



ANALYZING THE RELATIONSHIP BETWEEN PhET SIMULATION USE AND STUDENTS' CONCEPTUAL UNDERSTANDING IN SCIENCE LEARNING

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Abstract

The objective of this research is to analyze the use of PhET Simulation in science learning and examine its relationship to their conceptual understanding. The research employed a quantitative approach with a descriptive correlational design. The study sample consisted of 30 students. Data were collected using a questionnaire on PhET Simulation usage and a test of students' conceptual understanding. The questionnaire instrument was validated and deemed reliable prior to use. Data analysis was conducted using descriptive statistics, normality tests, and Spearman's rho correlation tests with the aid of SPSS. The results indicated that the average score for PhET Simulation usage was 39.10 out of a maximum of 48, which falls into the high category. Meanwhile, the average score for students' conceptual understanding was 70.33, with a relatively high variation among the students. The normality test results showed that one of the variables was not normally distributed; therefore, hypothesis testing was conducted using Spearman's rho correlation. The Spearman's rho correlation test yielded a coefficient of 0.082 with a significance level of 0.667 ($p > 0.05$), indicating that there was no significant relationship between PhET Simulation usage and students' conceptual understanding. The findings suggest that PhET Simulation use has not become a dominant factor in improving students' conceptual understanding, as it is still influenced by prior ability, learning motivation, and the instructional strategies employed by teachers.

Keywords: PhET simulation, science learning, conceptual understanding

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INTRODUCTION

The development of information technology has brought changes to the science learning process, which requires students not only to understand concepts theoretically but also to be able to relate them to real-world phenomena in daily life. Essentially, science learning emphasizes the process of discovering concepts through observation, experimentation, and scientific verification. However, in school learning practices, many students still experience difficulties in understanding abstract concepts because the learning process tends to be teacher-centered and lacks the utilization of interactive learning media. This condition results in students memorizing concepts rather than understanding them deeply, which impacts their low conceptual understanding in science learning (Susilawati et al., 2022). Furthermore, science concepts that are abstract and difficult to visualize often lead to student misconceptions because they struggle to connect macroscopic, microscopic, and symbolic representations in science education (Rahmawati et al., 2022).

The use of technology-based learning media, such as interactive simulations, can serve as a solution to address these issues. Learning technology can be utilized to support a more interactive, flexible, and student-centered learning process, thereby increasing students' engagement in learning (Nana, 2020). Interactive simulations allow students to explore concepts independently through engaging, dynamic, and easy-to-understand visualizations, thereby helping to bridge the gap between theory and real-world phenomena. Simulations also provide opportunities for students to conduct virtual experiments, manipulate variables, and directly observe the resulting changes. Research indicates that the use of interactive simulations can enhance student engagement, learning activities, and a deeper understanding of concepts compared to conventional learning (Perkins et al., 2006). Furthermore, simulation-based learning supports the inquiry learning process as students can explore concepts through observation, investigation, and independent discovery (Sun et al., 2022).

One of the most widely used interactive simulation media in science learning is PhET Simulation, developed by the University of Colorado Boulder. PhET Simulation is designed based on educational research to help students understand abstract concepts through interactive and user-friendly virtual experiments. Through PhET, students can manipulate variables, observe changes directly, and explore concepts that are difficult to observe in real-world learning. PhET is also capable of visualizing the relationships

between macroscopic, submicroscopic, and symbolic concepts, thereby helping students build a better understanding of concepts (Perkins et al., 2006). Additionally, the use of PhET can increase learning motivation, student interaction, curiosity, and active student engagement during the learning process (Banda & Nzabahimana, 2022; Mrani et al., 2020).

Although there has been extensive research on PhET simulation, most previous researchers have only viewed PhET as a tool or experimental testing method in the classroom. Very few studies have examined the frequency or extent of students' independent use of PhET and then measured this as a variable. Furthermore, PhET research is typically general in nature and has not focused much on material requiring logical physical balance, such as simple machines, particularly levers. Furthermore, the characteristics of eighth-grade students at a private junior high school in Depok are also interesting to study. Students in urban private schools generally have easy access to devices (cell phones/laptops), but this high level of access does not necessarily guarantee their understanding of the science concepts being taught.

Therefore, this study no longer considers PhET as a learning method used by teachers, but rather measures the extent to which students' independent use of PhET influences their conceptual understanding of levers.

PhET Simulation is an interactive learning medium developed to assist students in understanding science concepts through virtual experiments. PhET allows students to manipulate variables, observe changes directly, and explore concepts that are difficult to observe in the real world. This medium is designed based on educational research, making it effective in explaining abstract concepts (Perkins et al., 2006). Various previous studies have shown that the use of PhET Simulation can improve students' conceptual understanding, learning outcomes, learning motivation, and critical thinking skills. However, some research also indicates that the use of PhET does not necessarily provide a direct and significant increase in conceptual understanding, as its effectiveness is influenced by various factors such as learning strategies, students' prior knowledge, teacher guidance, and the instructional design employed (Rahmawati et al., 2022).

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METHOD

This study employed a quantitative approach using a descriptive correlational design to analyze the relationship between the use of PhET Simulation in science learning and students' conceptual understanding. A quantitative approach was selected because the study focused on the objective measurement of variables in the form of numerical data, while the correlational design was intended to determine the degree of relationship between the independent and dependent variables without administering any specific treatment to the research subjects (Cresswell, 2014). The variables in this study consisted of an independent variable and a dependent variable. The independent variable was the use of PhET Interactive Simulations in science learning, whereas the dependent variable was students' conceptual understanding. The use of PhET was measured through indicators including intensity of use, ease of use, interactivity, and the ability to visualize concepts. Meanwhile, students' conceptual understanding was assessed based on their ability to explain, interpret, apply, and draw conclusions related to science concepts. The use of interactive simulations such as PhET Interactive Simulations can assist students in understanding abstract concepts through more concrete visualizations (Wieman et al., 2008).

PhET usage was measured using the following indicators: (1) ease of use, (2) interest and motivation to learn, (3) independent activity and exploration, and (4) clarity of information. These four indicators were compiled into a 12-question PhET usage questionnaire.

The student conceptual understanding indicator was measured based on (1) understanding the basic theory and function of simple machines, (2) application of the law of lever equilibrium, and (3) analysis of the relationship between variables and lever mechanical strategies. These three indicators were compiled into 10 questions given to students.

Research Design

This type of research is quantitative research with a descriptive correlational design. This design is used to describe the conditions of PhET Simulation usage in science learning and to analyze the relationship between its use and students' conceptual understanding. Correlational research allows researchers to identify relationships between variables without performing variable manipulation (Sugiyono, 2016). The methods section requires the author to describe in detail how the research was conducted. The components of the methods section include the research design, research targets, data collection techniques, and data analysis techniques.

Research Targets

The subjects in this study were 30 eighth-grade students at a private junior high school in Depok. The sampling technique used was purposive sampling, namely sample selection based on certain criteria, in this case students who have participated in science learning using PhET Simulation and students in urban private schools generally have easy access to gadgets (cellphones/laptops). A total of 30 student respondents is considered adequate for simple statistical analysis in educational research (Sugiyono, 2016).

Data Collection Techniques

The research instruments used consisted of questionnaires and tests. The questionnaire was used to measure the level of use of PhET Simulation with a four-level Likert scale, namely (1) Strongly disagree, (2) disagree, (3) agree and (4) strongly agree. While the test was used to measure students' conceptual understanding in the form of multiple-choice questions. Before being used, the instruments were tested for validity and reliability to ensure their feasibility as data collection tools (Arikunto, 2013).

Before being used in actual data collection, both research instruments first went through an empirical trial phase on 30 eighth-grade students outside the research sample to determine their level of validity and reliability. The results of the validity test showed that all items in the questionnaire instrument on the use of PhET Simulation and the test questions on the concept of understanding the lever material were declared valid. Meanwhile, based on the reliability test using the Cronbach's Alpha formula assisted by SPSS software, a reliability coefficient of 0.843 was obtained for the questionnaire on the use of PhET Simulation and 0.919 for the concept understanding test. Both values were far above the required minimum limit (0.60), so both instruments were declared reliable

with a very high level of internal consistency and were suitable for use in research.

Data collection techniques were conducted through the implementation stages of science learning using PhET Simulation, followed by the administration of questionnaires to measure media usage and tests to measure students' conceptual understanding. The data obtained consisted of questionnaire scores and student test results. Data processing and analysis were performed using IBM SPSS Statistics software. The data analysis stages included instrument validity testing using Product Moment correlation to determine the relationship between each item and the total score, as well as reliability testing using the Cronbach Alpha coefficient to measure instrument consistency. Subsequently, a normality test was conducted to determine whether the data were normally distributed as a requirement for using parametric statistics.

RESULTS AND DISCUSSION

The data collection process was conducted at a private school in Depok City. The PhET simulation learning implementation was carried out in 60-minute sessions. The teacher's role throughout this activity focused on being a facilitator, not an information center. To support the development of understanding of the lever material, students were provided with guided inquiry-based worksheets as navigation instruments for the virtual experiment. To optimize cognitive interaction, the use of the virtual simulation was conditioned collaboratively by dividing students into independent study groups of 2–3 students. Furthermore, class dynamics

revealed variations in student focus; some students demonstrated high enthusiasm in tinkering with the simulation variables, while others still experienced concentration difficulties and distractions such as opening other websites and chatting outside the lesson despite the teacher's warnings.

The learning process included the implementation of PhET on simple machines (levers) with the learning objective of analyzing the relationship between mass and distance and equilibrium. Figure 1 shows a PhET display that supports these learning objectives.

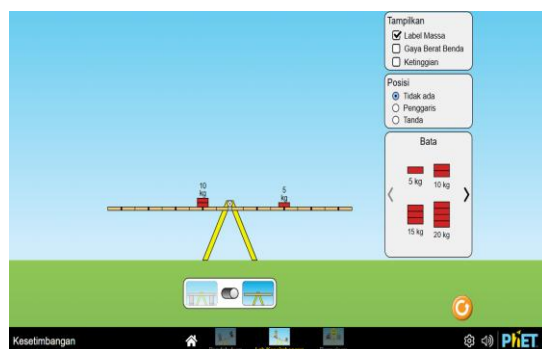


Figure 1. Equilibrium material in PhET

The differences in focus and level of student engagement in this class align with the results seen in the study's descriptive statistical data. This analysis was used to obtain an overview of the mean, minimum, maximum, and standard deviation values for the two variables studied: PhET Simulation usage and student conceptual understanding. A summary of this data can be seen in Table 1.

Table 1. Descriptive statistics of research variables

Varibel	Mean	Minimum	Maximum	Standard Deviation
PhET usage	39.10	26	48	4.678
Concept understanding	70.3	20	100	20.424

Note: Personal Data

Based on Table 1, the average score for students using the PhET Simulation was 39.10, with the lowest score being 26 and the highest being 48. The standard deviation was relatively small, at 4,678. This small value indicates a nearly even distribution of data. This demonstrates that the majority of eighth-grade students consistently exhibited high levels of activeness and interaction when attempting the virtual simulation. This fact also aligns with classroom observations, where the majority of students appeared enthusiastic.

In contrast, the data for students' conceptual understanding showed very diverse results. Although the average score was quite good, at 70,3,

the gap between the lowest and highest scores was significant, ranging from 20 to a perfect 100. This diversity of student responses is emphasized by the very large standard deviation, reaching 20,424.

This striking difference in the distribution of data for the conceptual understanding variable provides important preliminary conclusions. These data demonstrate that although nearly all students actively and frequently used the same PhET simulation, their actual abilities in answering calculation and analysis problems involving levers remained significantly different. This large gap in scores was likely influenced by a loss of concentration or digital distractions in some

students, who were seen engrossed in browsing websites outside of the subject matter during class. This indicates that high PhET usage does not necessarily translate directly to high conceptual understanding in all students, as conceptual understanding can also be influenced by other factors such as student interest, the use of learning models, the learning process, and even the students' own cognitive abilities (Fine Eirene Siahaan & Cintia Sihotang, 2023; Safitri et al., 2021).

Next, to determine whether the characteristics of the score distribution meet the requirements for advanced statistical analysis, the data for both variables were then tested using the Shapiro-Wilk Normality Test. This step is crucial for determining whether parametric or non-parametric statistical methods should be used in the relationship analysis. A summary of the normality test results is presented in Table 2.

Tabel 2. Normality test results

Varibel	Sig. Shapiro Wilk	Interpretation
PhET usage	0.505	Normal
Concept understanding	0.018	Abnormal

Note: Personal Data

Based on Table 2, the results of the Shapiro-Wilk normality test show that the significance value for the PhET usage variable is $0.505 > 0.05$, indicating a normal distribution. Meanwhile, the conceptual understanding variable has a

significance value of $0.018 < 0.05$, indicating a non-normal distribution. Therefore, the hypothesis test was conducted using Spearman's rho correlation.

Tabel 3. Hasil uji korelasi Spearman's rho

Variables	Spearman's Rho	Sig	N	Interpretation
PhET use – Conceptual Understanding	0.082	0.667	30	Low relationship

Note: Personal Data

Based on Table 3, the Spearman's Rho correlation test results show a significance value (Sig.) of 0.667. Because this significance value is much greater than the standard error rate of 0.05 ($0.667 > 0.05$), it is statistically concluded that there is no significant relationship between the level of PhET Simulation use and students' conceptual understanding of levers.

In addition to being insignificant, the correlation coefficient (Spearman's Rho) obtained is also very small, at only 0.082. This coefficient value approaching zero indicates that the strength of the relationship between the two variables falls into the very weak or very weak category.

These findings clearly demonstrate that high levels of PhET Simulation use do not guarantee or have a significant relationship with high levels of student conceptual understanding. Although eighth-grade students were very active and enthusiastic and spent a lot of time tinkering with the virtual Balancing Act simulation in class, this high level of digital interaction did not automatically translate into a correct understanding of how to solve calculation problems and analyze the law of lever equilibrium. This reaffirms that technological visualization alone is not enough; Students still require strict guidance (scaffolding) from teachers so that "playing" with simulations

can transform into in-depth scientific understanding.

Based on the results of the Spearman's Rho correlation analysis, which showed no significant relationship between the level of PhET Simulation usage and conceptual understanding, several logical reasons can explain this phenomenon.

First, the questionnaire instrument used in this study tended to measure students' perceptions, visual impressions, and general satisfaction with the PhET media, rather than the quality of their in-depth cognitive engagement. The high average score on the PhET usage variable indicates that students felt interested, enjoyed, and helped by the simulation visualization. However, this basic interest does not reflect the occurrence of critical thinking or complex information processing in students' brains when solving physics problems involving levers. This aligns with research that suggests students who actively operate virtual simulations risk becoming trapped in purely mechanical activities. They tend to complete tasks mechanically without a deep or meaningful curiosity (Kisworo et al., 2025). Furthermore, student characteristics also influence the success of simulations in learning (Smetana & Bell, 2012).

Second, during the independent exploration process, students were strongly indicated to be interacting with virtual simulations without

adequate conceptual guidance from the teacher. When students were allowed to freely manipulate simulation variables without strict direction, they tended to focus solely on the mechanical activity or visual aspects (such as seeing objects moving or balancing). As a result, students failed to connect the simulated images to the actual mathematical formulation and laws of lever equilibrium in the real world. This was further exacerbated by classroom dynamics, where some students lost focus and became distracted by opening other websites due to a lack of intensive comprehension control. Previous research supports that digital multitasking for non-academic purposes has been shown to hinder learning because humans have limited cognitive capacity to process multiple activities simultaneously. When teacher supervision and comprehension control are less intensive, the presence of technology actually makes it difficult for students to apply selective attention, resulting in wasted learning time. Therefore, teachers need to implement stricter classroom conditioning strategies and train students' regulation skills so that the use of simulation technology can be effective and sustainable (Pérez-Juárez et al., 2023). Furthermore, achieving effective results from the use of computer simulations in science learning requires directed instruction from the teacher as a facilitator (Rutten et al., 2012). Furthermore, without clear direction, students tend to interact only superficially with the simulation without understanding the concepts in depth (Istiqfarin & Subekti, 2025).

Third, the PhET Simulation platform in this learning process appears to still be predominantly a passive visualization tool and has not been fully integrated as part of a well-structured inquiry-based learning activity. Although students are provided with worksheets, the activities often shift to merely technical instructions for moving digital objects, rather than a scientific investigation to discover the concept of mechanical advantage. Without a strong scaffolding structure from the teacher to bridge virtual visualizations into abstract understanding, students' high levels of PhET play will never translate directly to improved conceptual understanding. Furthermore, the effectiveness of simulations like PhET depends heavily on how teachers direct the use of the media in learning activities, the quality of teacher guidance, and scaffolding support throughout the learning process (Sun et al., 2022; Wieman et al., 2008). Furthermore, the use of simulations without integrating appropriate learning strategies can have a less significant impact on student learning outcomes (Manlapig, 2024).

This aligns with research stating that the effectiveness of PhET Simulations is highly dependent on teacher guidance and the implementation of directed learning strategies such as guided inquiry, as simulations are only one component of effective learning (Getahun et al., 2026). PhET helps students visualize abstract concepts through animated visual displays and active experiments that users can use, thus training them to experiment (Perkins et al., 2006; Susilawati et al., 2022).

Thus, although students reported high levels of PhET use, this study did not find a statistically significant relationship between PhET use and student conceptual understanding. This is supported by the assertion that the use of virtual laboratory simulations in science learning will be more effective when accompanied by appropriate pedagogical guidance and support (Smetana & Bell, 2012). Furthermore, other research shows that the combination of virtual simulation and a structured learning approach can improve students' conceptual understanding more optimally than using simulation alone (Zacharia & Olympiou, 2011). Therefore, optimizing the use of PhET Simulation needs to be supported by a comprehensive learning design to provide a maximum impact on students' conceptual understanding.

CONCLUSION AND SUGGESTION

Conclusion

Based on the research results, the use of PhET Simulation in science learning is in the high category with an average score of 39.10. Meanwhile, the average score for students' conceptual understanding is 70.33, with a fairly high level of variation among students. The results of the Spearman's rho correlation test show a correlation coefficient of 0.082 with a significance of 0.667, indicating that there is no significant relationship between the use of PhET Simulation and students' conceptual understanding. Consequently, the use of PhET in this study has not yet become a dominant factor influencing students' conceptual understanding, as conceptual understanding is also affected by various other factors such as prior knowledge, learning strategies, learning motivation, and teacher guidance during the learning process.

Suggestion

Based on the research results, the use of PhET Simulation in science learning should not only serve as a visualization tool but also be integrated with relevant learning strategies, conceptual explanations, discussions, and teacher guidance to ensure students gain a better understanding of the

material. Teachers are also advised to provide clear directions and student worksheets (LKPD) during the use of PhET so that students can focus more on conceptual understanding rather than just the simulation's interface. Furthermore, future research is expected to utilize larger sample sizes, explore different topics, and examine other factors influencing students' conceptual understanding—such as learning motivation, prior knowledge, and instructional models—so that the research findings can be more developed and comprehensive.

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