ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 10| Issue: 3| March 2024|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2024: 8.402 || ISI Value: 1.188

PHYSICS EDUCATION TECHNOLOGY (PhET) INTERACTIVE SIMULATIONS AS TEACHING AID IN ENHANCING STUDENTS' PERFORMANCE IN PHYSICS

Melvin C. Eleo[1], Ylcy B. Manguilimotan[2]
[1]*Master of Arts in Education major in Teaching Science, Graduate School Education Department, Saint Mary's College of Tagum, Inc., Tagum City, Philippines*
[2]*Graduate School Professor, Graduate School Education Department, Saint Mary's College of Tagum, Inc., Tagum City, Philippines*

Article DOI: https://doi.org/10.36713/epra15991
DOI No: 10.36713/epra15991

ABSTRACT
This study aimed to determine the effectiveness of Physics Education Technology (PhET) interactive simulations in enhancing students' performance in Physics. It is a quantitative study involving pretest-posttest quasi-experimental research. The respondents for this study were 60 Grade 11 senior high school students, specifically from two sections in a public secondary school in the Division of Davao de Oro. They were categorized into two groups: the experimental group and the control group. The pretest and posttest questionnaire, derived from the Grade 11 Physical Science module, underwent pilot testing to ensure its validity and reliability and was utilized as the instrument. The mean, mean gain score, T-test for correlated mean, and T-test for uncorrelated mean were employed as the statistical treatments for this study. The results revealed that before the intervention, the student's performance in both groups was at the same level. However, during the post-test, the control and experimental groups improved their Physics performance, albeit at different levels. A significant difference was observed between the mean gain scores of the two groups. This suggests that the intervention, Physics Education Technology (PhET) interactive simulation, is more effective compared to the conventional method of teaching. The researcher recommends that students play an active role in the learning process. Teachers should incorporate PhET interactive simulations into their classes, and administrators should provide relevant training and workshops on the proper use of PhET interactive simulations. Future researchers are encouraged to conduct studies on other areas related to PhET interactive simulations.

KEYWORDS: *Education, students' performance, Physics Education Technology (PhET), quasi-experimental, Pretest-Posttest design, Grade 11 students*

I. INTRODUCTION

Physics, a theoretical science, requires practical experiences and models to understand concepts. Instructors should incorporate inquiry, discovery, demonstration, simulation, practical work, lab-based activities, and other experiences. Physics is less popular among students due to perceived difficulty and complexity (Yunzal & Casinillo, 2020).

Physics had the highest percentage of failed Senior High School exam students in Kupang City, Indonesia, due to heavy emphasis on formula memorizing without practical laboratory work (Nggadas & Ariswan, 2019). A study by Najib et al. (2022) found a lack of understanding of physics concepts in secondary schools in Peninsular Malaysia's Northern State. Teacher-centered training and inadequate laboratory facilities, reagents, and equipment hinder students' comprehension of physics topics. Qualified technicians and teachers also hinder exposure to laboratory activities (Zengele & Alemayehu, 2020).

The National Institute for Science and Mathematics Education Development at the University of the Philippines (UP-NISMED) and the Science Education Institute, Department of Science and Technology (SEI-DOST) in the Philippines have identified a lack of learner-centered classrooms and instructional strategies as contributing factors to students' subpar academic performance in physics. Insufficient laboratory equipment and a teacher-centered approach are also identified as factors (Rabino et al., 2021). Jornales (2020) also asserted that the lecture method is often used in physics classes and students are rarely given engaging and challenging homework.

The researcher found that in Laak North District secondary schools, Grade 11 students' proficiency in Physics was satisfactory, with a mean percentage score of 78.88%. Most students' grades fell between 75 and 80, indicating a lack of laboratory tools and equipment, leading to teacher-centered tactics, and limited experiential learning through laboratory activities.
To deal with several of the above concerns, in this study, the researcher designed and assessed inquiry activities that involved students in the exploration of physics ideas using Physics Education Technology (PhET) simulations. PhET is a

simulation software that is an online collection of interactive simulations and educational materials used to teach and learn physics and other subjects. It motivates students through interactive exploration, creates game-like challenges, interfaces abstract physics with mathematical models, and uses numerically accurate physical representations (Bello, 2018). It provided an open learning environment, allowing students to test hypotheses, isolate and manipulate parameters, and use visual aids like pictures, graphs, and numerical figures. This approach helps learners overcome difficulties in science experiments due to technical obstacles, lack of materials, or rapid subject recognition (Garcia, 2021).

The researcher underscores the need to investigate PhET simulations' effectiveness in enhancing students' physics learning. The study aims to provide teachers with a new perspective on teaching science, focusing on the value of simulations in understanding abstract concepts. It also addresses the lack of adequate laboratory equipment in schools.

II. OBJECTIVES

The objective of this study was to determine whether interactive simulations created using Physics Education Technology (PhET) as a teaching tool may improve students' performance in physics.
Specifically, it aims to answer the following questions:

1. What is the level of student performance in the control and experimental groups in terms of their pre-test scores?
2. What is the level of student performance in the control and experimental group in terms of their post-test scores?
3. Is there a significant difference in the pre-test and post-test scores of the control and experimental groups?
4. Is there a significant difference in the mean gain score of the control group and experimental group?

III. METHODOLOGY

This is quantitative research that is quasi-experimental in nature. Respondents of the study were the Grade 11 senior high school students for School Year 2023-2024 who are pursuing their education in one of the secondary educational institutions in the municipality of Laak, Davao de Oro, Philippines. The researcher selected two randomly ordered sections (control group & experimental group), each with 30 students. To maintain the heterogeneity of the groups, a T-test for uncorrelated mean was conducted during the pre-experimentation phase. The results yielded no significant difference suggesting that randomization employed in assigning participants to the control and experimental groups was effective in creating comparable groups at the baseline.

The research instrument that was utilized in this study was a researcher-made test which consisted of 40-item multiple-choice questions produced by the researcher. Before being employed in the study, it was first subjected to content validation and pilot testing. The Classical Item and Test Analysis Spreadsheet was also used in measuring the reliability of the test. This instrument was conducted through a pretest and post-test to the control and experimental groups to gather data for this study.

Physics Education Technology (PhET) simulation was the intervention utilized by the experimental group participating in this study. During the implementation of the intervention, the class convened for four hours weekly over a month, utilizing the computer laboratory as the designated classroom for the participants' physics instruction. Each student was equipped with a tablet computer on which the PhET program was installed. On the other hand, within the instructional framework of the control group, the facilitator refrained from integrating PhET simulations as a pedagogical tool when teaching designated physics topics. Instead, the instructional medium entailed the utilization of the Self-Learning Module (SLM), alongside conventional teaching methodologies. The class convened four times a week for over a month.

The Mean, Mean Gain Score, T-test for correlated mean, and T-test for uncorrelated mean are the statistical tools that were used in analyzing and interpreting the data result of this study.

IV. RESULTS

Table 1. Level of Students' Performance in the Control and Experimental Group in Terms of Pre-Test Scores

Groups	Pre-Test			
	Mean Score	Mean Percentage Score	SD	Descriptive Equivalent
Control	11.50	28.75	7.71	Low
Experimental	11.17	27.93	6.16	Low

Table 2. Level of Students' Performance in the Control and Experimental Group in Terms of Post-Test Scores

Groups	Post-Test			
	Mean Score	Mean Percentage Score	SD	Descriptive Equivalent
Control	20.60	51.50	7.47	Moderate
Experimental	25.20	63.00	10.82	High

Table 3. Significance of Difference in the Pre-Test and Post-Test Scores of the Control and Experimental Groups

Groups	Pre-Test Mean Percentage Score	Post-Test Mean Percentage Score	Mean Difference	t-value	p-value
Control	28.75	51.50	-22.75	16.688	0.000
Experimental	27.92	63.00	-35.08	19.939	0.000

Table 4. Significance of the Difference in the Mean Gain Scores of the Control and Experimental Groups

Groups	Mean Gain Score	SD	Difference	t-value	p-value
Control	22.75	7.47	-12.33	-5.541	0.000
Experimental	35.08	9.64			

V. DISCUSSION

Table 1 found no significant difference in pre-test scores between the control and experimental groups, suggesting that randomization effectively created comparable groups at baseline, based on the preliminary analysis of pretest scores using a T-test for uncorrelated samples. The scores and standard deviations indicate a consistent baseline performance with low pretest performance, indicating reliability. The observed standard deviations show variability within each group, clustering around mean scores. These initial metrics serve as a reference point for assessing performance improvements and differences throughout the study.

The student's prior knowledge of physics and the environment in which they were exposed can be ascribed to the results of their pretest. Another fact to this is that learning competencies in Physics have not been introduced to the students (Migalang & Azuelo, 2022). The data of the current study mirrored those of Ndihokubwayo, et al. (2019), who found that there was a deficiency in the students' conceptual understanding of physics. This was further emphasized by Asgari, et.al (2018), who was quoted by Uwambajimana and Minani (2023), who claimed that while most texts describe these ideas in abstract terms, learners typically do not have a thorough knowledge of these concepts.

An overview of the post-test performance levels of students in the control and experimental groups is shown in Table 2. The mean scores and standard deviations show different levels of post-test performance between the control and experimental groups. The control group showed moderate achievement, while the experimental group showed higher achievement and greater variability. The standard deviations indicate varying responses within each group, highlighting factors influencing improvement. The post-test results showed that the mean score obtained by students in the researcher-made test after the intervention was statistically different for the two groups. The post-test score was higher than that of the pre-test. These demonstrate how the use of PhET simulation in teaching and learning affects the students' performance in Physics.

Similarly, the results were like that of Uwambajimana and Minani (2023) stressed out Simulations enhance student discovery by making abstract concepts concrete and providing quick feedback, allowing learners to change virtual world settings and develop fresh understanding. Nyirahabimana et al. (2022) showed that when multimedia, including PhET simulation, was used in teaching, students were more motivated. The ability of computer simulations to help students envision, think about, and explain abstract concepts was cited as the reason for the experimental group's performance (Chumba et al., 2020). The study's findings are also consistent with Susilawati et al. (2022) assertion that by presenting conceptual and visual model animations, PhET simulation can help students better understand the physics subjects they are studying. Furthermore, PhET includes experimental and theoretical simulations that actively involve users. PhET media can be used to teach Physics since users can change experiment-related activities (Ginting et al., 2020).

Table 3 showed a significant increase from pre-test to post-test percentage scores of the control and experimental groups. This significant difference indicates a statistically significant improvement and rejects the null hypothesis of no significant difference between the pretest and post-test scores of the control and experimental groups. However, the results highlighted the significant difference in the pretest and post-test scores of the experimental group. This indicates that the observed improvements were not due to chance variations but rather to the intervention's impact. The experimental group demonstrated a more pronounced positive effect compared to the control group, highlighting the intervention's effectiveness in enhancing students' academic performance.

The noteworthy outcome is consistent with Nyirahabimana et al. (2022) findings, which showed that students were more motivated and engaged in meaningful learning when multimedia, including PhET simulation, was employed in the classroom. Furthermore, according to Ersoy and Dilber (2014), who were quoted by Lukita and Jayanagara (2023), simulations increased the scope of student discovery by giving prompt feedback on the experience and by giving the abstract greater concreteness. Additionally, the results showed that students could remember the lessons they had learned when a PhET simulation was used. Students who used a PhET simulation were more excited and engaged in their studies (Rustana et al., 2020).

Table 4 indicates a significant difference in performance between the two groups. A T-test for uncorrelated samples was conducted to compare mean gain scores between the control and experimental groups. A t-value of 5.541 indicates a significant difference in percentage scores between the two groups, indicating lower mean gain scores in the Control group. The p-value for both groups is 0.000, rejecting the null hypothesis of no significant difference. This suggests that the observed difference is statistically significant, and the experimental group performed better in the post-test.

Masita et.al. (2020) found that PhET interactive simulations effectively engage students, encouraging active participation in questions, arguments, inferences, and decision-making, ultimately preparing them for higher-order thinking by the end of the course. Nkemakolam et al. (2018) highlighted the benefits of PhET interactive simulations over traditional lecture formats, highlighting their ability to reduce abstract concepts and enhance students' achievement, particularly in Physics, by allowing students to see, investigate, and create scientific explanations.

VI. CONCLUSIONS

Based on the findings of this study, the following conclusions are drawn:

1. Both the control and experimental groups' pretest results for Physics show low performance from the students. Before the experiment, all groups performed at the same level.
2. According to the post-test result, the experimental group showed high academic improvement, while the control group showed only moderate improvement.
3. The results of the pre-test show that there is no significant difference between the experimental and control groups' performance levels in physics, whereas the results of the post-test show that there is significant variation between the two groups' performance levels.
4. The result demonstrates that there is a significant difference between the experimental and control groups' levels of student performance in physics. Consequently, the researcher's usage of an interactive simulation based on Physics Education Technology (PhET) as a teaching strategy for the experimental group proved to be more successful than the traditional approach of instruction for the control group.

VII. RECOMMENDATIONS

Based on the findings, analysis, and conclusions drawn in this study, the following commendations are summarized:

1. Students should actively engage by using PhET simulations in manipulating variables, conducting virtual experiments, and taking an active role in the learning process to accomplish better academically and become more adept at solving scientific problems.
2. To increase student performance, science teachers should utilize lesson plans that integrate PhET interactive simulations in their lessons on abstract ideas in physics. This will engage and inspire students to gain a deeper conceptual knowledge of the material and improve their performance in physics.
3. School administrators should support their teachers in using PhET simulation since it can remove some concepts' abstraction by giving them greater concreteness, which makes the notion easier for pupils to understand. School administrators should provide funding sources for the procurement of computer packages for the utilization of PhET interactive simulation. To capacitate teachers to become more proficient in teaching science subjects, including Physics, Learning Action Cells (LAC) should be organized on the use of PhET interactive simulation. This will enable the teachers to use this technology and improve student performance in the classroom.
4. The study's findings could serve as a springboard for future investigations by scientists and science educators into the ways that technology—specifically computer simulations—influences other academic subjects, learning styles, gender, and a host of other factors.

IX. COMPLIANCE WITH ETHICAL STANDARDS

This research study was reviewed for research ethics compliance by the Saint Mary's College of Tagum, Inc. - Research Ethics Committee (SMCTI-REC) to guarantee the privacy, social security, and well-being of human research participants and to maintain the integrity of the research.

The respondent's well-being was safeguarded well during the entire duration of the study. The participation of the respondents was completely voluntary and have the right to withdraw at any time without providing any reason during the conduct of this study. Parental Informed Consent and Informed Assent were sought from the parents and respondents, respectively before this research started. The privacy of the respondents is of paramount reputation; thus, complete anonymity and confidentiality were treated with utmost importance through discrete coding. No individual identities were used in any reports, presentations, or publications resulting from the research study.

Furthermore, the researcher declares no conflict of interest exists in the conduct of the study. The researcher adheres to the originality of this research and plagiarism was strictly avoided. There was no bias in the interpretation of the findings and results were used purely for research.

X. ACKNOWLEDGEMENT

The researcher would like to acknowledge the support and gratitude of all the people who made significant contributions to this study.

XI. REFERENCES

1. *Asgari, M., Ahmadi, F., & Ahmadi, R. (2018). Application of conceptual change model in teaching basic concepts of physics and correcting misconceptions. Iranian Journal of Learning and Memory, 1(1), 69-83. http://journal.iepa.ir*
2. *Bello, A. Q. (2018). Introduction to Physics Education Technology (PhET) Simulation Software. Natural Sciences Department, College of Arts and Sciences, Bukidnon State University Fortich Street, 8700 Malaybalay City, Philippines*
3. *Chumba, A. K., Omwenga, E. N., & Atemi, G. (2020). Effects of using computer simulations on learners' academic achievement in physics in secondary schools in Ainamoi Sub-County, Kericho County. Journal of Research Innovation and Implementations in Education, 4(1), 126-138*
4. *Garcia, A. (2021). Interactive Simulations in Teaching Linear Equations. 8(July 2020), 4611–4617.*
5. *Ginting, F. W., Novita, N., & Rahmadani, Y. (2020). Application of the TGT Model Through PhET Simulation to Increase Students' Understanding of Optical Instruments. Physics Learning Innovation Research Journal, 3(2), 1–9. https://doi.org/10.29103/relativity.v3i2.3341*
6. *Jornales, R. R. (2020). Effectiveness of Physics Education Technology (PhET) Interactive Simulations in Teaching Physical Science, International Journal of Science and Research (IJSR), Volume 9 Issue 12, December 2020, pp. 60-64*
7. *Lukita, C., & Jayanagara, O. (2023). Evidence from SMA Students' Performance on the Impact of Physics Education Technology (PhET) Simulations. International Transactions on Education Technology (ITEE), 3(1) 105-110*
8. *Masita, S.I., Donuata, P.B., Ete, A.A. & Rusdin, M.E. (2020). Use of PhET Simulation in Increasing Students' Understanding of Physics Concepts. Journal of Physics Education Research, 5(2), 136- 141. https://doi.org/10.36709/jipfi.v5i2.12900*
9. *Migalang, G. & Azuelo, A. (2020). Students Cognitive Learning and Motivation through Hybrid Instructional Strategy. Journal of Science and Mathematics Education in Southeast Asia. https://eric.ed.gov/?q=migalang&id=EJ1307630*
10. *Najib, M., Yaacob, A., & Md-Ali, R. (2022). Exploring the Effectiveness of Interactive Simulation as Blended Learning Approach in Secondary School Physics. Proceedings 2022, 82, 103. https://doi.org/10.3390/ proceedings2022082103*
11. *Ndihokubwayo, K., Kinya, S., Ikeda, H., & Baba, T. (2019). An Evaluation of the Effect of the Improvised Experiments on Student-Teachers Conception of Static Electricity. LWATI: A Journal of Contemporary Research, 16(1), 55-73*
12. *Nggadas, D. E. P., & Ariswan, A. (2019). The mastery of physics concepts between students is learning by ICT and laboratory experiments-based teaching. Momentum: Physics Education Journal, 3(1), 21-31. https://doi.org/10.21067/mpej.v3i1.3343*
13. *Nkemakolam, O. E., Chinelo, O. F., & Jane, M. C. (2018). Effect of Computer Simulations on Secondary School Students' Academic Achievement in Chemistry in Anambra State. Asian Journal of Education and Training, 4(4), 284–289. https://doi.org/10.20448/journal.522.2018.44.284.289*
14. *Nyirahabimana, P., Minani, E., Nduwingoma, M., & Kemeza, I. (2022). Instructors and students' practices and behaviors during a quantum physics class at the University of Rwanda: Exploring the usage of multimedia. International Journal of Learning, Teaching and Educational Research, 21(9), 309-326. https://doi.org/10.26803/ijlter.21.9.18*
15. *Rabino, A., Dayagbil, F., Palompon, D., & Garcia, L. (2021) Teaching and Learning Continuity Amid and Beyond the Pandemic. Front. Educ. 6:678692. doi 10.3389/feduc.2021.678692*
16. *Rustana, C. E., Andriana, W., Serevina, V., & Junia, D. (2020). Analysis of student's learning achievement using PhET interactive simulation and laboratory kit of gas kinetic theory. Journal of Physics: Conference Series, 1567, 022011. https://doi.org/10.1088/1742-6596/1567/2/022011*
17. *Susilawati, A., Yusrizal, Y., Halim, A., Syukri, M., Khaldun, I., & Susanna, S. (2022). The Effect of Using Physics Education Technology (PhET) Simulation Media to Enhance Students' Motivation and Problem-Solving Skills in Learning Physics. Jurnal Penelitian Pendidikan IPA, 8(3), 1157–1167. https://doi.org/10.29303/jppipa.v8i3.1571*
18. *Uwambajimana, S. & Minani, E. (2023). Impact of Using Physics Education Technology (PhET) Simulations on Improving Students' Performance in Electrostatics. Journal of Research Innovation and Implications in Education, 7(1), 22 – 30.*
19. *Yunzal, A. N., & Casinillo, L. F. (2020). Effect of Physics Education Technology (PhET) simulations: Evidence from STEM students' performance. Journal of Education Research and Evaluation, 4(3), 221-226. Retrieved from https://ejournal.undiksha.ac.id/index.php/JERE*
20. *Zengele, A., & Alemayehu, B. (2020). The status of secondary school science laboratory activities for quality education in the case of Wolaita Zone, Southern Ethiopia. Journal of Education and Practice. www.iiste.org ISSN 2222-1735 (Paper) ISSN 2222-288X (Online) Vol.7, No. 31. Sodo University P.O. Box 138, Wolaita Sodo University Ethiopia. Retrieved at www. files eric.ed.gov/fulltext/EJ1122534.pdf on November 23, 2022.*