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The Effect of Using Phet Simulation Media on Physics Learning Achievement: A Literature Review

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ABSTRACT

This study aims to examine the effect of using PhET (Physics Education Technology) simulation media on students' physics learning achievement through a literature review approach. Eight relevant scientific articles were selected based on specific inclusion criteria, such as the use of PhET in physics learning and the presentation of quantitative data on student learning outcomes. The review results indicate that all the articles concluded that there was a significant improvement in student learning outcomes after using PhET media. This simulation has proven effective in helping students understand abstract physics concepts, increasing participation and motivation to learn, and supporting critical thinking skills. Additionally, PhET is flexible and can be applied in various learning models, such as problem-based learning and scientific inquiry. Despite its numerous advantages, the success of PhET implementation depends heavily on teachers' readiness and the availability of technological infrastructure. Thus, PhET simulations have the potential to become an innovative and efficient learning tool in enhancing the quality of physics education.

Keywords: PhET Media, Learning Achievement, Physics Learning, Interactive Simulation, Literature Review

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INTRODUCTION

Education in the 21st century requires a learning process that focuses not only on cognitive achievement but also on the development of critical, collaborative, creative, and communicative thinking skills. One of the greatest challenges in science education, particularly physics, is presenting abstract concepts in an engaging and easily understandable manner for students. Physics, as part of the natural sciences, has complex and abstract subject matter that is often difficult to grasp without visualization and hands-on experiments (1).

In many schools, limited laboratory facilities and learning media are major obstacles to physics education. This results in learning that is still dominated by lectures and memorization of formulas, causing students to become passive and unable to understand concepts in depth (2). As a result, students' academic performance in physics tends to be low, and interest in science has declined.

With the development of information technology, various digital-based learning innovations have been developed to address these challenges. One learning medium that has received widespread attention is PhET (Physics Education Technology), an interactive computer-based simulation developed by the University of Colorado Boulder. PhET allows students to conduct virtual experiments with attractive, interactive visualizations that respond to variable manipulation.

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Several studies have shown that the use of PhET in physics education can significantly improve learning outcomes. A study by Saputra et al. (2020) showed that the use of PhET simulation media in teaching Newton's laws resulted in a significant improvement in learning outcomes compared to conventional methods (4). A similar study by Yuafi and Endryansyah (2015) on vocational high school students showed an increase in learning outcomes scores from 6.96 to 87.58 after PhET -based learning (5). Even in the context of higher education, the use of PhET helps students understand school physics experiment concepts more deeply and meaningfully.

In addition, PhET media can also improve students' science process skills, especially when combined with scientific inquiry-based learning models. According to research by Aritonang et al. (2017), the combination of the scientific inquiry model and the use of PhET significantly improved the scientific process skills of junior high school students in Medan (7). The use of PhET also increased students' active participation in discussions, collaboration, and independent problem-solving activities.

However, the effectiveness of this media greatly depends on the teacher's skills in designing learning activities and facilitating student exploration. Without proper integration into learning strategies, PhET media will only become ordinary visual aids. Therefore, training for teachers and the provision of adequate technological infrastructure are necessary for the optimal implementation of this media.

Based on this background, this article aims to systematically review the literature discussing the influence of using PhET simulation media on students' physics learning achievement. This study is expected to provide a comprehensive overview of the effectiveness of PhET and serve as a reference in the development of innovative and technology-based physics learning strategies.

RESEARCH METHODS

This study uses a literature review approach with a qualitative descriptive method. This review was conducted to analyze in depth various previous studies that discussed the effect of using PhET (Physics Education Technology) simulation media on students' physics learning achievement. The type of literature review is narrative, which involves synthesizing findings from various relevant previous studies without conducting meta-statistical analysis (meta-analysis). This approach was chosen to provide a comprehensive understanding of trends, effectiveness, and the potential use of PhET media in the context of physics education. Data sources were obtained from national and international journal articles available online in the form of reputable scientific publications, conference proceedings, and officially published theses or dissertations. Article searches were conducted through several databases such as Google Scholar, DOAJ, Garuda, and ResearchGate.

The inclusion criteria used in the selection of articles are:

- Articles explicitly discuss the use of PhET media in physics education.
- Articles report student learning outcomes quantitatively or qualitatively.
- The research was conducted on junior high school, high school, or university students.
- The article was published between 2009 and 2024.
- The article is available in Indonesian or English.

The exclusion criteria are:

- Articles that only discuss non- PhET simulation media.
- Articles that do not provide data or information about student learning outcomes.

After the articles were collected and selected based on the above criteria, the following steps were taken:

1. Classification of articles based on educational level, physics material taught, learning models used, and learning outcome indicators.
2. Content analysis to identify the effects of PhET media on learning outcomes, including improvements in grades, conceptual understanding, and learning motivation.
3. Thematic synthesis, which involves summarizing findings based on common themes emerging from various studies, such as the effectiveness of the media, its advantages, limitations, and implementation strategies.

In this study, there were 8 (eight) articles that met the inclusion criteria and were used as analysis materials. These articles were sourced from accredited physics education journals, national seminar proceedings, and publications by science education lecturers/researchers

RESULTS AND DISCUSSION

This study identified eight research articles that met the inclusion criteria, namely studies that discussed the use of PhET (Physics Education Technology) simulation media in physics learning and measured its effect on student learning achievement. The results of these studies are summarized in Table 1 and analyzed thematically to see the impact of PhET use on student learning outcomes, conceptual understanding, and critical thinking skills.

Table 1. Summary of Research Results on the Use of PhET Media on Physics Learning Achievement

No	Author & Years	Topi cal / Materi al	Research Subject	Design Research	Key Results
1	Saputra et al. (2020)	Newton's Laws	High School in Kediri	Quasi-experiment	The posttest mean increased significantly ($p < 0.05$) after PhET use (4).
2	Yuafi & Endryansyah (2015)	Electrical circuits	State Vocational School 7 Surabaya	Experiment	The average score increased from 6.96 to 87.58 (5).
3	Zahara et al. (2015)	Static fluid	MAN Rukoh Banda Aceh	Pretest–Posttest control	PhET improves learning outcomes and critical thinking (2).
4	Teasy et al. (2021)	School physics experiments	Students of Palangka Raya University	Pre-experimental	N-Gain = 0.732 (high category) in concept understanding (6).
5	Aritonang et al. (2017)	Force and pressure	Junior High School Students in Medan	Experiment	Improving science process skills in the Scientific Inquiry + PhET model (7).
6	Gunawan et al.	Static	prospective	Quasi-experiment	Increase in concept mastery

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No	Author & Years	Topi cal / Materi al	Research Subject	Design Research	Key Results
	(2015)	electricity (Coulomb)	teacher students		68.6% (1).
7	Chairunisa (2024)	Elasticity and motion	Grade X students of Pontianak High School	Classroom experimental study	PhET classes outperform conventional ones in grades and participation (8).
8	Kharida et al. (2009)	Elasticity	UNNES Students	Literature study–experiment	PhET + PBL improves outcomes and collaboration skills (9).

Of the eight studies reviewed, all showed a positive impact of using PhET simulation media on student achievement in physics, both at the secondary and tertiary levels. The main findings included:

Of the eight studies reviewed, all showed a positive impact of using PhET simulation media on student physics learning achievement, both at the secondary and university levels. Key findings include:

1. Academic Score Improvement: All studies reported a significant increase in posttest scores following the use of PhET simulation media compared to conventional methods (4), (5), (8).
2. Improved Conceptual Understanding: PhET simulations were found to help students understand abstract physics concepts such as static fluids, forces, dynamic electricity, and Newton's laws in a more visual and practical way (6), (1).
3. Student Engagement and Independence: PhET media facilitates independent exploration and active student participation in the learning process, whether in problem-based learning, scientific inquiry, or blended learning models (7), (9).
4. Effectiveness in Various Learning Models: The use of PhET combined with scientific inquiry, problem-based learning, and exploratory-based worksheets shows high effectiveness in student learning outcomes and science skill development.

One of the main advantages of PhET is its ability to present abstract physics concepts visually and interactively. For example, in subjects such as static fluids, Coulomb's force, and electrical circuits, students often experience difficulties because these concepts are not easily observed directly in everyday life or in limited laboratory experiments. PhET simulations bridge this gap by providing graphical representations and dynamic animations, which help students build a more concrete conceptual understanding (1),(6)

According to Zahara et al. (2015), the use of PhET in static fluid learning not only significantly improves learning outcomes but also contributes to the development of students' critical thinking skills. This is due to the characteristics of PhET simulations, which require students to observe, interpret, and evaluate the results of the virtual experiments they conduct (2).

A study by Herlina and Jumadi (2020) showed that in electric field material, students who used PhET demonstrated higher ability in explaining the direction and strength of the field compared to in the control class (12). This was reinforced by Rachmadi and Rahayu (2021), who found that dynamic visualization in PhET can reduce misconceptions on the topics of electric current and voltage (13).

The quantitative effect of PhET media on improving student learning outcomes is also evident in the increase in pretest and posttest scores in various studies. For example, in a study by Yuafi & Endryansyah (2015), 10th grade students at SMKN 7 Surabaya experienced an increase in their average scores from 6.96 to 87.58 after participating in learning using PhET (5). Similar findings were reported by Saputra et al. (2020), who demonstrated that the use of PhET simulations was significantly more effective than lecture-based methods in improving students' final grades on Newton's Laws material (4).

PhET simulations give students the opportunity to ask questions, make predictions, test hypotheses, and analyze results—all essential elements of scientific process skills. Other research shows that students who use PhET in inquiry-based learning experience a significant increase in critical thinking skills compared to control groups (14).

This suggests that PhET media not only improves immediate understanding, but also has the potential to improve long-term retention of subject matter, as students construct knowledge through more active and meaningful learning experiences.

A study by Chairunisa (2024) highlights students who learned using PhET media showed higher engagement, both in group discussions and in independent exploration of the available simulations. This media allows students to experiment with various parameters on their own, observe the results, and draw conclusions, without being limited by time and space as in conventional laboratory experiments (8).

According to the constructivist approach, effective learning occurs when students actively construct their own knowledge through direct experience. PhET aligns well with this principle as it provides a learning environment that facilitates exploration, manipulation of variables, and reflection, as emphasized in the scientific inquiry learning model (1).

Motivation is a key factor in improving learning outcomes. PhET not only enhances understanding but also encourages active student engagement due to its exploratory and interactive nature. Research by Parong and Mayer (2018) concluded that simulations that allow free exploration, such as PhET, can increase students' curiosity and intrinsic motivation (14).

PhET media also demonstrates high flexibility in its application. Several studies have combined PhET with other pedagogical approaches, such as problem-based learning, guided inquiry, or the use of exploration-based worksheets. As a result, this combined learning model has shown significant improvements in student learning outcomes and collaborative skills (9).

PhET media is flexible and can be combined with various learning models such as Problem-Based Learning, Project-Based Learning, Blended Learning, and Flipped Classroom. In a study by Haryanto and Subali (2021), the implementation of a PhET -based flipped classroom model resulted in improved long-term retention among high school students in learning about rotational dynamics (16).

This integrative model supports the notion that the success of PhET media does not only depend on the technology, but also on the instructional design used by teachers in managing it in the classroom. Thus, teacher training in the development of PhET -based teaching tools is very important to maximize the potential of this media in learning.

Although there is ample evidence of its effectiveness, the implementation of PhET also faces a number of challenges, especially in schools with limited internet access or technological devices. Not all teachers have adequate ICT skills to make optimal use of this media, so professional training and infrastructure support are needed to ensure that PhET can be integrated evenly and sustainably in all educational units.

CONCLUSION

Based on the results of data analysis and discussion, it can be concluded that the implementation of the *Scientific Inquiry* learning model has a positive impact on improving students' science process skills in physics learning. Students who participated in learning through the scientific inquiry approach demonstrated higher achievements in science process skills compared to those who received instruction through direct teaching methods.

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