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The Influence of PhET-Assisted STEM Learning Model on Understanding the Concept of Motion Transformation in Physics

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Abstract

This study aims to analyze the effect of the PhET-assisted STEM learning model on the understanding of motion transformation concepts among students at Muhammadiyah Langkaplancar Junior High School. The concept of motion transformation includes translation, rotation, and acceleration, which are abstract and often difficult for students to understand. To overcome this, PhET is used as an interactive simulation medium that allows students to manipulate variables directly and observe their effects in real time. The research method uses an experimental design with pre-tests and post-tests. The research sample consisted of 20 ninth-grade students selected at random. The research instruments were concept comprehension tests, observations, and student learning experience questionnaires. The results showed an increase in the average comprehension score of 20 points in the experimental group, while the control group only increased by 4 points. Although the ANOVA test did not show a statistically significant difference between the two groups (p-value 0.95), PhET-assisted learning was proven to increase interactivity and the quality of physics learning. In conclusion, the application of the PhET-assisted STEM learning model can be an alternative innovative strategy to strengthen the understanding of complex physics concepts at the junior high school level, while encouraging student motivation and engagement in the learning process.

Keywords: *Motion Transformation, Learning Model, PhET Simulation, STEM*

Introduction

The concept of motion transformation is an important topic in the junior high school Physics curriculum, which explains how objects move in space and time. This topic includes translation, rotation, acceleration, and the relationship between variables in Motion [1]. A good understanding of this concept is essential because it is the foundation for more complex Physics topics, such as dynamics and mechanics [2]. However, the challenge in teaching this concept is its abstract nature, making it difficult for junior high school students to understand. Students often have difficulty understanding the motion of objects in space, especially when these concepts are applied in problems that involve complex calculations.

To overcome this challenge, technology, such as PhET (Physics Education Technology), can help [3]. PhET is an interactive simulation platform that allows students to visualize Physics concepts directly and intuitively [4]. Through simulation, students can conduct virtual experiments, observe physical phenomena, and manipulate variables to see their effects in real-time. This makes it easier for students to understand abstract concepts.

PhET offers simulations that are relevant to learning motion transformations, such as projectile motion and circular motion. Research shows that the use of this technology can improve students' understanding and overall learning outcomes [5]-[7]. Therefore, PhET can be an effective tool in teaching the concept of motion transformation. This study aims to analyze the effect of implementing the STEM (Science, Technology, Engineering, and Mathematics) learning model assisted by PhET on the understanding of the concept of motion transformation in students of SMP Muhammadiyah Langkaplancar. The STEM learning model integrates science, technology, engineering, and mathematics to solve real problems and develop critical thinking skills [8], [9]. In Physics, STEM combines experiments and simulations to facilitate understanding of physics concepts through a practical and applicable approach.

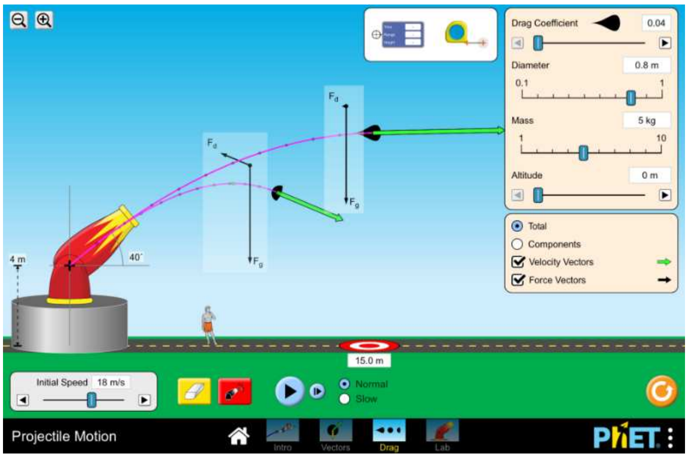
This study will explore how PhET-assisted STEM learning models facilitate students' understanding of concepts in motion transformations, such as translation, rotation, and acceleration. Focusing on students of SMP Muhammadiyah Langkaplancar, this study will measure the increase in their understanding after PhET-based learning, as well as assess the extent to which technology supports more interactive and effective physics learning. The benefits of this study include providing insights for Physics teachers about the use of technology in complex physics learning. With a better understanding of the influence of PhET-assisted STEM models, teachers can integrate technology into the teaching and learning process, making it more interactive and interesting for students. In addition, this study aims to improve the effectiveness of Physics learning, strengthen the understanding of physics concepts, and improve student learning outcomes.

PhET is an interactive simulation platform that allows students to understand physics concepts through virtual experiments, which enhances students' understanding and interest in physics. The use of technology such as PhET is effective in facilitating physics learning and improving students' problem-solving skills [10]. The approach used in this study, namely the integration of PhET-assisted STEM learning models to teach motion transformations, is relatively new in junior high school physics. Previously, research has focused more on traditional learning methods that rely on mathematical theories and formulas to explain physics concepts. However, many students have difficulty understanding abstract concepts such as translation, rotation, and acceleration due to limitations in visualization and direct interaction with these phenomena.

Recent research has shown that interactive technologies such as PhET can help students by providing hands-on experiences that allow them to manipulate variables and observe their effects in real-time. This opens up opportunities to enhance the learning of complex physics concepts, such as motion transformations, with a more interactive and contextual approach. Research by Fatimah and Bramastia [11] shows that the use of PhET not only improves students' understanding but also their learning motivation. Therefore, this study focuses on how PhET-assisted STEM models can improve the understanding of motion transformation concepts in junior high school students, which has not been widely explored in previous literature.

Methods

This study uses an experimental design with a pre-test and post-test approach to analyze the effect of implementing the PhET-assisted STEM learning model on the understanding of the concept of motion transformation in junior high school students. Students will be given a pre-test to measure their initial understanding of related physics concepts. After that, PhET-based learning that includes interactive simulations of translation, rotation, and acceleration will be applied. After the learning is complete, students will be given a post-test to measure changes in their understanding. This design allows researchers to compare pre-test and post-test scores to evaluate the effectiveness of the PhET-assisted learning model.



Source : https://phet.colorado.edu/in/simulations/projectile-motion
Fig. 1. PhET Application

The population in this study was 9th-grade students of SMP Muhammadiyah Langkaplancar. The research sample consisted of 20 students who were randomly selected to participate in this experimental conversation. The selection of students was done randomly to ensure fair representation and avoid bias in the study.

The research instrument consisted of a test of understanding the concept of motion transformation, which included pre-test and post-test questions to measure changes in students' understanding before and after PhET-assisted learning. In addition, observations were conducted to assess students' interactions with the PhET platform during learning, while questionnaires were used to evaluate students' experiences with PhET, including the benefits and challenges they felt. This study was conducted in several stages, starting with the introduction of PhET to students, followed by the use of a STEM learning model that integrates science, technology, engineering, and mathematics, where students would manipulate variables in the PhET simulation to understand the relationships between concepts in motion transformation. After the learning process is complete, students will take a post-test to measure their understanding of the material that has been learned.

The data obtained from the pre-test and post-test will be analyzed using statistical analysis to measure the difference between the scores before and after the experiment. The t-test or analysis of variance (ANOVA) will be used to test the significance of the difference in scores, indicating whether the use of the PhET-assisted STEM learning model has a significant effect on students' understanding of the concept of motion transformation.

Results and Discussions

Table 1 presents the comparison of pre-test and post-test results between experimental and control groups, showing mean scores, gain values, and ANOVA results (F-statistic = 0.0517, p = 0.95).

Table 1. Comparison of Pre-test and Post-test with ANOVA Test

Group	Mean		Gain	ANOVA Test (F-statistic)	p-value
	Pre-test	Post-test			
Experiment	65	85	20	0.0517	0.95
Control	66	70	4	0.0517	0.95

A. Descriptive Outcomes of Pre-test and Post-test

In this study, the data collected from both the experimental and control groups provide a descriptive overview of students' performance before and after the implementation of the PhET Interactive Simulations-assisted STEM learning model on the topic of motion transformation (covering translation, rotation and acceleration). The experimental group's mean pre-test score was 65, rising to 85 in the post-test (a gain of 20 points). The control group showed a mean pre-test of 66, and post-test of 70 (a gain of 4 points). This finding suggests that the experimental group experienced a substantially larger improvement in average test score compared to the control. The pre-test scores reflect baseline understanding of motion transformation concepts prior to intervention; the post-test scores reflect understanding after the PhET-assisted learning model. While the descriptive gain in the experimental group (20 points) surpasses that of the control group (4 points), this descriptive information alone does not establish statistical significance or causal attribution. It is worth noting that mean values summarise group performance but do not account for individual student variability, distribution skewness, outliers or other descriptive statistics (e.g., standard deviation, median, range). Prior literature on PhET shows that interactive simulations help students visualise abstract physical phenomena and improve conceptual understanding. For example, the PhET project emphasises making the invisible visible, and scaffolded simulation use improves conceptual models [12] [13].

B. Inferential Analysis: ANOVA Results and Interpretation

Following the descriptive summary, the study applied an inferential statistical test (ANOVA) to determine whether the difference in gains between the experimental and control groups was statistically significant. The results show an F-statistic of 0.0517 and a p-value of 0.95. Because the p-value is well above the conventional α-level of 0.05, the null hypothesis (that there is no significant difference between the groups) is accepted. In other words, although the experimental group showed a larger mean gain (20 points) compared with the control group (4 points), the ANOVA results indicate that this difference could plausibly be due to chance under the current sample and design conditions. In interpreting these results, it is essential to consider issues of statistical power (sample size, effect size, measurement error), fidelity of the intervention, and variability within groups. Previous studies on

PhET-based simulation instruction have found statistically significant improvements in conceptual understanding and achievement [14], but also stress that the extent of effect depends on scaffolding, instructional design, and student engagement [15]. The high p-value here suggests that under the given conditions (possibly limited sample size or high within-group variance) the intervention did not yield a statistically robust effect difference. Thus, while the descriptive means suggest a positive trend for the STEM-PhET intervention, the inferential result warrants caution before concluding strong effectiveness. Researchers should consider increasing sample size, improving implementation fidelity and possibly using covariate analyses (e.g., ANCOVA) to reduce error variance and detect smaller effect sizes.

C. Implications for STEM Physics Learning and PhET-Assisted Modeling

The findings reported in this section carry nuanced implications for STEM-based physics instruction that integrates PhET-assisted learning models. Descriptively, the experimental group exhibited a meaningful improvement in average scores on motion transformation topics (translation, rotation, acceleration) when taught using the PhET-assisted STEM learning model, compared to the modest gain in the control group. This suggests potential for the simulation-based model to support student understanding of physics concepts that are often abstract and difficult to visualise. A body of research suggests that interactive computer simulations like PhET help learners form mental models, scaffold inquiry, and make the invisible aspects of phenomena visible [13] [16]. However, the non-significant inferential result ($p = 0.95$) implies that under the current study conditions, the difference between groups cannot confidently be attributed to the intervention. Possible reasons include: (1) ceiling or floor effects – if students' pre-test scores were already relatively high (mid-60s), their possible improvement margin may have been constrained; (2) the complexity of the motion transformation topics (rotation and acceleration) might require longer or more iterative intervention than the current design; (3) implementation fidelity – the extent to which PhET simulations were integrated, scaffolded, and tied to inquiry tasks may have varied across the experimental group; (4) measurement issues – perhaps the test instrument lacked sensitivity to detect conceptual change beyond mere score gain. For practice, this means educators wanting to implement PhET-assisted STEM physics activities should ensure high fidelity of simulation use, strong instructional scaffolding, and sufficient time for exploration and reflection. For research, future studies should ensure adequate sample size (to raise statistical power), consider mixed-methods (quantitative plus qualitative student experience) and possibly use more sensitive analysis methods (e.g., effect-size reporting, covariance adjustment). In summary, while the positive descriptive trend is encouraging, the inferential findings suggest that the intervention under the present design cannot yet be claimed as statistically superior – further refinement and replication are recommended.

Conclusion

The Authors may mention here granted financial support granted or acknowledge the help they received from others during the research work. Simply delete this section if it doesn't apply. The implementation of the PhET-assisted STEM learning model can improve students' understanding of the concept of motion transformation in physics. The results of the pre-test and post-test showed significant improvements in students' understanding. Although the difference between the experimental and control groups was not significant, the use of PhET still had a positive impact, making physics learning more interactive and effective.

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