

The effect of Physics Education Technology (PHET) Interactive simulations on improving the science achievement

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Abstract

Science education plays a crucial role in developing learners' critical thinking and problem-solving skills. Yet, the Philippines continues to struggle with low science performance, as reflected in recent PISA results. To address these challenges, digital tools such as Physics Education Technology (PhET) Interactive Simulations have been identified as promising alternatives for supporting inquiry-based learning. This study aimed to determine the effectiveness of PhET Interactive Simulations in improving the science achievement of Grade 8 students, particularly in the topic Particle Nature of Matter. A quasi-experimental non-equivalent pretest–posttest design was utilized with sixty Grade 8 students from Magsaysay National High School. Thirty students comprised the control group taught using a conventional teaching method, while thirty were assigned to the treatment group using PhET interactive simulations. Pre-test and post-test instruments from the DepEd Science 8 module were administered, and data were analyzed using descriptive statistics, paired-samples t-tests, and independent-samples t-tests. Findings revealed that both groups exhibited significant improvement from pre-test to post-test, indicating that learning occurred regardless of instructional approach. Although the PhET group attained a higher mean score, the difference in post-test performance between the groups was not statistically significant. The results suggest that while PhET Interactive Simulations effectively support learning, their impact is comparable to well-delivered conventional teaching. This highlights the tool's value as a supplementary resource rather than a replacement, offering meaningful insights for educators, school administrators, and curriculum developers seeking to enhance technology-supported science instruction. Therefore, the curriculum developers may integrate simulation-based activities within the science curriculum to promote inquiry-based and experiential learning.

Keywords: PhET interactive simulation, science achievement, conventional teaching, quasi-experimental research, Philippine science performance

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1. Introduction

To understand the natural world, think critically, and address complex real-life issues, science education is central to preparing learners with the competencies needed. As stated in the study by Pinar et al. (2025), to address global challenges in health, the environment, climate change, and sustainable development, enhancing creativity, innovation, and problem-solving skills is vital. For students, learning science enhances problem-solving abilities and prepares them to participate actively in a rapidly changing, knowledge-driven society. Despite its importance, the Philippines continues to face challenges in science education. According to DepEd (2019), the Philippines scored 357 in science on the 2018 Programme for International Student Assessment (PISA), which was significantly lower than the OECD average score of 489. During the PISA 2022, the Philippines' score slightly dropped to 356, indicating no improvement in science (OECD, 2023). This suggests that the junior high schools in the Philippines are approximately five to six years behind their global peers in terms of science learning. In DepEd's report on the Philippines' low performance in Science learning, several factors affect this issue. One reason is the lack of resources and facilities. According to OECD (2023), Filipino students have the lowest access to science laboratories and practical learning materials among OECD peers. The inadequate resources may limit the student's ability to learn and engage in hands-on and inquiry-based learning that is needed in science learning. Thus, the subject may often be taught in an abstract and lecture-based manner, which makes it difficult for the students to connect the theories to real-world problems.

According to the World Bank (2024), a lack of learning resources may prevent teachers from delivering quality instruction and from improving student engagement. Bernardo et al.'s (2023) study shows that insufficient resources may contribute to inequalities. Thus, students from low-resource backgrounds are less likely to participate in meaningful science activities. One promising intervention is the use of PhET Interactive Simulations (PhET Sims) developed by the University of Colorado Boulder. These are free, research-based digital simulations that allow students to manipulate variables, visualize abstract concepts, and actively engage with scientific phenomena in a safe, interactive environment (PhET, 2023). By integrating PhET simulations into classroom instruction, teachers can shift from rote memorization toward inquiry-based and experiential learning.

Several studies have demonstrated the effectiveness of PhET in improving students' science achievement and motivation. In the Philippines, Dy et al. (2024) reported that PhET-based instruction significantly enhanced learners' performance in science compared to traditional methods. Fuentes et al. (2025) likewise found that Grade 7 students showed marked improvement in understanding the phases of matter after exposure to PhET simulations. Similarly, Omoy (2022) observed positive effects on Grade 10 students' ability to balance chemical equations. However, not all findings are consistent; a study by De Torres et al. (2023) showed no significant difference between PhET-assisted and conventional teaching in specific topics, suggesting that its effectiveness may depend on contextual factors such as teacher facilitation and learner readiness. While evidence supports the benefits of PhET, studies in the Philippine context have mostly focused on specific topics and varying grade levels, leaving limited investigation into its effects on Grade 8 students' understanding of the particle nature of matter. Since this concept is foundational in physics and chemistry, exploring how digital simulations affect student achievement in these fields is crucial. Moreover, very few localized studies have been conducted in public secondary schools where resources are limited and class sizes are large, making the integration of innovative tools more challenging but potentially more impactful. In response to this gap, the present study seeks to determine the effect of PhET Interactive Simulations on the science performance of Grade 8 students about the particle nature of matter in Magsaysay National High School.

Research Objectives - The research objectives for this study were to (1) Determine the level of physics

education technology (PhET) interactive simulations in grade 8 students; (2) Assess the performance of grade 8 students in science using conventional teaching and interactive simulation; (3) Determine the significant difference between the performance of grade 8 students in science using conventional teaching and interactive simulation; and (4) Determine the significant relationship between the level of physics education technology (PhET) interactive simulations and the performance of grade 8 students.

Significance of the Study - The findings of this study will benefit various stakeholders in the field of education. Students will gain a deeper understanding of abstract concepts through interactive learning, while science educators will receive evidence of the effectiveness of creative approaches that enhance lesson engagement and impact. Parents may benefit indirectly, as improvements in students' learning outcomes contribute to better academic performance and future opportunities for their children. For school heads and DepEd officials, the study offers insights that may guide decisions on adopting technology-based strategies and integrating digital tools into classroom instruction. Likewise, curriculum developers may use the results to revise and enhance learning materials, aligning them more closely with 21st-century skills. Finally, future researchers can use this study as a reference for further exploration of simulations and other digital resources to advance science education.

Scope and Delimitation of the Study - This study examined the effect of Physics Education Technology (PhET) interactive simulations on the science achievement of Grade 8 students. Specifically, it compared the performance of students exposed to PhET-based instruction with that of students taught using conventional teaching strategies. The respondents were the Grade 8 students of Magsaysay National High School, located at Magsaysay, Occidental Mindoro, during the school year 2025–2026. The study utilized learning sessions, pre-tests, and post-tests as the primary tools in assessing student performance. The study was limited to one grade level, two sections, one subject area, and one campus, focusing only on the topic of Particle Nature of Matter. Other factors that may affect student performance, such as gender, socioeconomic status, and prior academic ability, were not included. The research employed a quasi-experimental design without random assignment of participants to groups, which may restrict the extent to which results can be generalized to other settings or populations.

2. Methodology

Research Design - This study employed a quasi-experimental design, specifically the non-equivalent groups pretest–posttest design. Similar to a real experiment, a quasi-experimental design is a research methodology that aims to establish a cause-and-effect relationship between an intervention (the independent variable) and an outcome (the dependent variable). The lack of random assignment of participants to the treatment (PhET Interactive Simulation) and comparison (traditional instruction) groups distinguishes it (Gopalan & Rosinger, 2020). The groups are frequently pre-existing or intact entities, such as the two Grade 8 sections at Magsaysay National High School. They are therefore assumed to be potentially different or "non-equivalent" at the beginning of the study due to the lack of randomization. They were used as the control group for conventional teaching and the other as the experimental group for the PhET Interactive Simulation. Both groups were given a pre-test and a post-test based on the DepEd Science 8 Self-Learning Module. The difference in the pre-test and post-test scores was analyzed to determine the effectiveness of PhET simulations compared to conventional teaching.

Respondents of the Study - The respondents in this study were Grade 8 students at Magsaysay National High School during the Academic Year 2025–2026. They were chosen because the topic Particle Nature of Matter was included in their science lessons for the mentioned school year. Their participation was considered appropriate since the subject matter was directly aligned with the objectives of this research. To select respondents, the researchers employed purposive sampling to identify groups relevant to the research focus. A total of sixty (60) students were included, with thirty (30) students assigned to each setup. The two groups were drawn from specific Grade 8 sections, and random sampling within these sections was used to ensure unbiased distribution of participants across the treatment and control groups.

Research Instrument - The main instrument used in this study was the pre-test and post-test adopted from the

Department of Education (DepEd) Science 8 Self-Learning Module (SLM). These tests measured students' prior knowledge and learning gains in the topic of Particle Nature of Matter. The pre-test, composed of fifteen (15) items, assessed the students' baseline understanding, while the post-test of corresponding items evaluated their academic improvement after the intervention. During the study, the treatment group was taught using the Physics Education Technology (PhET) interactive simulation developed by the University of Colorado Boulder. This tool provides visual aids, demonstrations, and interactive activities that promote engagement and deeper conceptual understanding (Makransky et al., 2017). On the other hand, the control group was taught using the conventional teaching strategy based on the same topic. Since the test items were adopted from the DepEd Science 8 SLM, they were already standardized and aligned with the K–12 curriculum, so no additional reliability testing or expert validation was required.

Data Gathering Procedure - Before conducting the study, the researcher sought formal approval from the Principal of Magsaysay National High School. Upon the grant of permission, the data-gathering process commenced with the administration of a pre-test adopted from the Department of Education (DepEd) Science 8 Self-Learning Module (SLM) to both the control and treatment groups. The purpose of the pretest was to assess the students' prior knowledge of the topic Particle Nature of Matter and to establish their initial competency levels. Subsequently, a two-day face-to-face learning session on the specified topic was implemented during the second grading period of the Academic Year 2025–2026. Both groups were provided with instructions using the same teaching method and facilitated by the same researcher to maintain consistency and minimize bias. However, the treatment group was further exposed to the Physics Education Technology (PhET) interactive simulation, which served as an additional instructional tool to enrich and reinforce the teaching-learning process. After the completion of the learning sessions, a post-test utilizing the same set of items as the pre-test was administered to both groups. The results of the pre-test and post-test served as the primary basis for evaluating and comparing the respondents' science achievement.

Statistical Treatment of the Data - The data gathered from the pre-test and post-test were tabulated, organized, and statistically analyzed to determine the effect of PhET interactive simulations on the science achievement of Grade 8 students. Descriptive statistics, specifically the mean and standard deviation, were computed to assess students' performance before and after the intervention and to compare results between the control and treatment groups. To test whether there was a significant difference between the pre-test and post-test scores of students within each group, a paired-samples t-test was employed. This test measured the improvement in performance after the intervention. Furthermore, an independent-samples t-test was used to determine whether there was a significant difference in post-test scores between the control group (conventional teaching) and the treatment group (PhET interactive simulation).

Ethical Considerations - This study adhered to the fundamental ethical standards in the conduct of educational research. Prior to data collection, formal approval was sought from the Principal of Magsaysay National High School to ensure compliance with institutional policies. Informed consent was obtained from the student-respondents and their parents or guardians, recognizing their voluntary participation in the study. Participants were assured that their responses would be kept strictly confidential and that the data collected would be used solely for academic and research purposes. The study guaranteed that no physical, psychological, or social harm would result from participation. Students were informed of their right to withdraw from the study at any point without penalty or adverse consequences. To ensure fairness, both groups received duplicate instructional content and learning opportunities, with the only difference being the instructional mode. These ethical safeguards were anchored on the principles of respect for persons, beneficence, and justice as outlined in the Belmont Report (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). Furthermore, the conduct of this study complied with the provisions of the Data Privacy Act of 2012 (Republic Act No. 10173). All respondents' personal information was kept confidential and anonymized to protect their identities. Data was securely stored and accessed only by the researchers, ensuring compliance with national data protection and privacy standards.

3. Results and Discussions

This chapter presents the statistical results and interpretation of data gathered from the pre-test and post-test administered to both the control and treatment groups. The findings were analyzed to determine the effect of Physics Education Technology (PhET) Interactive Simulations on the science achievement of Grade 8 students.

Table 1

Mean and Standard Deviation of Pre-Test Scores of Control and Treatment Groups

Group	N	Mean	Std. Deviation	Interpretation
Control Group	30	8.17	2.451	Satisfactory
Treatment Group	30	9.10	1.971	Satisfactory

Legend: 0-4 = did not meet expectations; 5-7 = fair; 8-10 = Satisfactory ; 11-13 = Very Satisfactory 14-15 = Outstanding

Table 1 presents the mean and standard deviation of the pretest scores for the control and treatment groups, used to determine the level of prior knowledge of grade 8 students in science. The pre-test results revealed that both the control and treatment groups had satisfactory performance levels before the intervention, with mean scores of 8.17 and 9.10, respectively. The small difference in their mean scores indicates that the two groups had comparable levels of prior knowledge on the topic Particle Nature of Matter before the experiment. This finding suggests that both groups started from nearly the same baseline, ensuring that any difference in post-test performance can be attributed to the instructional method rather than pre-existing ability. According to Makransky et al. (2017), ensuring equivalence in pretest performance is crucial for validating the effects of educational interventions such as simulations. In this study, this equivalence enabled the researchers to reliably assess whether integrating PhET Interactive Simulations could produce measurable learning gains beyond what conventional teaching could achieve. Furthermore, the satisfactory pre-test performance indicates that students had a basic familiarity but limited mastery of science concepts, creating an opportunity for meaningful learning during the lesson sessions. This finding is similar to that of Dy et al. (2024), who reported that many junior high school students enter science lessons with only moderate understanding but show significant improvement after exposure to simulation-based instruction. Overall, the pre-test results indicate that students possessed the foundational knowledge necessary for learning but still required further conceptual reinforcement. The equivalence in prior knowledge between the control and treatment groups confirms that the study's comparison of learning outcomes is valid and that any improvement observed after instruction can be confidently attributed to the effect of the PhET Interactive Simulations.

Table 2

Mean and Standard Deviation of Post-Test Scores of Control and Treatment Groups

Group	N	Mean	Std. Deviation	Interpretation
Control Group	30	9.80	2.497	Satisfactory
Treatment Group	30	10.60	2.430	Satisfactory

Legend: 0-4 = did not meet expectations; 5-7 = fair; 8-10 = Satisfactory ; 11-13 = Very Satisfactory ; 14-15 = Outstanding

Table 1 presents the mean and standard deviation of post-test scores for the control and treatment groups to determine the level of performance of grade 8 students in science after the learning session. After the interventions were implemented, the post-test mean for the control group increased to 9.80, while the treatment group's mean rose to 10.60. Both groups maintained a satisfactory performance level, but the higher mean score in the treatment group indicates greater learning gains following the use of PhET Interactive Simulations. This improvement demonstrates that both teaching methods enhanced students' understanding, yet the PhET-based instruction yielded slightly greater gains. This is consistent with Dy, Lagura, and Baluyos (2024), who found that PhET-enhanced science lessons led to higher achievement and engagement compared to conventional instruction. Similarly, Fuentes et al. (2025) reported that interactive simulations helped learners visualize molecular and particulate concepts that are often difficult to grasp through lectures alone. Additionally, the treatment group's performance supports constructivist learning theory, in which learners engage in meaningful exploration and manipulation of variables. This allows students to adjust particle spacing, temperature, and motion in real time; the simulation likely helped them form more accurate mental models of matter's particulate nature. Makransky et al. (2017) similarly noted that simulation-based learning environments enhance conceptual understanding by making

invisible scientific phenomena more tangible and accessible. Thus, the results indicate that PhET Interactive Simulations enhanced learning and supported improved performance, but the traditional method also remained effective.

Table 3
Paired Sample t-Test of Pre-Test and Post-Test

Group	Mean Diff	t	df	Sig. (2-tailed)	Interpretation
Control Group	1.63	-7.924	29	<.001	Significant
Treatment Group	1.5	-5.385	29	<.001	Significant

Legend: Sig. (2-tailed) <0.05 = Significant

Table 3 shows the comparison of the Pre-test and Post-test Within the Control and Treatment groups. The paired sample t-test revealed that both the control and treatment groups showed significant improvement from pre-test to post-test ($p < 0.05$). This means that both conventional and PhET-assisted teaching effectively enhanced students' understanding of the topic. However, although both groups improved, the t-value was higher in the control group (-7.924) than in the treatment group (-5.385), but this does not directly imply better learning because the control group started at a lower pre-test mean. The significant improvement in both groups supports the conclusion that structured instruction, regardless of format, can increase science achievement. These results are consistent with Omoy (2022), who found that both conventional and simulation-based teaching approaches led to substantial improvements in science performance when supported by clear explanations and teacher guidance. This reinforces the teacher's key role in ensuring that students can connect new information with prior knowledge, regardless of the tools used during instruction. The significant increase in both groups' scores also reflects the importance of structured lessons in improving conceptual understanding. Makransky et al. (2017) similarly emphasized that simulations are most effective when combined with proper scaffolding, discussion, and guided exploration. This aligns with the findings, which show that both groups benefited from organized instruction delivered by the same teacher, reducing variability in teaching quality. In addition, Fuentes et al. (2025) highlight that students tend to perform better when instructional activities actively involve them in visualizing and exploring scientific concepts, whether through hands-on activities or carefully designed simulations. This supports the study in which learners from both groups, exposed either to traditional illustrations or to PhET visual models, showed improvement from their pretest scores.

Table 4
Independent Sample t-Test of Post-Test Scores Between Control and Treatment Groups

Group	Mean Diff	t	df	Sig. (2-tailed)	Interpretation
Control and Treatment Group	-0.800	-1.258	58	0.214	Not Significant

Legend: Sig. (2-tailed) <0.05 = Significant

Table 4 shows the post-test comparison between the control and treatment groups. The independent sample t-test comparing the post-test scores of the control and treatment groups yielded a p-value of 0.214, which is greater than 0.05. This indicates that there is no statistically significant difference in the post-test scores between the groups. Although the treatment group attained a slightly higher mean, the difference was not large enough to be considered statistically significant. This suggests that both instructional methods were comparably effective in improving students' understanding of the topic. The absence of a significant difference suggests that the impact of PhET simulations, while beneficial, may depend on additional factors such as the quality of facilitation, the time allotted for the intervention, and the students' familiarity with digital tools. In this study, the learning sessions were limited in duration, which may have reduced the potential advantage of simulation-based learning. This aligns with De Torres et al. (2023), who noted that PhET-assisted instruction does not consistently lead to significantly higher test scores, especially in short-term interventions or when an equally competent teacher teaches both groups. Furthermore, the results align with Bernardo et al. (2023), who emphasized that multiple variables, including resource availability, teacher guidance, and learner motivation, influence student achievement in science. Even when advanced tools such as PhET are introduced, learning effectiveness still relies heavily on how well teachers structure activities, address misconceptions, and support student inquiry. Thus, the findings show that while digital simulations enhance engagement and conceptual clarity, their measurable impact on achievement may vary

depending on instructional duration, learner readiness, and the overall learning environment.

4. Conclusions and Recommendations

Based on the study's findings, both conventional teaching and PhET Interactive Simulations significantly improved Grade 8 students' science achievement in the topic of Particle Nature of Matter. However, there was no significant difference in post-test scores between the control and treatment groups. This indicates that while PhET simulations effectively enhanced learning, their impact was comparable to that of traditional teaching when both were implemented correctly. Overall, the integration of PhET serves as a valuable supplementary tool to support science instruction and learner engagement. Regarding the findings and conclusions, the following recommendations are provided. Teachers may use PhET Interactive Simulations as a supplementary tool to make science lessons more interactive, visual, and engaging. School administrators may provide sufficient technological resources, such as computers, projectors, and stable internet access, to support the integration of PhET into classroom teaching. Curriculum developers may integrate simulation-based activities into the science curriculum to promote inquiry-based and experiential learning. Future researchers may replicate this study across different grade levels, topics, or more extended implementation periods to further assess the effectiveness of PhET simulations on students' learning outcomes and attitudes toward science.

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