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Overcoming Misconceptions of Elementary School Students in Energy Materials and Their Changes Using the Colorado PhET Application

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Abstract: *Given the critical role of energy in our daily lives and the increasing complexity of energy systems, addressing misconceptions about energy among elementary students is imperative for fostering energy literacy and responsible citizenship. This research aims to overcome elementary school (SD) students' misconceptions in understanding the concept of energy and its changes by using the PhET Colorado simulation application. Misconceptions in science learning at the basic level can hinder students' understanding of more complex concepts at the next level of education. The PhET Colorado app provides interactive simulations that allow students to learn through virtual experiments, thereby helping clarify concepts that are difficult to understand. This research uses an experimental method with a pretest-posttest control group design. Students were divided into two groups: an experimental group that used PhET simulations and a control group that used conventional learning methods. Data was collected through written tests and observation of learning activities. Data analysis was carried out by comparing the pretest and posttest results of the two groups to measure the increase in understanding of the concept of energy and its changes. The results showed that the use of the PhET Colorado simulation significantly improved students' understanding of the concept of energy and its changes. Students who study with PhET experience a greater reduction in misconceptions compared to students who study through conventional methods. These findings indicate that interactive simulation-based learning can be an effective strategy in overcoming misconceptions in elementary school students, as well as increasing their interest and motivation in learning science.*

Keywords: *Misconceptions, Energy, Energy Change, PhET Colorado.*

Abstrak: Penelitian ini dilakukan untuk mengatasi miskonsepsi pemahaman siswa Sekolah Dasar (SD) dalam memahami konsep energi dan perubahannya dengan memanfaatkan aplikasi simulasi PhET Colorado. Miskonsepsi dalam pembelajaran IPA pada tingkat dasar dapat memengaruhi pemahaman siswa terhadap konsep-konsep yang lebih kompleks di jenjang pendidikan berikutnya. Aplikasi PhET Colorado menyediakan simulasi interaktif yang memungkinkan siswa untuk belajar melalui eksperimen virtual, sehingga membantu mengklarifikasi konsep-konsep yang sulit dipahami. Dalam penelitian ini metode yang digunakan adalah eksperimen dengan desain pretest-posttest control group. Siswa terbagi menjadi dua kelas: kelas eksperimen yang memanfaatkan penggunaan simulasi PhET dan kelas kontrol yang menerapkan metode pembelajaran konvensional. Data didapatkan dari tes tertulis dan observasi kegiatan pembelajaran. Analisis data diperoleh dengan membandingkan hasil pretest dan posttest dari kedua kelas untuk mengukur tingkatan pemahaman konsep energi dan perubahannya. Hasil yang diperoleh dari penelitian menunjukkan bahwa penggunaan simulasi PhET Colorado secara berkala mampu meningkatkan pemahaman siswa tentang konsep energi dan perubahannya. Siswa yang

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belajar dengan PhET mengalami pengurangan miskonsepsi yang lebih besar dibandingkan dengan siswa yang belajar melalui metode konvensional. Temuan ini menunjukkan bahwa pembelajaran berbasis simulasi interaktif dapat menjadi strategi efektif dalam mengatasi miskonsepsi pada siswa SD, serta meningkatkan minat dan motivasi mereka dalam belajar IPA.

Kata Kunci: Miskonsepsi, Energi, Perubahan Energi, PhET Colorado.

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INTRODUCTION

Learning is a collection of activities designed to help a person understand something more easily. In learning activities at school, teachers must know all aspects of the learning process and how effective and efficient learning is carried out. By conducting an assessment. Teachers can focus their attention on students who have not yet understood the material and find their learning difficulties.

Given the importance of energy in everyday life and its role in addressing global challenges such as climate change, addressing elementary school students' misconceptions about energy concepts has become increasingly urgent. This study aims to address this by leveraging the advantages of the PhET Colorado simulation. The PhET Colorado interactive simulation, with its engaging visualizations and intuitive manipulation capabilities, has been shown to be effective in helping students build strong conceptual understanding. Its features, such as the ability to visualize unseen phenomena, allow students to actively explore the concept of energy and its changes. Thus, PhET Colorado offers an innovative solution to address challenges in elementary science learning, particularly in addressing the abstraction of energy concepts, the lack of learning aids, and common misconceptions. Through this simulation, it is hoped that students can build a strong foundation for further science learning, develop critical thinking skills, and become energy-literate citizens.

Understanding energy concepts early on is important because: A Foundation for Further Science Learning: Energy is a central concept in physics. A strong understanding of energy will make it easier for students to learn other science topics, such as electricity, heat, and motion. Encourage Interest in Science: Colorado's engaging and interactive PhET simulations can help spark students' interest in learning science. By conducting virtual experiments, students will feel more engaged and motivated to learn more about the world around them. Equip Students with 21st Century Skills: The use of Colorado's PhET simulations encourages students to develop critical thinking, problem-solving, and collaboration skills. These skills are critical to student success in the 21st century.

Science learning is scientific learning that involves the interaction between learning components to achieve goals in the form of predetermined competencies. Basically, learning science means about phenomena about the environment. Ideally, science learning in schools is expected to be a vehicle for students to learn about themselves and their environment (Ilhami et al., 2019). A person who studies science is expected to be able to understand the environment and solve problems they encounter in the surrounding environment (Susilawati & Ilhami, 2019). Science learning at the elementary school (SD) level has an important contribution in building a foundation of knowledge and understanding of complex scientific concepts at the next level of education. One of the key topics in the elementary science curriculum is the concept of energy and its changes. However, many students lack mastery of energy concepts and their changes.

Students' lack of knowledge of a learning material is one of the factors that do not achieve students' learning targets or goals in the learning process as well as having a serious impact on student achievement in school. One example of a factor that does not achieve learning targets in schools is that there are still many students who experience misconceptions during the learning process. Misconception is defined as a mismatch between a concept that is understood and an actual concept, causing a difference in meaning between concepts (Indriyani, 2023). There are misconceptions in learning that can affect the learning outcomes carried out by students. Misconceptions can occur because there are mistakes by students in obtaining a basic concept of material in class. According to Mukhlisa in Wulandari (2024), a concept can be said to be a misconception if it meets several criteria or characteristics such as: 1) the existence of the wrong meaning of the concept, 2) the use of the wrong concept, 3) the classification of improper examples, 4) the meaning of different concepts, 5) the hierarchical relationship between concepts is not correct.

Common misconceptions found among elementary school students include the understanding that energy only exists when there is movement, energy can be depleted or lost, and only living things have energy. This misconception not only interferes with students' understanding of the concept of energy itself, but also affects their understanding of other concepts related to energy, such as the law of conservation of energy and energy conversion.

To overcome this problem, an innovative and effective learning approach is needed. One solution that can be applied is the use of interactive simulations. Colorado PhET Application. PhET Colorado is a virtual practicum learning simulation developed by the University of Colorado. PhET Colorado contains physics, mathematics, biology, and chemistry learning practicum simulations that are useful for teaching and learning activities in the classroom (Bhakti, et al. 2019). These simulations allow students to conduct virtual experiments and observe scientific phenomena in person, thus helping them understand abstract concepts better.

This study specifically selected the PhET Colorado simulation application as an optimal solution due to its numerous advantages. The application offers interactive and intuitive visualizations that present abstract energy concepts in a visual and interactive format, enabling students to conduct virtual experiments directly. This approach effectively addresses common misconceptions stemming from limited direct experience with energy phenomena. Additionally, the PhET Colorado simulation provides flexibility and customization, allowing teachers to adapt simulations to students' understanding and learning objectives by controlling variables, which enables students to actively explore cause-and-effect relationships between various energy forms. The application is also accessible and cost-effective, being freely available on both desktop and mobile devices, thus eliminating the need for expensive hardware or software. Furthermore, supporting research demonstrates its effectiveness in enhancing students' understanding of complex science concepts, including energy, by helping them build accurate mental models of natural phenomena.

The PhET Colorado simulation has been widely researched as a digital-based learning medium, with studies highlighting its effectiveness in both online and offline learning environments. For example, research by Sidik et al. shows its effectiveness in teaching electrical measuring devices and direct current electricity applications, while Pulungan et al. (2022) report its successful use in online science lessons on static electricity. Pretest and posttest results in these studies reveal that PhET simulations significantly improve students' understanding and knowledge of scientific concepts. By providing interactive and visual representations of energy concepts, this simulation-based approach not only reduces misconceptions but also increases student engagement and motivation in learning science.

This study aims to evaluate the effectiveness of the PhET Colorado application in addressing elementary school students’ misconceptions about energy and its transformations. Using an experimental method with a pretest-posttest control group design, the study compares the understanding of students using PhET simulations with those using conventional learning methods. Through analyzing pretest and posttest results, the study seeks to determine the extent to which the PhET simulation improves understanding of energy concepts and reduces misconceptions. The findings are expected to contribute to more effective science learning strategies at the elementary level and provide educators with valuable insights into using technology to enhance the quality of learning.

RESEARCH METHODS

This study employed an experimental method with a pretest-posttest control group design to evaluate the effectiveness of the Colorado PhET simulation application in addressing elementary school students' misconceptions about energy concepts and their changes. The research utilized a quasi-experimental design involving two groups: an experimental class, which used the PhET Colorado simulation application for learning, and a control class, which employed conventional learning methods. The subjects included 10 fifth-grade students from SD Negeri Brambang, Jombang Regency, as the control group, and 18 fifth-grade students from SD Negeri Ngudirejo 1, Jombang Regency, as the experimental group. The instruments used comprised a written test (pretest and posttest) to assess understanding of energy concepts, observation sheets to monitor student engagement and learning activities, and student questionnaires to gather perceptions on the use of PhET simulations in science learning.

The research procedure consisted of three stages: preparation, implementation, and data analysis. In the preparation stage, the researchers developed research instruments, determined the subjects, divided them into control and experimental groups, and trained teachers to use the PhET application. During the implementation stage, a pretest was conducted in both groups to measure their initial understanding of energy concepts. Over four weeks, the experimental group was taught using the PhET Colorado simulation application, while the control group followed conventional methods, with each session lasting two lesson hours per week. Observations were carried out during the intervention to monitor student engagement, followed by a posttest to evaluate improvements in understanding. Finally, in the data analysis stage, quantitative analysis using a t-test was employed to compare pretest and posttest results between the two groups, identifying significant differences in learning outcomes. Additionally, qualitative analysis of observation and questionnaire data provided insights into students' perceptions of PhET simulations and their impact on learning motivation.

The study adhered to ethical research standards, including obtaining permission from schools and parents and ensuring the confidentiality of student data. By employing a comprehensive methodology, this study aims to assess the potential of the PhET Colorado application in reducing misconceptions and enhancing elementary students' understanding of energy concepts. The findings are expected to contribute valuable insights for improving science education at the elementary level.

RESULTS AND DISCUSSION

This research aims to address elementary school students' misconceptions about the concept of energy and its transformations through the use of the Colorado PhET simulation application. The data analysis results, derived from pretest and posttest scores as well as observations of learning activities, are presented in tables and graphs to provide a clear and accessible interpretation of the finding. Pretest and Posttest Results will described beloew.

Table 1. Pretest and posttest results from the control class and experimental class

Group	Average Pretest Score	Average Posttest Score	Increased
Control Classes	56.1	68.7	12.6
Experimental Classes	55.2	85.6	30.4

The analysis of the pretest and posttest results reveals a notable difference in student improvement between the control class and the experimental class. In the control class, the average pretest score was 56.1, which increased to 68.7 on the posttest, reflecting an improvement of 12.6 points. In contrast, the experimental class, which used the Colorado PhET simulation application, showed a more significant gain. The average pretest score for this class was 55.2, which increased to 85.6 on the posttest, demonstrating an improvement of 30.4 points. These results suggest that the experimental class benefited more from the use of the PhET application, as it experienced a greater increase in understanding compared to the control class that used conventional methods. This demonstrates the effectiveness of the PhET simulation in improving students' comprehension of the concept of energy and its changes.

In addition to these improvements, the analysis of misconceptions revealed that the use of the Colorado PhET application helped reduce misunderstandings in the experimental class. By offering interactive and visual simulations of energy concepts, the PhET application provided students with a clearer understanding of energy and its transformations, addressing common misconceptions that are typically challenging to overcome through traditional teaching methods. Misconception Analysis will describe below.

Table 2. Decrease in the number of students who experience misconceptions after learning

Misconception	Number of Students (Pretest)	Number of Students (Posttest)	Decline
Energy only exists when there is movement	18	5	13
Energy can be lost or depleted	18	3	15
Only living things have energy	18	2	16

The analysis of misconceptions shows a significant reduction in the number of students holding incorrect beliefs about energy. Specifically, the misconception that "energy only exists when there is movement" decreased from 18 students to just 5. Similarly, the misconception that "energy can be lost or depleted" dropped from 18 students to 3, and the belief that "only living things have energy" was reduced from 18 students to only 2. This decrease in misconceptions suggests that the Colorado PhET simulation effectively helped clarify students' understanding of energy concepts and their changes, providing a more accurate mental model of energy.

Furthermore, observations during learning activities revealed that students in the experimental class, who used the PhET simulation, were more active and engaged in the learning process compared to students in the control class. This increased engagement was also reflected in the results of the student questionnaire, which showed that students in the experimental class were more motivated and positive about their learning experience. The PhET simulation seemed to enhance students' involvement by making abstract concepts more interactive and visually accessible, further confirming its effectiveness as a learning tool.

Table 3. The results of the questionnaire show students' perception of the use of PhET:

Questionnaire Questions	Agree (%)	Disagree (%)
PhET simulations make lessons more engaging	90	10
PhET simulations help understand energy concepts	88	12
I am more motivated to study science with PhET	85	15

The analysis of the student questionnaire reveals a positive response to the use of the PhET simulation in the classroom. The majority of students, 90%, agreed that the PhET simulations made learning more engaging. Additionally, 88% of students felt that the simulations helped them better understand the concept of energy and its changes. Furthermore, 85% of students reported feeling more motivated to learn science as a result of using the PhET simulation. These findings suggest that the PhET application not only enhanced students' understanding of complex scientific concepts but also significantly boosted their interest and motivation in learning science.

This study demonstrates that the use of the PhET Colorado simulation application significantly improves elementary school students' understanding of the concept of energy and its changes. The higher increase in posttest scores in the experimental class shows the effectiveness of PhET in addressing misconceptions, with a notable reduction in the number of students experiencing misunderstandings. This suggests that interactive simulations can help students grasp difficult scientific concepts more easily. Additionally, student observations and questionnaire responses indicate that the PhET application not only enhances understanding but also increases students' interest and motivation in learning science. These findings align with previous research highlighting the positive impact of technology-based learning on student engagement and comprehension.

However, there are several limitations in this study. The sample was limited to students from a few elementary schools, so the results may not be generalizable to all schools, especially considering the variations in curriculum, teaching methods, and student characteristics. The duration of the intervention may have been too short to observe long-term effects, and a longer intervention period might be necessary for deeper understanding. Teacher integration of the PhET application also played a crucial role, as variations in teachers' technology proficiency could influence the outcomes. Additionally, students' technological abilities may have impacted their adaptation to the PhET application, with less tech-savvy students potentially requiring more time to adjust. Limited access to technological resources, such as computers and internet connectivity, in some schools also posed a challenge. Lastly, the study did not evaluate the long-term impact of using the PhET application, and further research is needed to determine whether the improvements in understanding are sustained over time. Despite these limitations, the study provides valuable insights into the potential of interactive simulations to enhance science education at the elementary level, suggesting that the integration of technology can be an effective strategy for improving the quality of learning.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that the Colorado PhET simulation application effectively addresses elementary school students' misconceptions about energy and its changes. Key findings include a significant improvement in understanding the concept of energy in the experimental class, with greater posttest score increases compared to students using conventional methods. Additionally, the PhET simulations reduced misconceptions, such as the belief that energy only exists with movement or that energy can be lost. Furthermore, students in the experimental class were more engaged and motivated in science learning, with most reporting that PhET made learning more interesting and helped clarify difficult concepts.

Based on these findings, several suggestions are made: First, schools should integrate more technology, like the PhET simulations, into the science curriculum to help students grasp abstract concepts through interactive learning. Teachers should also receive training on using PhET effectively to enhance their teaching methods. Additionally, educators should develop learning materials that incorporate PhET simulations to further deepen students' understanding. Further research is needed to explore the use of PhET in other subjects and educational levels. Finally, schools should invest in infrastructure improvements, such as stable internet access and adequate computer devices, to support the effective use of these interactive tools in the classroom. These steps will help improve science education and foster a deeper understanding of scientific concepts among elementary school students.

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