



The Effect of Using PhET Simulation in E-Modules on Students' Learning Outcomes in Electromagnetism

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Abstract: This study aims to determine the effect of using PhET (Physics Education Technology) simulations on e-modules covering electric and magnetic materials on the learning outcomes of students at SMA N 2 Muhammadiyah in the 2023/2024 academic year. The type of research used is a descriptive method with a quantitative approach. The population of this study is all students in grade XII of SMA N 2 Muhammadiyah, with a total of 90 participants. The sampling technique used was cluster random sampling, and grade XII was selected as the class to be tested. Grade XII was taught using the direct learning model with the PhET (Physics Education Technology) simulation media. After obtaining the final test results for the class, which were homogeneous and normally distributed, the research hypothesis was tested using a paired-sample test with a significance level of 5% and obtained a Sig. (2-tailed) value of 0.000, so it can be said that the Sig. value is < 0.05 . Based on the results, it can be concluded that there is an effect of using PhET (Physics Education Technology) simulation media on students' physics learning outcomes.

Keywords: Electromagnetism; High school; Learning outcomes; Module; PhET simulation

Introduction

Education is an important factor in the development of a country. Through education, students are expected to be ready to face the era of globalization that continues to develop today. This is in line with one of the objectives of education in the independent curriculum. The independent curriculum upholds the concept of independent learning, which is to provide freedom and independence for students and schools so that students can explore their respective interests and talents more deeply (Purnawanto, 2022). In general, the objective of learning is to improve knowledge, skills, and attitudes in a balanced manner (Wiyono et al., 2024).

One important aspect of the educational process is improving the quality of learning (Amanah et al., 2023). Improving the quality of learning in schools depends not only on the quality of teachers and learning

materials, but also on how accurate students' understanding of the material being studied is (Rasam et al., 2019). Analytical thinking skills play an important role in solving physics problems (Mahzum et al., 2024). In 21st-century learning, skills are required that demand students to be able to practice various skills in learning activities, such as critical thinking, innovation, and problem solving through analysis and negotiation, effective communication skills, and collaboration, known as 4C skills (Putri & Mufit, 2023).

Based on the results of observations, several problems were found in physics learning, including that students still think that physics is difficult, has many formulas, and is boring. In addition, students are less active in asking questions when they do not understand the explanations given by the teacher. This results in low learning outcomes for students. Understanding physics concepts will be difficult for

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students if they only listen to and take notes on the teacher's explanations.

According to research conducted in the field of physics education in recent years, one of the main sources of difficulty in physics lessons is due to students' misunderstanding of the physics concepts being studied (Samudra et al., 2014). Some common difficulties often experienced in using physics concepts are difficulty understanding concepts, difficulty identifying the concepts used, and difficulty applying concepts to existing questions (Charli et al., 2018). One learning medium that can be used by students to support their physics learning outcomes is electronic-based teaching materials, also known as e-books or e-modules (Pratiwi et al., 2023).

E-modules have several advantages, including helping students develop their ability to interact with their environment and learning materials (Hidayah et al., 2022; Wiyono et al., 2022; Nazhifah & Wiyono, 2023). Electronic teaching materials have the potential to substantially improve student learning outcomes, which is in line with the general trend of technological advancement (Derrydamawati et al., 2024). The advantages of e-modules are that they can increase student motivation, enable the assessment of student success levels, provide more structured learning materials, and allow for changes in the display format (Nadia et al., 2024; Haryanti et al., 2025). Thanks to technological advances, electronic teaching materials have become more diverse and interesting for students to learn from (Hasan et al., 2025).

The use of e-modules can utilize PhET simulation media to support learning (Doyan et al., 2023a, 2023b). Learning supported by PhET visualizations can encourage students' analytical, evaluative, and synthesizing skills (Kadek et al., 2025). PhET is educational media software that contains various physics learning simulation materials for classroom teaching and can also be used for independent learning (Khoiriyah et al., 2015; Hariyanto, 2017; Meadows & Caniglia, 2019; Saputra et al., 2020; Muzana et al., 2021; Nurdini et al., 2022; Lestari et al., 2024). The PhET application as a virtual laboratory was created to present various problem-solving activities carried out during the learning process in the classroom (Mahzum et al., 2024). This PhET software is capable of displaying abstract physics animations that cannot be directly observed by the human eye, such as atoms, electrons, photons, and magnetic fields (Perkins et al., 2012). With the PhET application, students can conduct independent or group experiments in problem solving in the laboratory and receive quick and accurate responses from the computer (Darrah et al., 2014). PhET media is a research-based interactive simulation

of physical phenomena that can support interactive and constructivist approaches, provide feedback, and convey information in physics learning (Nugroho et al., 2025). Simulating PHET as a means of experiment simulation can encourage students to conduct their own experiments at home, thereby improving their understanding of the concepts (Agustina et al., 2024).

Based on previous research, the use of PhET simulation media as a learning tool has been extensively studied and shows a significant success rate. The use of PhET as a learning tool and its results show that students are more active in the learning process (Abadi et al., 2023). According to Marliani et al. (2024) the use of PhET media on critical thinking skills and physics learning outcomes shows an improvement in students. Research conducted by Nurhayati et al. (2014) states that the learning outcomes of students taught using the demonstration method assisted by PhET animation software are better than the learning outcomes of students using conventional methods. The difference in student learning outcomes was due to the fact that the demonstration method assisted by PhET animated software media attracted students' attention to follow the lessons in class, and students did not only imagine the physics concepts taught by the teacher in the abstract. Similarly, research conducted by Yuafi & Endryansyah (2015) concluded that there is an effect of applying a direct learning model that uses Physics Education Technology (PhET) learning media on student learning outcomes because it can create active, creative, efficient, and enjoyable learning.

Based on the results of interviews conducted by the researcher with a physics teacher at Muhammadiyah Palembang High School, Mrs. Devi Ardiantini, S. Pd., who stated that the average score for the electromagnetic physics test was still low at 51. The teacher's preliminary explanation was that there were several problems in physics learning, including that students still considered physics difficult, full of formulas, and boring. Students find it difficult to understand the physics concepts explained by the teacher. This results in low student learning outcomes.

Based on the above description, the author is interested in applying the use of PhET simulations in teaching physics, particularly electromagnetic material. The author chose this material because, based on research conducted by Yustiandi et al. (2023), it was concluded that students' difficulties in learning electromagnetic induction are as follows. First, students have difficulty determining the direction of the induced current in the coil. Second, students have difficulty determining the induced current in the loop. Third, students have difficulty understanding the electromotive force.

Electromagnetic material has many abstract concepts and calculations that are considered difficult for high school students to understand. The electromagnetic material studied in this research includes the concepts of magnetic fields, magnetic induction, and magnetic force.

Based on the reasons outlined above, the author intends to conduct research on "The Effect of Using PhET Simulation in E-Modules on Students' Learning Outcomes in Electromagnetism" at Muhammadiyah High School in Palembang in the 2024/2025 academic year.

Method

The research design and method used in this research is a descriptive method with a quantitative approach. Descriptive research is conducted by seeking information related to existing phenomena, clearly explaining the objectives to be achieved, planning how to approach them, and collecting various types of data presented (Sriyanti et al., 2025). Data are presented in the form of numerical descriptions as a tool for analyzing information about what is to be known in accordance with the data collection techniques or procedures as material for preparing reports (Jayusman & Shavab, 2020).

This study was conducted by presenting facts that show the effectiveness of using PhET simulations in learning (Amanah et al., 2023). The research location was deliberately chosen based on factors that supported conducting the study at that school. This research was conducted at SMA N 2 Muhammadiyah, South Sumatra. The research population consisted of all 90 grade XII students at SMA N 2 Muhammadiyah in the 2023/2024 academic year, divided into 3 classes. The sampling technique used in this study was cluster random sampling. The sample was taken randomly from individual groups, in this case, grade XII classes available at SMA N 2 Muhammadiyah. The sample in this study was grade XII with 34 students as the sample. This study used a one group pretest-posttest design, which is a study that includes a pretest before the treatment and a posttest after the treatment, as shown in the following figure.

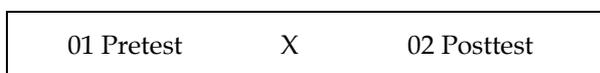


Figure 1. One group research design pretest-posttest

Explanation:
 01 = Pre-test
 02 = Post-test

X = Learning model accompanied by virtual practicum using the PhET Simulation application

This study consisted of three stages: preparation, implementation, and processing. The following is a description of each stage.

First, the preparation stage was carried out, which began with observing the school, requesting research permission, and discussing the research schedule and the schedule for the teacher to deliver the material. The research subjects were determined, and a research instrument in the form of an e-module was created with the help of PhET simulation. The second stage is the implementation stage, where 12th grade students are given e-module after they have studied the material on magnetism beforehand, and then the data from the e-module is collected. The final stage is the processing stage. At this stage, data processing and analysis are carried out, and conclusions are drawn based on the data obtained in the previous stages.

Data collection techniques were carried out using test results (pre-tests and post-tests) and observation data. To see the effect of using PhET simulations in e-module, the data analysis techniques used in this study were descriptive analysis and inferential analysis. Descriptive analysis in this study was used to describe student learning outcomes through the average scores of each student formed by the PhET Simulation media and to describe the initial ability scores of students obtained based on the pre-test and post-test results converted into N-Gain (normalised gain). Inferential analysis was conducted using a paired samples test. Previously, a prerequisite inferential statistical test was conducted in the form of a normality test (to ensure that the data was normally distributed) aimed at determining whether the sample data could be validly generalised to the population and a homogeneity test to ensure that the data group variance was the same.

The effectiveness test data analysis was conducted using N-gain analysis with the normalised gain equation according to Hake (1998).

$$(g) = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{max}} - S_{\text{pre}}} \tag{1}$$

S_{pre} is the score obtained before treatment, is the score obtained after treatment, and S_{max} is the maximum score that can be obtained. The N-gain score obtained is interpreted according to Hake (1998) in accordance with the following table.

Table 1. N-gain score category

| Criteria of N-gain value | Category |
|-----------------------------|----------|
| $N\text{-gain} \geq 0.7$ | High |
| $0.7 > N\text{-gain} > 0.3$ | Medium |
| $N\text{-gain} < 0.3$ | Low |

Result and Discussion

Descriptive analysis in this study aims to describe students' initial abilities before treatment (pre-test) and their final abilities after treatment (post-test). The data analyzed were obtained from pre-tests and post-tests given to students to see the effect of using PhET Simulation media on students' mathematics learning outcomes both before and after treatment.

The data were analyzed descriptively to obtain the mean, minimum score, maximum score, standard deviation, and variance. First, the pre-test and post test data were analyzed and converted into N-Gain scores, as shown in Table 1.

Table 2. List of classifications and frequency percentages of N-Gain learning outcomes for the pretest and posttest groups

| Normalized Gain | Classification | Number of Student | Percentage Frequency (%) |
|-------------------|----------------|-------------------|--------------------------|
| $0.00 < g < 0.30$ | Low | 4 | 11.76 |
| $0.30 < g < 0.70$ | Moderate | 10 | 29.41 |
| $0.70 < g < 1.00$ | High | 20 | 58.83 |
| Total | | 34 | 100 |

Based on Table 1, the data obtained is the N Gain value in class XII in the "High" classification, namely the interval $0.70 \leq g \leq 1.00$, the "Medium" classification with the interval $0.30 \leq g \leq 0.70$ and the "Low" classification with the interval $0.00 < g < 0.30$. Meanwhile, the number of students in the "high" classification is 20 people or with a frequency of 58.83%, the "medium" classification is 10 people with a frequency of 29.41%, and the "low" classification is 4 students or with a frequency of 11.76%.

Table 3. Paired samples statistics results

| Pair 1 | | Mean | N |
|--------|----------|-------|----|
| Pair 1 | Pretest | 63.35 | 34 |
| | Posttest | 88.88 | 34 |

The table above shows that the average learning outcomes of students have improved. From a pretest score of 63.35 to a posttest score of 88.88. There is a difference in the average scores between the pretest and posttest after using the PhET simulation as part of the e-module assignment.

The table above shows that the average learning outcomes of students experienced a significant increase in scores. From a pretest score of 63.35 to a posttest learning outcome score of 88.88. The percentage of learning outcomes increased by 25.53 from the pretest to the posttest after using the PhET simulation contained in the e-module.

Paired Samples Test Results

Table 4. Paired samples test

| Pair 1 | Pretest-Posttest | Mean | t | Df | Sig. (2-tailed) |
|--------|------------------|--------|--------|----|-----------------|
| Pair 1 | Pretest-Posttest | -25.53 | -9.877 | 29 | .000 |

It is known that the Sig. (2-tailed) value is $0.000 < 0.05$, so it can be concluded that there is a significant difference between learning outcomes before and after using PhET simulations as part of the e-module.

Meanwhile, students admitted that they were more interested and motivated in working on the e-module with the help of PhET simulations. Through PhET simulations, students can easily apply electromagnetic concept formulas.

The PhET simulation specifically for electromagnetism provides two types of simulations: The first simulation uses formulas to determine the strength of the magnetic field and the direction of the magnetic lines through the movement of a magnetic compass and a magnetic bar. The second simulation is to determine the magnitude of magnetic induction power by changing the speed of the generator and changing the number of wire coil windings. With the help of this PhET simulation, students are not only interested in the features of the simulation, but they will also find it easier to understand the concept of electromagnetism in a more contextual way, which can be observed directly through the simulation. More importantly, in the end, students will find it easier to understand the overall material on electromagnetism.

Furthermore, based on the N-Gain pretest and posttest results, 20 out of 30 students achieved high scores, meaning that more than 58,83% of students learned more effectively. Based on the hypothesis test conducted using the SPSS programme, the results of the Paired Sample Test Statistics analysis obtained a sig. (2-tailed) value of $0.000 < 0.05$. Thus, it can be concluded that there is a significant effect of the use of PhET Simulation media on the physics learning outcomes of students in class XII at SMA 2 Muhammadiyah.

The results of this study are in line with previous research conducted by Hasanah et al. (2025), which states that the use of PhET simulations in guided inquiry learning of wave material has a significant effect on learning outcomes, supported by an average N-Gain test result of 0.74 and a difference in the increase in free-test and post-test results of 20.2. Furthermore, Abdi et al. (2021) in their research entitled "The Application of a PhET Simulation-Based STEM Approach to Improve Student Understanding in Physics Lessons" concluded that PhET simulations can improve students' understanding of physics lessons with an average N-Gain test result of 0.5 and a difference of 17.4 between the free-test and post-test

results. These research results are also in line with those found by Aina & Hariyono (2023), who stated that the application of PhET simulations in physics learning can improve the science abilities of high school students, supported by an average N-Gain test result of 0.718 and a difference between the free-test and post-test of 49.91.

Conclusion

The use of PhET simulations as media in e-module in grade XII is effective in helping students better understand and improve their understanding of the concept of magnetism. This can be seen from the average learning outcomes of students in the post test where they used PhET simulation media as learning media. The percentage of learning outcomes increased by 25.53 from the pre-test to the post-test results. Based on these research results, the researcher suggests that further research be conducted with a larger sample size at the high school level. This can be used as a comparison of the effect of using PhET on student learning outcomes.

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Author Contributions

F.K., I., and W.K., Conceptualization, methodology, writing-original draft, supervision, data curation, formal analysis, visualization, writing-review and editing. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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