. T-test results

Data	α	t_{count}	t_{table}	Decision
Experimental Class	0.05	11.5	1.67	H_a is accepted and H_0 is rejected

Based on Table 8, The t-test results at a 0.05 significance level indicate that $t_{count} > t_{table}$, so H_0 is rejected and H_a is accepted. This means that, with a 95% confidence level, there is an effect of the WEE model assisted by PhET on students' cognitive learning outcomes on the topic of global warming in grade X of SMA Negeri 9 Tasikmalaya in the 2023/2024 academic year. The data also shows a difference in the average cognitive ability scores of students, where the group that received the treatment had higher posttest scores. A complete comparison is presented in Figure 1.

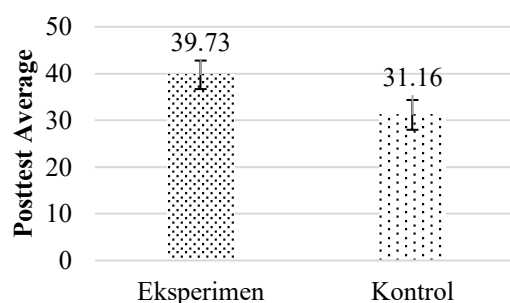


Figure 1. Average posttest scores of cognitive learning outcomes

The assessment of students' cognitive abilities is based on the average percentage score of the posttest from nine essay questions that measure cognitive domain indicators. The categories of cognitive abilities are determined based on the revised Bloom's taxonomy according to Nafiati (2021). The assessment results are presented in Table 9.

Table 9. Posttest score percentage per indicator of cognitive learning outcomes

No	Indicator	Experimental Class		Control Class	
		Percentage (%)	Category	Percentage (%)	Category
1	Understanding (C2)	92	Very Good	72	Good
2	Applying (C3)	87	Very Good	68	Good
3	Analyzing (C4)	82	Very Good	64	Good
Average		87	Very Good	68	Good

Based on the analysis of the posttest results on Table 9. It shows that students' learning outcomes in the experimental class using the WEE model assisted by PhET fall into the very good category. While in the control class with direct learning assisted by PhET, they are in the good category for all indicators. The highest percentage in the experimental class is found in the understanding indicator (C2), which is 92%. This is influenced by the wondering stage in the WEE model, which helps students understand the basic concepts of global warming, such as the greenhouse effect mechanism, the role of greenhouse gases in increasing the Earth's temperature, and their impact on the environment. This stage also fosters students' curiosity through questions that guide them toward a deeper understanding. This stage is effective in strengthening students' comprehension, as supported by Atma (2024) and Haryati et al., (2021) who stated that questioning skills and curiosity can enhance students' abilities at the C2 level. This ability is also reinforced through the explaining stage, where students present the results of experiments and receive clarification from the teacher.

At the cognitive level of applying (C3), the percentage of student learning outcomes in the experimental class reached 87%. This is supported by the exploring stage in the WEE model, where students apply the concept of global warming through a greenhouse effect simulation on PhET. This activity helps students understand the relationships between factors directly and connect theory with practice. Research by Haryati et al., (2021) also shows that practical activities provide students with the opportunity to apply theory in real contexts. Additionally, a study by Ika et al., (2021)

indicates that the use of PhET virtual laboratory simulations can significantly improve student learning outcomes. with average post-test scores increasing from 67 to 79 on molecular geometry material. Another study also supports this finding. showing that the PhET application is effective in enhancing students' cognitive learning outcomes on the topics of traveling waves and stationary waves. Although the percentage of C3 is slightly lower than C2. The exploring stage still contributes greatly to the ability to apply concepts.

At the cognitive level of analyzing (C4), the percentage of student learning outcomes was 82%. the lowest compared to other levels. The exploring stage in the WEE model also trains students to analyze data and phenomena during experiments. According to research by Atika & Nora. (2023), analytical skills are important for problem-solving. However, some students experienced difficulties in observing and analyzing phenomena in the PhET simulation, resulting in shallow analysis. This affects cognitive achievement at the C4 level. although it still falls into the very good category.

Overall, the Wondering, Exploring, Explaining (WEE) learning model assisted by PhET has been proven effective in improving students' cognitive learning outcomes. although the success rate varies at each cognitive level. This difference occurs because the higher the cognitive level, such as in the aspect of analyzing (C4). the greater the demand on students' thinking abilities. This aligns with the opinion of Akbar et al.. (2024), who stated that C4 is a more complex cognitive level because it requires analysis and understanding of the relationships between concepts. Therefore, to optimize students' analytical abilities. Teachers are advised to design practical activities that are more in-depth and structured. Practicals should not only focus on technical skills but also encourage students to think critically. understand the connection between theory and practice. and be able to draw conclusions based on the data obtained.

The findings of this study are also reinforced by various previous studies that demonstrate the effectiveness of PhET simulations in enhancing students' cognitive abilities. Research by Tusoy & Baraquia (2025) showed that the use of PhET simulations in teaching force and motion can improve students' cognitive scores from 1.51 (initial understanding level) to 3.64 (relational level) based on the SOLO taxonomy. Similar results were also obtained by Banda & Nzabahimana (2021) who found that PhET is effective in improving students' conceptual understanding of oscillation and wave materials. In addition, the study by Purwaningsih et al.. (2023) emphasizes that PhET simulations help learners understand abstract concepts through engaging visualization and interactivity. Whereas Rohmawati et al.. (2023) showed that the integration of PhET simulation media in problem-based learning positively affects students' critical thinking skills. Thus, the implementation of the WEE learning model assisted by PhET can be considered an effective strategy to improve students' cognitive learning outcomes. especially on material that requires higher-order analytical skills.

The research results indicate that external factors, such as the use of learning models, the learning media used, and the learning environment, influence students' learning outcomes. This information was obtained through the analysis of cognitive test results. observation of student activities and comparison between the experimental class and the control class. The WEE model assisted by PhET has been proven to improve students' learning outcomes on the topic of global warming in Grade X at SMA Negeri 9 Tasikmalaya. This model encourages students to express opinions, observe, experiment, analyze, and present findings independently. Each stage in the WEE model reinforces the understanding of the concepts being studied,

as reflected in the average posttest scores and the scores of each cognitive level in the experimental class being higher than those in the control class. Thus, it can be concluded that the WEE learning model assisted by PhET has a positive effect on students' cognitive learning outcomes in global warming material.

CONCLUSION

Based on the research results, the PhET-assisted WEE model has a positive effect on students' cognitive learning outcomes in the subject of global warming. The positive impact, seen from the students' learning outcome data, is in the form of posttest scores after students participated in learning using the PhET-assisted WEE model. The application of the WEE model combined with virtual practicum has been proven effective in improving students' understanding and cognitive abilities. This research is limited to the topics of global warming and the use of virtual laboratories. Therefore, future research is recommended to combine the WEE model with hands-on laboratory practice to compare the effectiveness of virtual and real laboratories in enhancing students' cognitive abilities. In addition, during the exploring stage, laboratory activities should be presented in a more in-depth and structured manner to better optimize higher-order cognitive skills (C4).

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