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OPTIMIZING STUDENTS' CRITICAL THINKING SKILLS THROUGH PHET SIMULATION-BASED PROBLEM-BASED LEARNING MODEL

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Abstract

This research is motivated by the low level of students' critical thinking skills in Natural Science learning, which stems from students' lack of activity and the implementation of teaching models that do not emphasize critical thinking skills. This study aims to determine the difference in critical thinking skills between the experimental class, which utilized the PhET simulation-aided Problem-Based Learning (PBL) model, and the control class, which utilized the Cooperative Learning model. Furthermore, it aims to analyze the difference in the improvement of critical thinking skills between the two groups. This research adopts a quantitative approach with a quasi-experimental research type and a non-equivalent control group design. The subjects of this study were sixth-grade students at SD Negeri 1 Cimaranten. Data were collected using a test instrument consisting of 6 essay questions. Based on the results, it can be concluded that: (1) there is a significant difference in critical thinking skills between the experimental class using the PhET simulation-aided PBL model and the control class using the Cooperative Learning model; (2) there is a significant difference in the improvement of critical thinking skills between the experimental class and the control class.

Keywords: *Critical Thinking Skills, Problem Based Learning Model Assisted by Multimedia PhET Simulation, Natural Sciences*

Abstrak

Penelitian ini dilatar belakangi rendahnya keterampilan berpikir kritis siswa dalam pembelajaran muatan Ilmu Pengetahuan Alam karena siswa tidak aktif dalam pembelajaran dan model pembelajaran yang diterapkan guru tidak menekankan pada keterampilan berpikir kritis. Penelitian ini bertujuan untuk mengetahui perbedaan keterampilan berpikir kritis siswa kelas eksperimen yang menggunakan model *problem based learning* berbantuan multimedia PhET simulation dengan kelas kontrol yang menggunakan model *cooperatif learning* dan untuk mengetahui perbedaan peningkatan keterampilan berpikir kritis siswa kelas eksperimen yang menggunakan model *problem based learning* berbantuan multimedia PhET simulation dengan kelas kontrol yang menggunakan model *cooperatif learning*. Penelitian ini menggunakan pendekatan metode kuantitatif, jenis penelitian quasi eksperimental, desain *non-equivalent control group*. Variabel penelitian ini siswa kelas VI SD Negeri 1 Cimaranten. Pengumpulan data berupa soal essay sebanyak 6 soal. Berdasarkan hasil penelitian dapat disimpulkan bahwa: (1) terdapat perbedaan keterampilan berpikir kritis siswa kelas eksperimen yang menggunakan model *problem based learning* berbantuan multimedia PhET simulation dengan kelas kontrol yang menggunakan model *cooperatif learning*, (2) terdapat perbedaan peningkatan keterampilan berpikir kritis siswa kelas eksperimen yang menggunakan model *problem based learning* berbantuan multimedia PhET simulation dengan kelas kontrol yang menggunakan model *cooperatif learning*.

Kata Kunci: Keterampilan Berpikir Kritis, Model Problem Based Learning Berbantuan Multimedia PhET Simulation, Ilmu Pengetahuan Alam

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INTRODUCTION

Education plays a vital role in the development of a nation. The quality of a country's education is influenced by several factors, such as educators, learning resources, and learning facilities. Teachers hold a crucial role in helping to improve the quality of learning within the classroom. In enhancing teaching quality, teachers need to implement innovative and creative measures in the classroom (Istiqomah & Indarini, 2021: 679).

According to Kusumaningrum (2018: 59), Natural Science (IPA) is a field of study that examines nature, specifically everything contained within the universe and the events occurring within it. The study of natural science is essential because all human activities are closely related to nature. Since human life depends on the environment, Natural Science is taught as a subject from the elementary to high school levels. Furthermore, Wedyawati & Lisa (2019: 156) state that Natural Science is an empirical science that discusses natural facts and phenomena. These facts and phenomena ensure that science learning is not merely verbal but also factual. The essence of science as a process is expected to create empirical and factual learning experiences. It can be argued that the improvement of a nation's educational quality is directly proportional to its society's thinking culture, including high-level thinking skills (Yasiro et al., 2021: 71).

Critical thinking, as one aspect of higher-order thinking, is a process of searching, generating, analyzing, gathering, and conceptualizing information as a reference with self-awareness and the ability to enhance creativity (Putri et al., 2021: 81). Critical thinking is required to solve problems, making critical thinking skills essential in decision-making. As a component of higher-order thinking, it plays a significant role in the learning process, particularly in Natural Science (IPA). Natural Science is concerned with the systematic discovery of natural phenomena. It is not merely the mastery of a body of knowledge consisting of facts, concepts, or principles, but also a process of discovery (Rahayu et al., 2018: 115). Natural Science serves as a vehicle for students to learn about themselves and their surroundings, as well as the prospects for further application in daily life (Fahmi et al., 2021: 87).

The correlation of critical thinking in Natural Science (IPA) learning lies in the necessity to prepare students to become resilient problem solvers, mature decision-makers, and lifelong learners (Fahmi, 2020: 27). As part of the national education process, Natural Science learning should be implemented through scientific inquiry to foster the ability to think, work, and behave scientifically, as well as to communicate these as essential aspects of life skills (Depdiknas, 2006). Therefore, critical thinking is an inseparable element in every transformation carried out within science-literate material. Success in Natural Science learning can be evaluated through the teacher's creativity in utilizing models or methods applied during the teaching process, particularly in making the science curriculum more engaging.

Based on observations conducted on November 20, 2023, in Grade VI of SD Negeri 1 Cimaranten, it was identified that there are challenges in improving students' critical thinking skills. The issues occurring in the classroom include the fact that although the teacher has utilized various learning models, including the implementation of the Problem-Based Learning

(PBL) model, the observations indicate that the teacher has not yet been fully able to train and emphasize critical thinking skills in students. From another perspective, student engagement during the learning process remains suboptimal; students pay insufficient attention to the teacher during lessons and lack the confidence to ask questions.
"Furthermore, the learning process remains teacher-centered, resulting in a monotonous classroom atmosphere where students become passive and fail to develop their own thinking. Consequently, when the teacher poses a question, only a few students respond. Most students remain silent and fail to provide the expected answers regarding a topic, all of which are aspects or indicators of critical thinking skills.
Moreover, the teacher rarely, or even never, utilizes media or teaching aids, partly due to time inefficiency. Furthermore, the media provided by the school remains very limited, while the learning tools and resources used by the teacher are restricted to textbooks and student worksheets (LKS). This naturally impacts students' achievement in understanding Natural Science (IPA). Therefore, a learning model and media are required to overcome these challenges, specifically by implementing Problem-Based Learning (PBL) assisted by multimedia.

Based on these observations, it can be concluded that the current teaching and learning activities in Natural Science for Grade VI at SD Negeri 1 Cimaranten lack emphasis on skill development, particularly critical thinking skills. This is due to the teacher-centered nature of the learning process. Consequently, it can be stated that the critical thinking skills of students in grades VI A and VI B at SD Negeri 1 Cimaranten, specifically in Natural Science, remain low. Below is the table of students' critical thinking skills in Natural Science for grades VI A and VI B at SD Negeri 1 Cimaranten:

Table 1. The Percentage of Students' Critical Thinking Skills in Grade VI A and VI B at SD Negeri 1 Cimaranten Academic Year 2023/2024

No	Critical Thinking Indicators	Observed	Percentage Observed	Not Yet Observed	Percentage Not Yet Observed
		VI A	VI B	VI A	VI B
1.	Providing elementary clarification	9	8	35%	45%
2.	Building basic skills	8	9	30%	50%
3.	Making inferences (Concluding)	9	7	50%	40%
4.	Providing further clarification	8	8	30%	45%
5.	Strategies and tactics	8	7	30%	40%

Based on the data table above, the criteria for low critical thinking skills are in the interval of 0% - 59%, while the criteria for moderate are in the interval of 60% - 79%, and the criteria for high are in the interval of 80% - 100% (Astari and Sumarni, 2020: 4). Based on Table 1.1 above, it can be concluded that the critical thinking skills of students in Grade VI A and Grade VI B at SD Negeri 1 Cimaranten in Natural Science (IPA) content are still categorized as low or have not met the criteria. This is because the percentage of students demonstrating observed critical

thinking skills is below 60%, thus classified as low. For this reason, an effort is needed. The researcher chose a learning method that can assist students in improving their critical thinking skills by using the Problem-Based Learning Model Assisted by PhET Simulation Multimedia.

This aligns with Mcelhaney et al. (2015: 55) who stated that: 'Dynamic visualisations can help students link multiple representations. Dynamic visualisations enable students to conduct virtual experiments about complex situations and can include various supports for experimentation such as providing records of trials'. Thus, the use of the Problem-Based Learning model assisted by PhET Simulations as interactive media can connect students' ideas with real life situations encountered daily by presenting science phenomena found in PhET Simulations. This indicates that using the Problem-Based Learning model assisted by PhET Simulations can increase the effectiveness of Natural Science learning. The implementation of the PhET Simulations-aided Problem-Based Learning model is an alternative in science learning that can create student-centered learning and actively engage students constructively; it is engaging and easy to implement, thereby facilitating student comprehension (Ekawati, 2021: 109).

This opinion is reinforced by previous research findings that can enhance learning. Among them, research conducted by Muzana, S. et al. (2021: 230) proved that the use of PhET simulations on the effectiveness of science learning can improve the quality of Natural Science education in Class X of SMA Muhammadiyah Limbung. Furthermore, research conducted by Pujiningsih, A. L. M. et al. (2022: 104) demonstrated an improvement in Natural Science learning through the use of PhET simulations. Therefore, the problem-based learning model assisted by virtual laboratory learning media is a learning model and media that engages students to be active in learning and is expected to be of interest to students and influence their critical thinking skills.

METHOD

The method used in this research is a quantitative method. This research method employs a quantitative approach because the data to be processed are ratio data, and the focus of this study is to determine the extent of the influence between the variables being investigated. According to Sugiyono (2019: 17), the quantitative research method can be defined as a research method based on the philosophy of positivism, used for researching specific populations or samples. Data collection uses research instruments, data analysis is quantitative/statistical, with the aim of testing predetermined hypotheses.

The type of research used in this study is experimental research. According to Sugiyono (2019: 111), the experimental research method is a research method conducted through experimentation, which is a quantitative method used to determine the effect of independent variables (treatment) on dependent variables (outcome) under controlled conditions. The specific type of experimental research method employed in this study is quasi-experimental.
This research design uses a Non-equivalent Control Group Design, which is almost the same as the pre-test – post-test control group design, except that in this design, the control group is

not selected randomly (Sugiyono, 2019: 116). The research design table according to Sugiyono is as follows:

Table 2. Non-equivalent Control Group Design Plan

Group	Pre-test	Treatment	Post-test
Experiment	O1	X1	O2
Control	O3	X2	O4

(Sugiyono, 2019:116)

Notes:
X1: Learning using the Problem-Based Learning model Assisted by PhET Simulation Multimedia
X2: Learning using the Cooperative Learning model
O1: Pre-test for the experimental group
O2: Post-test for the experimental group
O3: Pre-test for the control group
O4: Post-test for the control group

In this research design, the study was conducted in two classes: the experimental group and the control group. The initial step involved administering a pre-test to both groups. After the pre-test, the researcher applied treatments to the students; the experimental group (Grade VI A) was taught using the Problem-Based Learning model assisted by PhET Simulation multimedia, while the control group (Grade VI B) was taught using the Cooperative Learning model. Finally, a post-test was administered to both groups to obtain data on the students' critical thinking skills.

The population used in this study consists of all students in grades VI A and VI B at SD Negeri 1 Cimaranten during the second semester of the 2023/2024 academic year. This study sampled all sixth-grade students at SD Negeri 1 Cimaranten, consisting of two classes: class VI A as the experimental group, with 27 students (17 females and 10 males), and class VI B as the control group, with 24 students (18 females and 6 males). Thus, the total number of participants from classes VI A and VI B is 51 students.

This study employs a written test instrument in the form of a subjective essay consisting of 12 questions, divided into 6 pre-test questions and 6 post-test questions. The test was administered twice: as a pre-test and a post-test. The instrument was validated (tried out) at a different school, specifically in Grade VI of SD Negeri 1 Mekarwangi.
The purpose of this test is to determine the comparison of students' critical thinking skills before and after the treatment. Prior to administration, the instrument was validated. The test covers five indicators of critical thinking skills according to Ennis (in Supriyati, 2022: 75). The blueprint for the critical thinking skills test instrument is presented in the following table.

Table 3. Blueprint of the Critical Thinking Skills Test Instrument

Basic Competency	Item Indicator	Critical Thinking Indicator	Test Form	Cognitive Domain (C4, C5, C6)	Item Number
3.4 Identify electrical components and their functions in simple electrical circuits	Analyze simple electrical circuits	Elementary clarification	Essay	C4	1, 2
	Create simple electrical circuits	Building basic skills (Basic support)	Essay	C6	4, 5, 15
	Conclude from statements regarding simple electrical circuits	Inference (Concluding)	Essay	C5	3, 8, 9, 10, 13, 14
4.4 Conduct experiments on simple series and parallel electrical circuits	Select facts on the application of series and parallel circuit properties in daily life	Further clarification (Advance clarification)	Essay	C4	11, 12
	Plan strategies in an event regarding simple series and parallel electrical circuits	Strategies and tactics	Essay	C6	7, 6
Total Items					**15**

Source: Ennis (in Supriyati, 2022:75)

Table 4. Scoring Rubric for Critical Thinking Skills

Item No.	Description	Score	Category
1.	Students can analyze images of simple electrical circuit components and state the functions of the battery and switch accurately and completely.	4	Very Good
	Students can analyze the components but only state one of the functions.	3	Good
	Students analyze the components but the explanation is incomplete or only partially fulfilled.	2	Fair

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	Students cannot analyze the components; provides an answer but the explanation is incorrect.	1	Poor
	Student does not write an answer or the answer sheet is blank.	0	Very Poor
2.	Students can analyze the concept of a lamp and state its function accurately and completely.	4	Very Good
	Students analyze the lamp's function but the explanation is less accurate.	3	Good
	Students analyze the lamp's function but it is only partially fulfilled and incomplete.	2	Fair
	Students provide an answer but the explanation of the lamp's function is incorrect.	1	Poor
	Student does not write an answer or the answer sheet is blank.	0	Very Poor
3.	Students can infer from images of parallel circuit objects and conclude the characteristics of parallel circuits accurately and completely.	4	Very Good
	Students infer the characteristics but only mention one characteristic.	3	Good
	Students infer the characteristics but the answer is still incorrect and incomplete.	2	Fair
	Students provide an answer but the explanation of the characteristics is incorrect.	1	Poor
	Blank answer.	0	Very Poor
4.	Students can design a series circuit and describe its arrangement accurately and correctly.	4	Very Good
	Students design the circuit but the explanation of the arrangement is less accurate.	3	Good
	Students design the circuit but the explanation is only partially fulfilled and incomplete.	2	Fair
	Students provide an answer but the explanation of the design/arrangement is incorrect.	1	Poor

	Blank answer.	0	Very Poor
5.	Students can accurately and completely describe how a parallel electrical circuit works.	4	Very Good
	Students describe the process but the explanation is less accurate.	3	Good
	Students describe the process but it is only partially fulfilled and incomplete.	2	Fair
	Students provide an incorrect explanation of the circuit's operation.	1	Poor
	Blank answer.	0	Very Poor
6.	Students can plan a statement and accurately state ways to conserve electricity.	4	Very Good
	Students plan the statement but the explanation of conservation is less accurate.	3	Good
	Students plan the statement but the explanation is only partially fulfilled.	2	Fair
	Students provide an incorrect answer regarding electricity conservation.	1	Poor
	Blank answer.	0	Very Poor
7.	Students can plan a statement and accurately state methods for turning off lamps or electrical appliances.	4	Very Good
	Students plan the statement but the explanation is less accurate.	3	Good
	Students plan the statement but the explanation is only partially fulfilled.	2	Fair
	Students provide an incorrect explanation of how to turn off the appliances.	1	Poor
	Blank answer.	0	Very Poor
8.	Students can accurately and completely infer the definition of a series circuit from a text.	4	Very Good

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	Students infer the definition but the explanation is less accurate.	3	Good
	Students infer the definition but it is only partially fulfilled and incomplete.	2	Fair
	Students provide an incorrect inference of the series circuit text.	1	Poor
	Blank answer.	0	Very Poor
9.	Students can infer from images of series circuit objects and conclude the characteristics accurately and completely.	4	Very Good
	Students infer the characteristics but only mention one specific trait.	3	Good
	Students infer but the results are still incorrect or incomplete.	2	Fair

The procedures of this study involve several prerequisite tests to ensure the instrument is valid for research use. (1) Validity Test: he validity test was conducted using the Product Moment correlation formula to determine the relationship between two variables (phenomena) measured on an interval scale (a scale that utilizes actual numerical values). Testing was conducted using a two-tailed test with a significance level of 0.05, and the results were compared with the rtable. Kriteria The testing criteria are: if $r_{\text{calculated}} \geq r_{table}$ the item is categorized as valid. Conversely, if $r_{calculated} \leq r_{table}$ then the item is declared invalid.

Based on the validity testing of the instrument items using the Product Moment correlation formula, the calculations are detailed in the appendix. The recapitulation of the validity test results for the instrument validity calculations, the trial data consisted of 15 items tested on 24 students, resulting in 12 valid items and 3 invalid items. (2) The reliability test aims to determine the consistency of the variable's measurement results in measuring the same phenomenon. Based on the reliability calculations, an overall reliability value of 0.83 was obtained, which falls into the very high reliability category. Therefore, this instrument is deemed suitable for use in this study, to be applied in both the experimental and control classes.

This study employs quantitative data analysis techniques using statistics. Once the data is collected, the next stage involves processing the data obtained from the research results. The type of data acquired from the study is quantitative interval data. Meanwhile, the data analysis utilized is parametric statistical testing.

(1) A normality test is a procedure used to determine whether the regression model follows a normal distribution or not. This is crucial because if the data for each variable is not normally distributed, the hypothesis testing cannot utilize parametric statistics (Sugiyono, 2019: 153). In this study, the researcher employs the Chi-Square normality test. Determining the Chi-Square value from the distribution table. Comparing $X^2_{\text{calculated}}$ with X^2_{table}.

If $X^2_{\text{calculated}} \leq X^2_{table}$ at the 0.95 confidence level (df), the data is declared normal. Subsequent calculations will proceed using the test of equality of means (t-test).
If $X^2_{\text{calculated}} \geq X^2_{table}$ at the 0.95 confidence level (df), the data is declared not normal. Subsequent calculations will utilize non-parametric statistics, specifically the Wilcoxon test.

(2) A homogeneity test is a test used to determine whether the data distribution from two or more variants originates from a homogeneous population, specifically by comparing two or more of their variances (Riadi, 2014: 101). Determining homogeneity:

If $F_{\text{calculated}} \leq F_{table}$ at the 0.95 confidence level (df), then both variances are declared homogeneous. Subsequent calculations will utilize the test of equality of means (t-test).
If $X^2_{\text{calculated}} \geq X^2_{table}$ at the 0.95 confidence level (df), then both variances are declared non-homogeneous. Subsequent calculations will utilize the test of equality of means (t-test).

(3) Hypothesis testing is a procedure conducted to statistically verify the truth of a statement and to draw a conclusion regarding the acceptance or rejection of that statement (Arifin, 2017: 17). Hypothesis testing is performed to assist in making accurate decisions regarding a proposed hypothesis. It utilizes equality and means to test two data averages, in this case, between the experimental group and the control group. The rules for hypothesis testing are as follows: If t_{table} 0,975 *(db)* $\leq t_{\text{calculated}} \leq t_{table}$ 0,975 *(db)*, then the hypothesis is accepted.
(4) N-Gain is a test that provides a general overview of the improvement in learning outcome scores between before and after the implementation of a specific treatment (Hake in Sundayana, 2014: 151). The results of the calculations are then interpreted using the N-Gain criteria as follows:

Table 5. N-Gain Criteria

Range	**Category**
N − Gain ≥ 0, 70	Tinggi
0,30 ≤ N − Gain < 0,70	Sedang
N − Gain < 0, 30	Rendah

RESULTS AND DISCUSSION

Results

The pre-test results for the experimental group, comprising 27 students, showed a total score of 1,401, with a mean of 51.88, a maximum score of 70, a minimum score of 33, and a standard deviation of 9.96. Meanwhile, the control group, consisting of 24 students, achieved a total score of 1,241, a mean of 51.50, a maximum score of 66, a minimum score of 37, and a standard deviation of 7.37. Thus, both the experimental and control groups possess similar average scores and exhibit relatively equivalent initial abilities.

The post-test results for the experimental group, comprising 27 students, showed a total score of 2,123, with a mean of 78.62, a maximum score of 95, a minimum score of 58, and a standard deviation of 11.40. Meanwhile, the control group, consisting of 24 students, achieved a total score of 1,652, with a mean of 68.83, a maximum score of 83, a minimum score of 54, and a standard deviation of 7.91. This demonstrates that the post-test results following the treatment exhibit different averages and varying levels of critical thinking skills.

The results of the normality testing for the pre-test data from the experimental and control groups are as follows:

Table 6. Normality Test of Pre-test Data for Experimental and Control Groups

Statistics	***Pre-test***	
	Experimental Group	**Control Group**
Means	51,88	51,50
Standard Deviation	9,96	7,37
$X^2_{calculated}$	4,5573	1,3982
X^2_{table}	7,81472	7,81472
Description	4,5573 ≤ 7,81472	1,3982 ≤ 7,81472
Conclusion	Normally Distributed	Normally Distributed

The normality test results for the pre-test data in the experimental group yielded an $X^2_{\text{calculated}}$ value of 4,5573 with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7,81472. Consequently, it can be concluded that the pre-test normality test for the experimental group is declared normally distributed, as $X^2_{\text{calculated}} \leq X^2_{table}$. The normality test results for the pre-test data in the control group yielded an $X^2_{\text{calculated}}$ value of 1.3982, with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7.81472. Consequently, it can be concluded that the pre-test normality test for the control group is declared normally distributed because as $X^2_{\text{calculated}} \leq X^2_{table}$.

The results of the normality testing for the post-test data from the experimental and control groups are as follows:

Table 7. Normality Test of Post-test Data for Experimental and Control Groups

Statistics	***Pre-test***	
	Experimental Group	**Control Group**
Means	78,62	68,83
Standard Deviation	11,40	7,91
$X^2_{calculated}$	4,7803	2,2293
X^2_{table}	7,81472	7,81472
Description	4,7803 ≤ 7,81472	4,7803 ≤ 7,81472
Conclusion	Normally Distributed	Normally Distributed

The normality test results for the post-test data in the experimental group yielded an $X^2_{\text{calculated}}$ value of 4,7803 with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7,81472. Consequently, it can be concluded that the post-test normality test for the experimental group is declared normally distributed, as $X^2_{\text{calculated}} \leq X^2_{table}$. The normality test results for the pre-test data in the control group yielded an $X^2_{\text{calculated}}$ value of 2,2293, with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7.81472. Consequently, it can be concluded that the post-test normality test for the control group is declared normally distributed because as $X^2_{\text{calculated}} \leq X^2_{table}$.

The results of the homogeneity testing for the pre-test data from the experimental and control groups are as follows:

Table 8. Homogeneity Test of Pre-test Data for Experimental and Control Groups

Statistics	***Pre-test***	
	Eksperimental Group	**Control Group**
Variance	99,25	54,34
$F_{\text{calculated}}$	1,826	
F_{table}	4,038	
n1	27	
n2	24	
Description	Homogeneous	

Based on the results of the homogeneity test using the F-test, it was found that $F_{\text{calculated}}$ is less than or equal to $\leq F_{\text{table}}$ The calculation results for the pre-test homogeneity of the experimental and control groups yielded an $F_{\text{calculated}}$ value of 1.826, which is less than or equal to ≤ the F_{table} value of 4.038. Therefore, it can be stated that the variances of the pre-test data for both the experimental and control groups are homogeneous.

The results of the homogeneity testing for the post-test data from the experimental and control groups are as follows:

Table 9. Homogeneity Test of Post-test Data for Experimental and Control Groups

Statistics	***Post-test***	
	Eksperimental Group	**Control Group**
Variance	130,38	62,63
$F_{\text{calculated}}$	2,081	
F_{table}	4,038	
n1	27	
n2	24	
Description	Homogeneous	

Based on the results of the homogeneity test using the F-test, it was found that $F_{\text{calculated}}$ is less than or equal to $\leq F_{\text{table}}$ The calculation results for the post-test homogeneity of the experimental and control groups yielded an $F_{\text{calculated}}$ value of 2.081, which is less than or equal to ≤ the F_{table}

value of 4.038. Therefore, it can be stated that the variances of the post-test data for both the experimental and control groups are homogeneous.

The results of the hypothesis testing or t-test are as follows:

Table 10. Hypothesis t-Test

$T_{calculated}$	T_{table}
3,599	2,000

The t-test results for the final assessment or post-test yielded a $t_{calculated}$ value of 3.599, which is greater than or equal to ≥ the t_{table} value of 2.000. It can be concluded that there is a significant difference in students' critical thinking skills between those who were taught using the PhET Simulation-aided Problem-Based Learning model and the students in the control class who were taught using the Cooperative Learning model after the treatment.

The results of the N-Gain testing in this study are as follows:

Table 11. N-Gain Data for Experimental and Control Groups

No	Group	*Pre-test*	*Post-test*	N-Gain	Criteria
1	Experimental	51,88	78,62	0,558	Moderate
2	Control	51,70	68,83	0,2902	Low

The N-Gain calculation results for the experimental class yielded a value of 0.558. This indicates that the students' critical thinking skills in the experimental class improved, falling into the 'moderate' category. Meanwhile, the N-Gain calculation for the control class resulted in a value of 0.2902. This shows that although there was an improvement in students' critical thinking skills in the control class, it remained within the 'low' category. Based on the N-Gain calculation table for the experimental and control groups, the results can be illustrated in the histogram below:

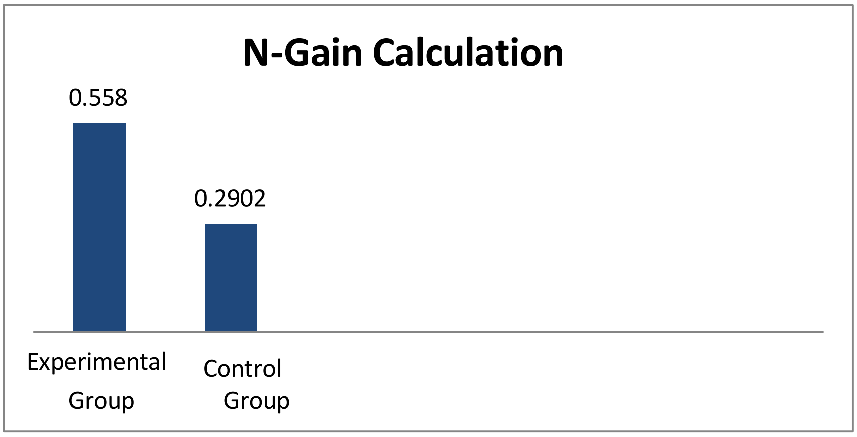

Figure 1. Average N-Gain Diagram

Based on Figure 1, it can be explained that there was an improvement in the experimental group, which was treated with the PhET Simulation-aided Problem-Based Learning model, achieving a value of 0.558. Meanwhile, the control group obtained an improvement of 0.2902. Therefore, it can be concluded that the N-Gain value in the experimental group is higher than the N-Gain value in the control group.

Discussion

The frequency distribution of pre-test scores for the experimental group is as follows: 3 students in the 30–36 range, 2 students in the 37–43 range, 8 students in the 44–50 range, 8 students in the 51–57 range, 3 students in the 58–64 range, and 3 students in the 65–71 range. The frequency distribution of pre-test scores for the control group is as follows: 2 students in the 37–41 range, 5 students in the 42–46 range, 5 students in the 47–51 range, 5 students in the 52–56 range, 5 students in the 57–61 range, and 2 students in the 62–66 range.

The frequency distribution of post-test scores for the experimental group is as follows: 3 students in the 55–61 range, 3 students in the 62–68 range, 7 students in the 69–75 range, 4 students in the 76–82 range, 5 students in the 83–89 range, and 5 students in the 90–96 range. The frequency distribution of post-test scores for the control group is as follows: 3 students in the 54–59 range, 3 students in the 60–64 range, 5 students in the 65–69 range, 5 students in the 70–74 range, 5 students in the 75–79 range, and 3 students in the 80–84 range. It can be concluded that the pre-test scores for both the experimental and control groups showed averages that were not significantly different, indicating relatively equivalent initial abilities. However, after the treatment was administered and data were generated for both groups, the post-test results revealed a significant difference in average scores and distinct levels of critical thinking skills.

The normality test results for the pre-test data in the experimental group yielded an $X^2_{\text{calculated}}$ value of 4,5573 with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7,81472. Consequently, it can be concluded that the pre-test normality test for the experimental group is declared normally distributed, as $X^2_{\text{calculated}} \leq X^2_{table}$. The normality test results for the pre-test data in the control group yielded an $X^2_{\text{calculated}}$ value of 1.3982, with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7.81472. Consequently, it can be concluded that the pre-test normality test for the control group is declared normally distributed because as $X^2_{\text{calculated}} \leq X^2_{table}$.
The normality test results for the post-test data in the experimental group yielded an $X^2_{\text{calculated}}$ value of 4,7803 with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7,81472. Consequently, it can be concluded that the post-test normality test for the experimental group is declared normally distributed, as $X^2_{\text{calculated}} \leq X^2_{table}$. The normality test results for the pre-test data in the control group yielded an $X^2_{\text{calculated}}$ value of 2,2293, with a 95% confidence level and 3 degrees of freedom (df). This resulted in an X^2_{table} velue of 7.81472. Consequently, it can be concluded that the post-test normality test for the control group is declared normally distributed because as $X^2_{\text{calculated}} \leq X^2_{table}$.
The results of the homogeneity test using the F-test, it was found that Fcalculated is less than or equal to ≤ Ftable The calculation results for the pre-test homogeneity of the experimental and control groups yielded an Fcalculated value of 1.826, which is less than or equal to ≤ the Ftable value of 4.038. Therefore, it can be stated that the variances of the pre-test data for both the experimental and control groups are homogeneous.
The results of the homogeneity test using the F-test, it was found that Fcalculated is less than or equal to ≤ Ftable The calculation results for the post-test homogeneity of the experimental and control groups yielded an Fcalculated value of 2.081, which is less than or equal to ≤ the

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Ftable value of 4.038. Therefore, it can be stated that the variances of the post-test data for both the experimental and control groups are homogeneous.

The t-test results for the final assessment or post-test yielded a tcalculated value of 3.599, which is greater than or equal to ≥ the ttable value of 2.000. It can be concluded that there is a significant difference in students' critical thinking skills between those who were taught using the PhET Simulation-aided Problem-Based Learning model and the students in the control class who were taught using the Cooperative Learning model after the treatment.

The N-Gain calculation results for the experimental class yielded a value of 0.558. This indicates that the students' critical thinking skills in the experimental class improved, falling into the 'moderate' category. Meanwhile, the N-Gain calculation for the control class resulted in a value of 0.2902. This shows that although there was an improvement in students' critical thinking skills in the control class, it remained within the 'low' category.

This is reinforced by the results of previous studies that have demonstrated an enhancement in learning. Among them, a study conducted by Muna, K. A., et al. (2023: 6) proves that the use of PhET simulations in Natural Science learning, specifically on Newton's Laws, led to an improvement. The data analysis of that study indicates a significant difference in learning outcomes between class VIII E (treatment group) and the control group. Based on the pre-test data, no students exceeded the Minimum Mastery Criterion (KKM), whereas the post-test results for both groups surpassed the KKM. The post-test score for the Experimental group was 84.33%, while the Control group's post-test score was 79.10%. Furthermore, the N-Gain calculation showed an average percentage of 63.12%, which, according to the N-Gain criteria (> 56), is categorized as 'moderately effective.

Furthermore, research conducted by Sumiyati et al. (2021: 3) demonstrates that their study shows a distinct influence on students' science learning outcomes. Descriptively, students' science learning outcomes after the experiment were higher than before the experiment. This review is based on the average science learning scores and the trends in students' science achievement. The mean score for science learning after the experiment was 80.75, whereas the mean score before the experiment was 59.5. Based on inferential data analysis using the pooled variance t-test, the calculated t-value ($tcount$) was 10.858, while the t-table at a 5% significance level and df= 38 was 2.02. These results indicate that the calculated t-value is greater than the t-table value ($t_{count} \geq t_{table}$) rendering the research findings significant. Thus, the significant difference indicates that the implementation of the Blended Learning Model integrated with PhET Simulation media has a positive effect on students' science learning outcomes.

CONCLUSION

Based on the research findings and hypothesis testing in this study, it can be concluded that there is a difference in the critical thinking skills of students in the experimental group (using the PhET Simulation-aided Problem-Based Learning model) compared to the control group (using the Cooperative Learning model) after the treatment. However, there is no difference in the critical thinking skills of students between the experimental group using the PhET Simulation-aided Problem-Based Learning model and the control group using the Cooperative Learning model after the treatment.

REFERENCES

Arifin, Z. (2017). *Evaluasi Pembelajaran. Bandung*: PT Remaja Rosdakarya.

Depdiknas. (2006). *Kurikulum Tingkat Satuan Pendidikan Sekolah Dasar Mata Pelajaran IPA SD/MI*. Jakarta: Depdiknas.

Ekawati, Y., Haris, A., & Amin, B. (2021). Penerapan Media Simulasi Menggunakan PHET (Physics Education And Technology) Terhadap Hasil Belajar Fisika Peserta Didik Kelas X SMA Muhammadiyah Limbung. *Jurnal Pendidikan Fisika Unismuh*, 3(1), 121393.

Fahmi, F., Fajeriadi, H., & Irhasyuarna, Y. (2021). Empowering of the As a Resource of Leaning Materials on the Topic of Classification of Lifestyle Based on the Advantage of Local Wetland. *BIO-INOVED: Jurnal Biologi- Inovasi Pendidikan, 3(2).*

Istiqomah, J. Y. N., & Indarini, E. (2021). Meta analisis efektivitas model problem based learning dan problem posing terhadap kemampuan berpikir kritis siswa sekolah dasar pada pembelajaran matematika. *Jurnal Cendekia: Jurnal Pendidikan Matematika*. 5(1), 670–681.

Kusumaningrum, Diana. (2018). Literasi Lingkungan dalam Kurikulum 2013 dan Pembelajaran IPA di SD. *Indonesian Journal of Natural Science Education (IJNSE)*, 1(2): 59.

Mcelhaney, K. W., Chang, H., Chiu, J. L., & Linn, C. (2015). Studies in Science Education Evidence for effective uses of dynamic visualisations in science curriculum materials. *Studies in Science Education*, 51(1), 49–85.

Muna, A. K., Tandililing, E., & Oktavianty, E. (2023). PENERAPAN MEDIA PEMBELAJARAN MENGGUNAKAN PhET SIMULATION UNTUK MENINGKATKAN HASIL BELAJAR PESERTA DIDIK PADA MATERI HUKUM NEWTON. *Jurnal Inovasi Penelitian dan Pembelajaran Fisika*, 4(1).

Muzana, S. R., Lubis, S. P. W., & Wirda, W. (2021). Penggunaan Simulasi PhET terhadap Efektifitas Belajar IPA. *Jurnal Dedikasi Pendidikan*, 5(1), 227- 236.

Pujiningsih, A. L. M., Gunawan, G., & Adi, Y. K. (2022). Pengaruh Penggunaan Model Discovery Learning Berbantuan PhET Simulations terhadap Hasil Belajar Siswa. *Jurnal of Madrasah Ibtidaiyah Education (JMIE)*, 6(1).

Putri, M. H., Fahmi, F., & Wahyuningsih, E. (2021). Efektivitas Perangkat Pembelajaran IPA untuk Melatih Keterampilan Berpikir Kritis Peserta Didik SMP pada Materi Pokok Listrik Statis. *Journal of Banua Science Education*, 1 (2), 79-84.

Rahayu, A. B., Hadi, S., Istya, M., Zaini, M., Sholahuddin, A., & Fahmi, F. (2018). Development of Guided Inquiry Based Learning Devices to Improve Student Learning Outcomes in Science Materials in Middle School. *European Journal of Alternative Education Studies*.

Sugiyono (2019). *Metode Penelitian Pendidikan*. Bandung: Alfabeta.

Sumiyati, dkk. (2021). Pengaruh Model Belajar Blended Learning menggunakan Phet Simulation terhadap Hasil Belajar Siswa Kelas VI Sekolah Dasar. *ẽl-Midad : Jurnal PGMI*, 13(2).

Sundayana, R. (2014). *Statistika Penelitian Pendidikan*. Bandung: Alfabeta.

Yasiro, L. R., Wulandari, F. E., & Fahmi, F., (2021). Analisis Kemampuan Berpikir Kreatif Siswa dalam menyelesaikan Soal pada Materi Pemanasan Global Berdasarkan Prestasi Siswa. *Journal of Banua Science Education*, 1(2), 69-72.