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THE EFFECT OF PHET SIMULATION MEDIA ON CRITICAL THINKING SKILLS IN ELECTRICAL CIRCUIT MATERIAL

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Abstract

Finding out how PhET simulations affect the critical thinking abilities of fifth-grade electrical engineering students at SDN Slipi 11 Jakarta Barat is the goal of this study. A quasi-experimental design with a pretest-posttest control group design is the research methodology employed. All fifth-grade students make up the study population, and the sample is divided into two classes: a control class that uses traditional instruction and an experimental class that uses PhET simulations. Descriptive tests to measure critical thinking skills that had undergone validity and reliability testing served as the instruments. The normality and homogeneity tests were completed before the hypothesis test. The data were homogeneous and regularly distributed, according to the hypothesis test results. With a significance value of 0.001 (<0.05), the Independent Sample t-test hypothesis test rejected H_0. This demonstrates how using PhET simulations significantly enhances students' capacity for critical thought. PhET simulations also promote active student participation and enhance the interactiveness and enjoyment of learning. PhET simulations could therefore develop into a cutting-edge teaching tool for science in elementary schools.

Keywords: PhET Simulation, Critical Thinking, Electrical Circuit Material

Abstrak

Mengetahui bagaimana simulasi PhET mempengaruhi kemampuan berpikir kritis siswa kelas lima materi rang aian listrik di SDN Slipi 11 Jakarta Barat adalah tujuan dari penelitian ini. Desain kuasi-eksperimental dengan desain kelompok kontrol pretest-posttest adalah metodologi penelitian yang digunakan. Seluruh siswa kelas lima menjadi populasi penelitian, dan sampel dibagi menjadi dua kelas: kelas kontrol yang menggunakan pengajaran tradisional dan kelas eksperimen yang menggunakan

simulasi PhET. Tes deskriptif yang telah melalui uji validitas dan reliabilitas digunakan sebagai instrumen penelitian. Uji normalitas dan homogenitas dilakukan sebelum uji hipotesis. Data terdistribusi secara homogen dan teratur, sesuai dengan hasil uji hipotesis. Dengan nilai signifikansi sebesar 0,001 (<0,05), uji hipotesis Independent Sample t-test menolak H_0. Hal ini menunjukkan bahwa penggunaan simulasi PhET secara signifikan meningkatkan kemampuan berpikir kritis siswa. Simulasi PhET juga mendorong partisipasi aktif siswa dan meningkatkan interaktivitas serta kenikmatan belajar. Oleh karena itu, simulasi PhET dapat berkembang menjadi alat pengajaran mutakhir untuk sains di sekolah dasar.

Kata Kunci: PhET Simulation, Berpikir Kritis, Rangkaian Listrik

INTRODUCTION

Technological advancements in the era of the 5.0 revolution have had a significant impact on all aspects of life. The use of digital technology, artificial intelligence, big data, and robotics has had a profound influence on human life, including in the field of education (Nasution et al., 2024). The rapid advancement of digital education can be enjoyed by adults and even elementary school children, who can experience the fast pace of technology in this era (Anggraeni & Manik, 2023). In this context, it is necessary to enhance human resources through learning that focuses on 21st-century skills, namely critical thinking skills (Daniar & Sari, 2022). Essential skills of thinking, according to Daniar & Sari (2022), refer to the sharpness of learners in thinking to address problems or phenomena in their surroundings. Critical thinking is a cognitive ability in individuals to deeply analyze an idea, concept, or problem (Nantara, 2021). Rational thinking is based on critical thinking about facts that can be observed in the surrounding environment (Ariza Rahmadana Hidayati et al., 2021). According to Ummah (2022) There are five indicators of critical thinking, namely: (1) providing a simple explanation, (2) developing basic skills, (3) drawing conclusions, (4) providing further explanations, and (5) making assumptions and integrating information. In simple terms, critical thinking is a systematic approach used to evaluate evidence, beliefs, logic, and the words used in others' statements.

Based on findings from observations made by researchers in a Jakarta public elementary school, it was found that in the process of teaching electrical circuits, educators only used conventional media such as books, blackboards, markers, and images. This results in students having difficulty understanding the material presented, leading to low critical thinking skills among students. The results further reinforce this Putri et al., (2021), who noted that if only written materials in the form of books containing topic summaries, questions, and daily tests are used as references, students will become bored and unenthusiastic about learning, which in turn reduces their enthusiasm for critical thinking. According to Arisandy (2021)In the use of conventional media, students still face challenges in understanding the data obtained, often absorb content passively, and are less involved in asking questions. According to Wahyugi & Fatmariza (2021) Students will feel bored and unmotivated when educators only make learning teacher-centered, and students will neglect critical thinking. The use of interactive media can foster critical thinking because students do not just receive information, but are directly involved in the learning process. In principle, learning media serve as a tool for conveying messages from educators, acting as messengers to students as recipients of the messages. By designing a structured and systematic learning environment, learning media helps create an effective learning process and supports the achievement of learning objectives to the fullest extent (Saleh & Syahruddin, 2023).

Learning media, in essence, is a tool used to transfer information from teachers as communicators to students as recipients, by designing an organized learning environment, thereby supporting students in achieving learning objectives (Legina & Sari, 2022). Learning media plays a crucial role in creating an atmosphere that supports the learning process, making it more effective, and enabling educators to deliver material in a way that encourages active learning. The material that requires media is science material used to stimulate higher-order thinking in learning.

Science lessons are related to humans and nature (Rosiyani et al., 2024). In the Merdeka curriculum, science has been replaced by IPAS, which is a blend of social studies and science, Berliana et al. (2024) explain that IPAS plays a crucial role because it discusses aspects of the universe and all the events that take place within it. In teaching, a teacher needs to use methods, media, and teaching tools that can help students understand the material (Amelia et al., 2022). One example is in science lessons, particularly topics related to electricity, such as simple electrical circuits. Although students can theoretically explain the differences between series and parallel configurations, they often struggle when applying this knowledge directly. Therefore, a medium is needed to facilitate understanding and critical thinking skills.

PhET Simulation offers interactive simulations as a virtual laboratory to support students in demonstrating material concepts. PhET simulations present graphic designs in the form of animations, with a focus on their relevance to real-life events (Wilda Susanti, 2022). This medium is used as an engaging learning tool because students actively participate in learning through direct exploration with intuitive digital simulations (Inayah & Masruroh, 2021). One of the important topics in science education is electrical circuits, which can be taught using interactive media such as PhET Simulation (Sadewi, 2023). This medium offers interactive simulations that enable students to understand electrical circuit concepts in an enjoyable and in-depth manner (Dasmo et al., 2020). Interactive media such as PhET simulations have been widely used to increase engagement and conceptual understanding. However, research examining its effect on critical thinking skills in elementary school students is still limited. This gap indicates the need for further study to determine the effectiveness of such media in developing critical thinking skills from an early age.

Given the aforementioned problems, it is well known that to enhance critical thinking abilities, learning must be supported by interactive media. PhET simulation media is used in this study because it has a lot of potential to encourage the development of critical thinking abilities in science education, particularly when it comes to primary school electrical circuit content. This study aims to ascertain how PhET simulation media affect fifth-grade science students' critical thinking abilities when studying electrical circuits.

METHODS

The methodology used in this study is quasi-experimental. Although a control group is included, the strategy does not completely control the factors affecting how the experiment is carried out (Adil, 2023). The design used is a pretest-posttest control design. All fifth-grade students at SDN Slipi 11 Jakarta Barat for the 2024/2025 academic year, totaling 64 students, constitute the population of this study. The sampling technique used was saturated sampling, which means that all members of the population served as research subjects. The population was divided into two classes, namely Class V-A with 32 students as the control group and Class V-B with 32 students as the experimental group.

Data collection was conducted through an exam, using 10 open-ended questions out of 20 questions designed to evaluate critical thinking indicators. These questions were designed based on five critical thinking indicators according to (Ummah, 2022). The following is a list of questions according to critical thinking indicators:

Table 1. Critical Thinking Question Grid

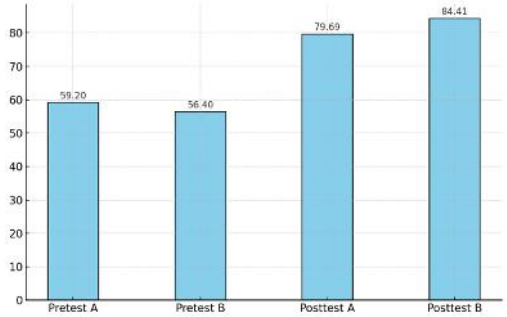
Skill Indicator Critical Thinking	Aspects	Indicator for each Problem	Problem form	Question Number
Provide a simple explanation	Explaining	Learners can explain simple things about parallel and series electrical circuits	Essay	1,2,6,7
Building basic skills	Basic skills	Learners can build basic skills based on problems that occur in series and parallel electrical circuits, and supporting materials.	Essay	3,4,5,9,
Summarize	Inference skills	Participants can conclude the story and statement related to series and parallel electrical circuits.	Essay	8,10,11,12
Provide further explanation	Context considerations	Learners can continue the in-depth explanation of the components and problems of the related circuits, series, and parallel electricity	Essay	13,14,17,18
Alleged and cohesiveness	Context appropriateness	Learners can conjecture about statements in daily life related to electrical circuits	Essay	15,16,19,20

Validity and reliability testing have been conducted to guarantee the measurement's reliability and validity instrument (Janna & Herianto, 2021). Validity testing was employed Cronbach's Alpha for reliability testing and the Product-Moment correlation technique, and this was done on instruments with more than one answer and in essay form (Novika et al., 2022). From these tests, 14 out of 20 questions were found to be valid and reliable, but only 10 questions were used to collect data.

Both descriptive and inferential methods can be used to analyze data collected. The mean, median, and mode are used in descriptive analysis to characterize the test results. Inferential analysis includes normality tests using the Lilliefors and Shapiro-Wilk tests. This test aims to ensure that the sample is drawn from a normal distribution using mean estimation (Nasrum, 2020). After the normality test showed that the data had a normal distribution, the next step in statistical analysis was to apply a homogeneity test. The homogeneity test was conducted by applying the F test, also known as Fisher's formula.

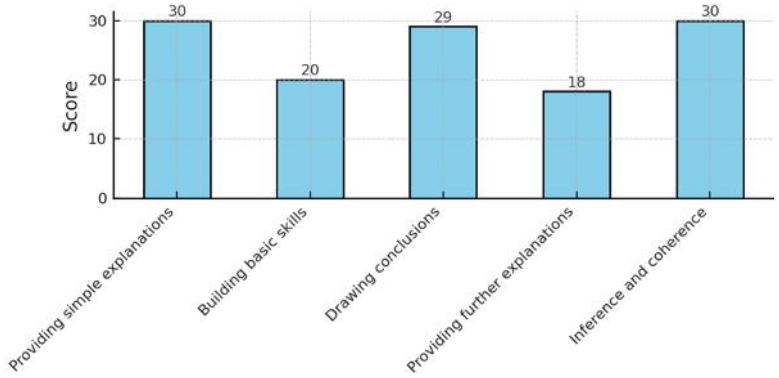
RESULTS AND DISCUSSION

This study set out to investigate how PhET media affected students' critical thinking abilities in electrical circuit material in grade V at SDN Slipi 11 in West Jakarta. Data collection was conducted using pretest and posttest assessments before and after the learning process was implemented in each group, specifically the experimental group and the control group. Based on the analysis conducted, data related to the pretest and posttest scores from the learning outcomes obtained in both groups were collected. To facilitate the comparison of learning outcome improvements between the two groups, the score data have been summarized in the form of a diagram as shown below:



Graph 1. Average Results of Pretest and Posttest

It is evident from the diagram that the two classes' pretest and posttest results differ from one another. Class A scored 59.20 on the pretest and 79.69 on the posttest. In contrast, the experimental class B received an average score of 56.40 on the pretest and 84.41 on the posttest. The average outcomes for each critical thinking skill indicator in the experimental class are as follows:



Graph 2. Average of Each Critical Thinking Skills Posttest Score

Based on the information shown in Figure 2, it can be explained that the highest average score for critical thinking skills was found in indicators that included providing simple explanations, making assumptions, and integration. This occurred because the use of PhET simulation media made students more accustomed to providing explanations through questions and guessing the causes of a problem.

To make sure the data satisfied the requirements, a number of prerequisite tests were carried out before the hypothesis testing. Using SPSS 25 for Windows, the study's tests included homogeneity and normality tests. Finding out if the collected data was normally distributed was the goal of the normality test. This is crucial because the majority of parametric:

Table 2. Normality Test

Class	N	α	Sig.
Pretest A (Control)	32	0.05	0.143
Postest A (Control)	32	0.05	0.827
Pretest B (Experiment)	32	0.05	0.220
Postest B (Experiment)	32	0.05	0.101

Based on the Shapiro-Wilk method in the normality test, it was proven that most of the data obtained met the assumptions of normal distribution. For the control class (Pretest A), the Shapiro-Wilk significance value is 0.143, while for Posttest A, the Shapiro-Wilk significance value is 0.827. In this context, the general threshold for rejecting the null hypothesis of normal distribution is usually set at α = 0.05. Thus, all values with significance greater than 0.05 can be said to follow a normal distribution. For the experimental class (Pretest B), the Shapiro-Wilk value is 0.220, while Posttest B has a Shapiro-Wilk value of 0.101 (above 0.05). Therefore, it is declared to be normally distributed because the value is greater than α = 0.05.

The homogeneity test is carried out following the completion of the normality test. This is necessary to determine whether the two groups being studied come from populations with the same variance or not :

Table 3. Homogeneity Test

Class	N	α	Sig.
Class Control	32	0.05	0.162
Class Experiment	32		

Pengujian homogenitas varian dengan Levene's Test menghasilkan nilai signifikansi 0,162 (untuk rata-rata). Dapat dilihat angka lebih tinggi dengan α = 0,05, dengan begitu dapat terlihat dan disimpulan bahwa varian kedua kelompok adalah homogen.

Based on the results of the tests that have been carried out, it is found that the population data in the experimental class and control class are normally distributed and have uniform variances. After fulfilling these conditions, the next step is to conduct statistical tests using the Independent Sample t-test. The criteria for testing indicate that H_0 is accepted if the significance value is more than 0.05, while H_1 is accepted if the significance value is less than 0.05. The following are the results of the test:

Table 4. Hypothesis Test

Class	N	α	Sig.	T Hitung	T Tabel
Class Control	32	0.05	0.001	-19868	1.99897
Class Experiment	32				

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A significance value of 0.001 was obtained from the analysis of the hypothesis testing, which is less than the predefined significance level of 0.05. The calculated t-value is -19868, while the table t-value is 1.99897. Therefore, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. This indicates that the use of PhET media has a significant impact on student learning in fifth-grade elementary school. The use of PhET media increased the average score in the experimental class by 84.41 points and the comparative score in the normal class by 79.69 points.

PhET media brings about positive changes in students, resulting in improved critical thinking skills and active, dynamic, and engaging learning. This is reinforced by Septiana et al. (2021). In their study, which found that PhET makes the learning process more interesting, less monotonous or boring, and can stimulate students' enthusiasm and motivation optimally. This can be observed from changes in students' attitudes during learning activities, where their critical thinking skills and enthusiasm for learning increased significantly compared to the conventional learning they typically experience. This is similar to previous research by Sari (2021), which found that using PhET enhances students' critical thinking skills and active participation in discussions, expressing opinions, and directly engaging in the learning process. This increase in positive responses from students is reinforced by Wiravanjava (2017), who claims that the development of critical thinking abilities and learning needs are significantly impacted by the use of PhET Simulation media.

Figure 2 shows that the highest indicator scores were found in simple explanations, hypotheses, and integration. It can be seen that students excel in linking hypotheses to concepts or information that they have learned. Furthermore, it is clear that each critical thinking indicator has its characteristics:

1. Providing Simple Explanations
   It is evident from Figure 2 that the indicator score for providing simple explanations received the highest score of 30. This is due to the use of PhET and the fact that students are familiar with simulations in images and can explain the differences between series and parallel circuits. This skill demonstrates mastery of the material, as only individuals who understand it well can simplify complex information without losing its essence (Yuni et al., 2019). In an academic context, this ability is important to ensure that ideas are effectively communicated to various audiences, thereby supporting the learning process and scientific discussions more optimally.
2. Building Basic Skills
   Additionally, Figure 2 shows that the score for building basic skills received a score of 20. This is because students are not yet proficient in managing problems to create complex explanations. This indicator refers to the development of thinking skills that form the foundation for more complex thinking, such as identifying facts, organizing information logically, and managing raw data into meaningful information (Handayani, 2020). This indicator includes understanding the main concepts in a subject before students can move on to higher levels of thinking.
3. Drawing Conclusions
   Based on Figure 2, it can be seen that the concluding score is 29. Because PhET media is being used, students are accustomed to simulations and explanations, enabling them to solve story problems. Concluding is the ability to extract the essence of information or text, whether it be a story, an article, or experimental results, and then formulate it into a concise yet accurate statement (Kurniawan et al., 2023). This process involves

selecting important information and simplifying it without losing its main meaning.

4. Providing Further Explanation
   Additionally, Figure 2 shows that the score for providing further explanation is the lowest at 18. This is because students are not yet proficient in providing further explanations related to in-depth explanations, and only explain the problems in the questions simply. The indicator of providing further explanation requires students not only to understand a concept but also to be able to analyze or elaborate on it in more detail, using analogies, examples, or connections to previous experiences (Agustin & Effendi, 2022). Thus, students can provide logical and relevant reasons for an idea or argument.
5. Conjecture and integration
   Based on Figure 2, it can be seen that the Conjecture and integration score received the highest score of 30. This is because the use of PhET media has accustomed students to conjecture and integrate various pieces of information into a unified understanding. This indicator signifies maturity in critical thinking, making predictions or assumptions based on available evidence, and connecting various information from different sources or disciplines to form a complete and meaningful understanding (Syafitri et al., 2024). This process involves inference, generalization, and integration of information, which are very important in interdisciplinary learning and complex problem-solving.

PhET Simulation provides significant benefits and impacts that make it easy for users to access interactive media, as reinforced by Verdian et al. (2021) PhET is highly flexible and can be used on various devices. There are many interactive simulations in various fields of science that help students learn through interaction and exploration. However, PhET Simulation also has limitations, as it requires a smartphone and a stable internet connection. This is reinforced by Abdurrahman et al. (2019), who note that the main drawback of PhET Simulation is that its use requires a computer or smartphone, which can be a barrier for less tech-savvy students. Additionally, the success of learning with PhET heavily depends on the independence of students, and if they don't know how to use this medium effectively, they might get bored (Ben Ouahi et al., 2020). To Overcome these constraints, schools need to provide internet access and training for educators so that they can master the use of PhET Simulations.

The research produced tangible results in the effort to innovate learning in the school environment, particularly in the application of technology as a medium to support science learning at the elementary education level. Furthermore, this research also served as one of the initial references for the application of PhET Simulation media at SDN Slipi 11 Jakarta Barat, which had never been used as part of the school's learning strategy.

CONCLUSION

Based on the findings that researchers conducted at SDN Slipi 11, West Jakarta, the use of educational resources, such as PhET Simulation on material about electrical circuits showed a significant positive impact on improving critical thinking abilities of the students. The findings of the Independent Sample t-test statistical analysis demonstrate this, which shows a significance level of 0.001, which is smaller than 0.05, which leads to the rejection of the null hypothesis. Analysis of the indicators shows a clear improvement, such as an increase in scores in the areas of identifying problems and analyzing evidence. This increase shows that students are better able to explain cause-and-effect relationships in electrical circuits and test alternative solutions independently. These findings are in line with the constructivist view that emphasizes the

importance of direct learning experiences, and are reinforced by (Agustin & Effendi, 2022) previous research showing that PhET can improve conceptual understanding and higher-order thinking skills in elementary school. The implementation of PhET Simulation not only facilitates students' understanding of abstract concepts in natural science but also creates an interactive learning environment, is fun, and encourages active involvement from students. Thus, the use of PhET media can be an innovative solution to enhance students' critical thinking abilities in science instruction at the elementary school level.

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