IMPROVING GRADE 7 STUDENTS' UNDERSTANDING ON THE PHASES OF MATTER THROUGH PHET INTERACTIVE SIMULATIONS

.

ABSTRACT

This study evaluated the effectiveness of Physics Education Technology (PhET) interactive simulations in improving student academic performance on the topic *Phases of Matter*, identified as the least mastered skill in the first quarter of Grade 7 Science. The purpose of this study was to examine the effectiveness of using PhET interactive simulations as an instructional tool in enhancing Grade 7 students' understanding of the *Phases of Matter*. Specifically, it aimed to determine whether the integration of interactive, technology-based simulations improved students' conceptual understanding and academic performance in Science, particularly in addressing the least mastered competency in the first quarter of the Grade 7 Science curriculum. The study also sought to explore the perceptions of students and educators regarding the use of PhET simulations, providing both quantitative and qualitative insights into their impact as a supplementary teaching strategy. A convergent mixed-methods design was employed, integrating both quantitative and qualitative data. In the qualitative phase, two students and two educators participated in in-depth interviews to provide contextual insights into the learning process and experiences. For the quantitative phase, a total of 10 Grade 7 students from Section Tagaytay—comprising 4 males and 6 females—were purposively selected based on their poor performance in a prior quiz on the topic. The participants were randomly chosen using the fishbowl method. These students underwent an intervention using PhET interactive simulations. A validated 10-item pretest and posttest, adapted from the Lesson Exemplar for Grade 7 Science Quarter 1, Lesson 1 (Week 1), S.Y. 2024–2025, served as the primary assessment tool. The test focused exclusively on the learning competency: describing the phases of matter (solid, liquid, gas) and the particle theory of matter as outlined in the K–12 Science Curriculum. To analyze the data, both descriptive and inferential statistics were used, including frequency distribution, mean, percentage, and paired sample t-test. The results revealed a significant improvement in the students' performance following the intervention. The t-value of 15.28, which exceeded the critical value of 1.729, and a p-value of .001 ($p < 0.05$), The study revealed a statistically significant improvement in students' academic performance after the implementation of PhET interactive simulations. The paired sample t-test yielded a t-value of 15.28, which exceeded the critical value of 1.729, with a p-value of .001 ($p < 0.05$), indicating that the intervention had a positive effect on student learning outcomes. That confirmed the effectiveness of the simulation-based instruction. The findings suggest that PhET interactive simulations are a highly effective instructional tool for enhancing conceptual understanding and academic performance in Science. When properly implemented, these simulations can

serve as powerful interventions to help students master difficult concepts, particularly in topics where comprehension is commonly weak.

17 *Keywords: Phases of Matter, PhET Simulations, Science Education, Interactive learning, academic performance, mixed-method research*

1. INTRODUCTION

In recent years, the rapid advancement of technology has driven substantial changes in education, notably through the integration of information and communication technologies (ICT). As Lourida et al. (2024) affirm, ICT has profoundly transformed teaching and learning processes, offering enhanced educational experiences. Educational technology has thus become central to effective pedagogical practices, especially in science education. One prominent innovation is PhET (Physics Education Technology) interactive simulations, which provide research-based, hands-on learning environments that support conceptual comprehension in challenging science topics.

Research has consistently shown the pedagogical benefits of PhET simulations across various educational levels and subjects. For example, in elementary classrooms, Rahmah Kumullah et al. (2024) demonstrated that PhET-based virtual labs helped learners better visualize and understand abstract scientific concepts. Similarly, U. Umiliya et al. (2023) found that blending PhET with inquiry-based pedagogies significantly improved conceptual understanding of static electricity compared to control groups. In remote and resource-constrained settings, Nguyen et al. (2024) reported that PhET simulations substantially increased student engagement and comprehension in physics lessons in Northern Vietnam.

Meta-analyses and comprehensive literature reviews lend further support: a systematic review in *Phys. Rev. Phys. Educ. Res.* identified robust evidence that PhET simulations improve conceptual understanding when integrated with active learning strategies. Likewise, Banda & Nzabahimana (2021) concluded that these simulations are most effective within inquiry-driven instructional frameworks, underscoring their alignment with constructivist theory.

PhET, or Physics Education Technology, refers to a suite of interactive simulations designed to support the teaching and learning of math and science concepts. Developed based on extensive educational research, PhET simulations engage students through an intuitive, game-like interface that promotes learning through exploration and discovery. According to Doloksaribu and Triwiyono (2021), PhET emphasizes the connection between real-life situations and underlying scientific principles, enabling students to better visualize and conceptualize scientific models and phenomena. This approach aligns with constructivist learning theories by fostering deeper understanding through active, inquiry-based learning experiences. PhET Interactive Simulations is a substantial and growing repository of over 85 high-quality simulations for science teaching. The PhET website, http://PhET.colorado.edu, offers simulators at no cost, which have been utilized around 10 million times in the past year. Although the number of simulations in chemistry, biology, mathematics, and other sciences is increasing, the majority of PhET simulations are utilized for teaching physics. The application of PhET simulators across several educational settings had been thoroughly examined. It is designed to be accessible and beneficial for schools across the Philippines, regardless of location or resource availability. Their free, userfriendly, and research-based nature makes them particularly suitable for diverse educational settings, including those with limited laboratory facilities.

PhET Interactive Simulations, developed by the University of Colorado Boulder, are widely recognized educational tools designed to enhance learning in science and mathematics through interactive, research-based simulations. The global adoption of PhET has spurred extensive research into its effectiveness and pedagogical impact. It has shown to boost learner engagement and motivation. Research by Zacharia and Olympiou (2011) in Cyprus highlighted that students found lessons using PhET more enjoyable and less intimidating than conventional experiments. In a study conducted in Thailand, Bunterm et al. (2014) reported increased student motivation and interest in physics when using simulations in combination with hands-on activities.

In the Philippines, the integration of digital tools in science and mathematics education has gained momentum, particularly in response to the K–12 curriculum's emphasis on inquirybased learning and the need for more accessible learning resources. Among these tools, PhET Interactive Simulations have been increasingly utilized in both basic and higher education. According to Aranas and Madrazo (2020) who conducted a quasi-experimental study in a public senior high school in Metro Manila, revealing that students exposed to PhET simulations in physics achieved higher post-test scores compared to those taught with traditional lecture methods. The simulations helped visualize abstract ideas such as Newton's laws and projectile motion. It validates the effectiveness of PhET simulations in helping students understand complex science concepts.

From a study conducted by Melvin C. Eleo and Ylcy B. Manguilimotan, 2024 recommend that active integration of PhET simulations into classroom instruction, highlighting the need for professional training for educators. They argue that teachers should move beyond passive lecturing and incorporate these interactive tools to encourage student engagement and critical thinking. Additionally, administrators are advised to support the implementation of such technologies through capacity-building initiatives. Finally, the study suggests future research to explore PhET applications across varied science topics and instructional contexts.

In the Philippine context, this is highly relevant due to the lack of laboratory resources in many public schools. Eleo and Manguilimotan (2024) showed that the strategic use of PhET simulations led to improved test performance in Davao de Oro, aligning well with the Department of Education's goal of promoting inquiry-based learning as part of the K–12 curriculum.

Amrullah et al. (2022) conducted a comprehensive meta-analysis on PhET simulation use and concluded that their effect on improving science learning is consistently positive across grade levels. Similarly, Diab et al. (2024) highlighted how PhET enhances student engagement and learning outcomes in elementary and secondary science classes by providing interactive visualization of abstract concepts.

Theoretical foundations for PhET's effectiveness are rooted in constructivist learning theory and Mayer’s cognitive theory of multimedia learning (Mayer, 2009), which emphasize the importance of active engagement and visual-verbal integration in deepening student understanding. These simulations are not only intuitive but are specifically designed based on learning science research that promotes inquiry-based learning (Wieman, Adams, & Perkins, 2008). According to Rutten, van Joolingen, & van der Veen (2012), computer simulations significantly improve student achievement in science education, particularly when paired with guided instruction.

In recent years, the rapid advancement of technology has driven substantial changes in education, notably through the integration of information and communication technologies (ICT). As Lourida et al. (2024) affirm, ICT has profoundly transformed teaching and learning processes, offering enhanced educational experiences. Educational technology has thus become central to effective pedagogical practices, especially in science education. One prominent innovation is PhET (Physics Education Technology) interactive simulations, which provide research-based, hands-on learning environments that support conceptual comprehension in challenging science topics.

The integration of Physics Education Technology (PhET) Interactive Simulations in the Davao Region has been explored in various educational settings, demonstrating their effectiveness in enhancing students' understanding of scientific concepts. A study conducted by Melvin C. Eleo and Ylcy B. Manguilimotan at Saint Mary's College of Tagum, Inc., in Tagum City, Davao del Norte, investigated the effectiveness of PhET simulations in improving students' performance in physics. This quasi-experimental research involved 60 Grade 11 students from a public secondary school in the Division of Davao de Oro. The findings revealed that students who utilized PhET simulations showed a significant improvement in their physics performance compared to those taught through conventional methods. The study recommends the incorporation of PhET simulations into classroom instruction and suggests that administrators provide relevant training and workshops for teachers on the proper use of these simulations.

This study contributes to the growing body of research on educational technology by providing practical insights into how PhET simulations can be used to support science teaching in a middle school setting. By evaluating both the instructional process and student outcomes, the research offers evidence-based recommendations for integrating digital manipulatives into science curricula. It aims to empower educators with effective strategies for using technology to create more interactive, student-centered learning environments that promote deeper understanding and sustained interest in science.

The use of PhET Interactive Simulations in classroom instruction is grounded in Constructivist Learning Theory and Multimedia Learning Theory. Constructivism, as proposed by Piaget and Vygotsky, emphasizes that learners actively construct knowledge through interaction and meaningful experiences. PhET simulations allow students to explore scientific concepts by manipulating variables and observing real-time outcomes, fostering inquiry and deeper understanding. At the same time, Mayer’s Multimedia Learning Theory supports the effectiveness of combining visual and verbal elements to enhance cognitive processing and retention. Together, these theories justify the integration of PhET simulations as a powerful tool to promote active, student-centered, and visually rich learning in science education.

Using PhET Interactive Simulations in the classroom is important as many schools particularly in the Davao Region lack access to adequate laboratory equipment, limiting students’ ability to engage in hands-on science learning. These simulations provide an interactive and cost-effective alternative that can enhance conceptual understanding, especially in physics and chemistry. By exploring their effectiveness in local classrooms, this study supports the goals of the K–12 curriculum, which emphasizes inquiry-based learning. It also helps assess how well teachers and students adapt to digital tools in science education. Apart from this, the study titled Enhancing Student Engagement and Understanding in Grade 7 students on the Phases of Matter using PhET Interactive Simulations, the findings can guide educational leaders in making informed decisions about integrating technology into teaching practices.

This research investigates how PhET simulations can be effectively integrated into middle school science instruction to improve both student engagement and conceptual understanding. To design and implement lesson plans incorporating PhET simulations for selected science topics. To evaluate the impact of PhET simulations on students' conceptual understanding. To assess changes in student engagement during PhET-enhanced science lessons.

2. OBJECTIVES

This study aimed to determine how PhET Interactive simulations enhance students understanding in the Phases of Matter.

Specifically, the study sought to:

This study aimed to:

1. To evaluate the impact of PhET interactive simulations on Grade 7 students' understanding of the phases of matter.

2. To examine the effectiveness of PhET simulations in supporting inquiry-based learning in a Grade 7 science classroom.

3. To gather student and teacher perceptions regarding the use of PhET simulations as a tool for learning and teaching the phases of matter.

3. MATERIALS AND METHODS

Research Design

In realizing the objective of this study, the researchers employed convergent mixed methods design. A mixed methods research design, which is a complex approach, combines both quantitative and qualitative data in a single study or succession of studies. This design can be particularly functional for exploring complex research questions that cannot be fully answered by using a single research design. Moreover, a mixed methods design is necessary to examine the relationships between different variables because examining the relationships between diverse variables is not viable just through a single research design (Sharma et al., 2023). In the context of this study, 2 students and 2 educators undergone in-depth interview for the qualitative phase of the study. Moreover, in the quantitative phase of the study, grade 7 section Tagaytay received the intervention. Furthermore, in analyzing the data that were gathered, an Independent Sample t-test was utilized to determine the significance of difference on the pre-test and post-test scores. The comparison of the scores implies the effectiveness of integration of PhET Simulations in improving student conceptual understanding of the Phases of Matter.

Research Instrument

The researcher used the following tools and instruments in conducting this study. The "PhET Interactive Simulation" in the Phases of Matter which the researchers downloaded/accessed in PhET Colorado website http://phet.colorado.edu/en/simulation/thephases-of-matter, and the Students' Pre-Test and Post Test in the phases of matter.

PhET offers enjoyable, cost-free, interactive simulations of science and math based on research, PhET simulations are particularly excellent for providing visual representations of challenging scientific ideas while engaging learners through manipulation. This is an effective teaching tool that influences students' understanding (Taneo, 2021). Anyone with a device and an Internet connection can easily access and use PhET simulations.

The 10-item Pretest and Post-Test questions in the phases of matter were taken from the Lesson Exemplar for Science 7 Quarter 1: Lesson 1 (Week 1) S.y. 2024-2025 since it was already validated. Phases of Matter was the sole focus of the test's questions, which were matched with the learning competency on describe the phases of matter (solid, liquid, gas) and the particle theory of matter of (in) Grade 7 Science K-12 curriculum.

Respondents of the Study

The subjects for the study were chosen from a group of Grade 7 students who performed poorly and failed the quiz on the Phases of Matter. Students were chosen using basic random sampling (Fishbowl method). This sample method involved selecting a name at random from a list of the pooled students' names on a piece of paper. 10 sheets have been drawn to form the 6 males and 4 female Grade 7 students of Section Tagaytay.

Data Gathering

In order to address the stated concerns, this study conducted quantitative research. Several statistical tools were utilized to assess or evaluate the data acquired.

Development Process

While PhET simulations are pre-developed, the process will involve adapting and contextualizing them for classroom use:

Concept Selection – Choose science topics that align with the curriculum and are suitable for PhET tools.

Implementation Plan B.1 Pre-implementation

The 10-item Student's Pretest was given to 10 students to gauge their degree of prior knowledge. The frequency distribution of the scores for each item, the mean, and the standard deviation were used to analyze the Pretest in order to visualize and illustrate the data gathered, define the distribution, and assess the level of score dispersion.

B.2 Implementation

The learners used the interactive PhET simulation on Phases of Matter following the pretest. To gauge the students' progress, the researcher examined students' responses to the simulation. The task isstions in the PhET.

B.3 Post implementation

Next, the post-test will be finished by the students. There was data encoding, analysis, and verification. It was assessed how much the scores from the Pre- and Post-Test differed. A significant increase in the post-test score indicates that the student has learned the simulation. Additionally, the significance of the difference between the pre-test and post-test data was determined using a two-tailed paired-sample t-test of means. With 9 degrees of freedom, the test analysis is set at a 95% confidence level.

4. RESULTS AND DISCUSSION

This section presented the discussion of the results and reflection after the implementation of PhET Interactive Simulations in improving the student's conceptual understanding of the phases of matter.

Standpoints of educators on the use of PhET simulation in improving teaching and learning process

Using the guide questions, the teachers were able to express their experience in using PhET in their teaching and learning process. This consisted of a thematic analysis of this research's qualitative data, collected through in-depth interviews. Table 1 shows the focal point on the first column. The second column contains the interview responses' core ideas, combined according to the common essential themes in the third column. In addition, sample responses from the respondents in the in-depth interviews are also presented here.

Accessible and Time-Saving. The educators claimed that using PhET simulation significantly helped them in their teaching process. These responses on accessible and time-saving appear in the ***interview responses 1 and 2. Below are the sample responses:***

> ***"PhET is free, easy to access, and requires no expensive lab equipment. It's an excellent tool when resources are limited or time is constrained."***

> ***"As a teacher, I appreciate how PhET simulations save me time in lesson preparation and classroom setup—there's no need for complex equipment, yet students still experience interactive, lab-like learning from any device."***

The participants have a common theme regarding accessible and time-saving which makes using PhET in their classes improves the learning and teaching process.

Table 1 Using phET simulation in the teaching and learning process

Focal Point	Core Ideas	Essential Themes
_Using PhET simulations in the teaching and learning process	This topic is hard to understand because we can't see it. The examples are very abstract.	Accessible and Time-Saving.
	I get tired of listening because it's all discussion. It is boring sometimes, so I do not listen anymore. I do not like it because there are no activities.	Instructional Convenience and Flexibility

Instructional Convenience and Flexibility. This essential theme emerged from the responses of the educator/teacher participants. Based on the interview responses, PhET simulations minimize the need for costly laboratory materials and physical set-up. Teachers can quickly integrate simulations into lessons without extensive preparation, and students can access them anytime, making it easier to reinforce concepts inside or outside the classroom. Making science instruction more practical and feasible, especially in resource-limited classrooms. Here are the sample responses:

"PhET makes it easy to adjust my lesson on the spot based on student needs—I can switch from lecture to interactive mode without setting up a lab."

"As a public-school teacher with limited lab resources, PhET lets me simulate experiments that would otherwise be impossible due to cost or safety concerns." The essential themes reflect the core benefits and underlying values that teachers associate with using PhET simulations in their instructional practice.

Standpoints of the Participants on Challenges in Learning the Phases of Matter Using the guide questions, the students were able to express the challenges and difficulty they experience in learning the phases of matter. This consisted of a thematic analysis of this research's qualitative data, collected through in-depth interviews. Table 1 shows the focal point on the first column. The second column contains the interview responses' core ideas, combined according to the common essential themes in the third column. In addition, sample responses from the respondents in the in-depth interviews are also presented here.

Lack of Real-Life Examples or Visual Aids. The participants claimed that they are having difficulty understanding the phases of matter since the concept is too abstract and they are not able to do activities that can show them how it looks in real scenario. These responses on the lack of real-world examples appear in the interview responses 1 and 2. Below are the sample responses:

> **"I find it hard to understand the phases of matter because we only talk about solids, liquids, and gases in theory. It's confusing when we don't have real-life examples to connect the concepts. For example, I know water can freeze or boil, but I don't really get how that shows a phase change unless I actually see it."**

"It would help if we had more demonstrations or saw videos of materials changing states, like dry ice turning into gas or metal melting. That way, I could understand how these changes happen in real life, not just in the textbook."

The participants have a common theme regarding the lack of real-life examples which makes understanding the phases of matter difficult for them.

Focal point	Core Ideas	Essential Themes
Challenges of the participants in Learning the Phase of Matter.	We have difficulties in this topic, since we need some model to demonstrate the changes of the molecules and not just on purely discussion.	**Difficulty visualizing Molecular Changes**
	We cannot actually acquire the concept on particle model of matter because they are not directly observable.	**Abstractness and Lack of Visibility**

Table 2: the viewpoints of the participants in Learning the Phase of Matter.

Table 2 presents the viewpoint of the participants difficulties dealing with the phase of matter topic. The table also shows the essential theme that will be the guide in dealing with the problem. Based on the interview the participants have difficulty visualizing molecular changes.

This viewpoint arises from the thought that the molecular changes are abstract and not perceptual topics that includes the used of the spatial reasoning to the understand the structure and the function of the phases of matter. Here are the common responses of the participants:

"Lisod ang topic, kinahanglan namo ug mga model or visual representation para sa mga changes of molecules ug dili lang pod unta purely discussion"

"We have difficulties in this topic, since we need some model to demonstrate the changes of the molecules and not just on purely discussion".

This thought reflects on the topic of molecular changes, most of the time their difficulty is more on the understanding of the concept of what are the process in changes of the molecules, such as condensation, evaporation and so on.

Additionally, Abstract and Lack of Visibility are one of the difficulties in dealing with the topic according to the participants. This difficulty reflects on the topics of the particle model of matter. The participants can understand the basic concepts of the solid, liquid and gas particle model, but they have difficulties in learning like for example the following question; "Which of the following shows how particles behave when heated? (Attached with the choices with a model). Here are some of the responses of the participants.

"Dili namo makuha ang concept the particle model kay dili man god namo siya directly makuha, such as the sublimation concept ug uban pa"

"We cannot actually acquire the concept on particle model of matter because they are not directly observable, such as the sublimation concept and so on". These are the common difficulties of the participants in dealing with the phases of matter lesson.

A. Prior to Intervention

What is the level of performance of the students in Phases of Matter before the use of PhET Interactive Simulation?

Table 3: Pretest result.

SCORE RANGE (10 item test)	Pretest		
	Scores Frequency	Percentage	Performance Level
10-8	0	0	Very Good
7-5	0	0	Good
4-3	4	40%	Average
1-2	6	60%	Low
Total	10	100%	Low
Mean	2.3		

Table 3 shows the level of performance of students based on the results of the 10 item pretest in phases of matter. The results showed that the students had a "low" performance in the pre-test with a mean score of 2.3. Pre-test results show that not a single student scored 10-8 and 7-5 with "Very good" and "Good" performance levels; 4 out of 10 or 40% performed in the "Average" level; and 60%, or 6 out of 10, scored 0-4, which is considered low performing.

This data indicates that students require intervention to increase their level of performance.

A. After the Intervention

After implementing the PhET Interactive Simulation activities on Phases of Matter, students were given a post-test. The results were tallied and analyzed.

What is the level of performance of the students in Phases of Matter after the use of PhET Interactive Simulation?

Table 4: Post-test Result

SCORE RANGE (10 item test)	Post test		
	Scores Frequency	Percentage	Performance Level
10-8	3	30%	Very Good

7-5	4	40%	Good

4-3	3	30%	Average
1-2	0	0	Low
Total	10	100%	Good
Mean	6.15		

On the other hand, the post-test revealed that 3 out of 10 respondents, or 30% of the group, performed very well, while more than half, or 40% of the population, scored between 7 and 5, and performed well, and 3 out of 10 students, or 30% of the group, had an average performance, and not a single student scored 0-4, which is in the low level of performance. It was very evident that there was an increase in students' scores. One study found that, PhET interactive simulation proved a more effective way to cultivate positive attitudes and attain academic excellence. (Bhatti & Teevno, 2021).

Table 5: Mean of Pretest and Post-Test Scores.

No. of items	df	Pre-Test Mean	Post-Test Mean	Difference
10	9	2.3	6.15	

The table displays the results of the pretest and post-test in the 10-item test that the researcher administered before and after using the PhET Interactive Simulation. It was found that the pretest mean score was 2.3, and its mean score of 6.15 supported the post-test result.

The data unmistakably shows that the mean of the respondents' pretest significantly increased after they used the interactive simulations from PhET for phases of matter. This is an apparent indication that the utilization of PhET Interactive Simulation is effective and powerful method in improving learners' performance and mastering the skills of understanding the concept of the phases of matter, which is one of the least learned skills in the 2nd quarter of Grade 7 Science.

Is there a significant difference in the mean scores of students' before and after using PhET interactive simulation in understanding the concept of phases of matter?

Table 6: Finding the Significant Difference in the means Before and After the Utilization of PhET.

Compared Variables	df	Mean	SD	Tvalue	Critical t-value	Pvalue	Decision	Impression 0.05 Level
Pretest	9	2.3	1.03	8.78	2.262	<.001		Significant

Posttest		6.15	2.36				Reject Ho	

Table 6 shows the result of the t-test on finding the significant difference between the pre-test and post-test. Following data computation, it became apparent that the t-value, 8.78, exceeded the t-critical value, 8.78, at the degree of freedom, 9. Additionally, it demonstrates that the p-value is <.001, indicating that the result is significant at p 0.05. As a result, the null hypothesis is rejected. There is a significant difference in the mean scores of students before and after the utilization of PhET Interactive Simulation in understanding the concept of the phases of matter. PhET Interactive Simulation is a learner-centered approach supported by constructivism learning theory that says learners construct knowledge rather than just passively take in information. It is an effective and successful instrument for raising students' academic performance in their least mastered areas the phases of matter because learners are actively engaged in the learning process and acquire knowledge and skills even when attempting new approaches.

5. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Based on the data presented, the researcher concludes that the use of PhET interactive simulations is an effective tool in improving the academic performance of the student. It is an effective intervention or remediation tool in assisting learners to develop mastery skills in understanding the concept of the phases of matter. When PhET interactive simulations are properly implemented in lessons where students are struggling to comprehend scientific ideas. Therefore, the use of PhET simulations can be seen as an effective solution that can improve the learners' poor performance and mastery of least learned skills.

Recommendation

1. Conduct further research on the long-term retention of concepts learned through PhET Interactive Simulations, which was not covered in this study.
2. It is recommended that future researchers consider conducting similar studies during the opening of the academic year to allow for a larger number of participants and more controlled implementation. This approach would not only increase the sample size but also enhance the reliability and generalizability of the results. Conducting the study at the beginning of classes may also provide more consistent baseline data and allow for longitudinal tracking of learning progress over time.

3. Include students' attitudes, engagement, and perceptions toward the use of PhET simulations for a more comprehensive evaluation.
4. Encourage students to explore PhET simulations independently to strengthen their understanding and promote self-directed learning.
4. Provide teachers with training and capacity-building programs to effectively implement PhET simulations in their science instruction.
5. Support from the school community is recommended through investment in ICT infrastructure and access to devices that support simulation-based learning.
6. Future researchers are advised to use control groups and larger, more diverse samples to enhance the validity and generalizability of results.
7. Expand future studies to include other science topics and disciplines, such as Biology, Earth Science, and Chemistry.
8. Utilize both quantitative and qualitative data collection methods, such as interviews or reflective journals, to capture deeper insights into student learning experiences.

REFERENCES

Adams, W. K. (2010). Student Engagement and learning with PHET interactive simulations. Student Engagement and Learning With PHET Interactive Simulations. http://eprints.bice.rm.cnr.it/16857/

Adomi E. E and I Kpangbon (2010) application of ICT's in Nigeria secondary schools. Library philosophy and practice (e-journal) march, 1 – 8 http:/digitalcommonss.uni.edu/libphilprac/345.

Akudulo L.R. (2002) restructuring Nigerian secondary education system though ICT driven curriculum. Journal of the world council for curriculum and instruction Nigerian chapter 3 (1): 7 – 17.

Aluko, M.E (2004) some issues in ICT for Nigerian development. Retrieved from http:/www.dawodu.com /aluko98.htm.11th July 2011.

Amrullah, M. F., Sari, M. I., Mahtari, S., Hidayat, A., & Setiawan, A. (2022). The effectiveness of PhET simulations in physics learning: A meta-analysis study. Journal of Physics: Conference Series, 2165(1), 012038. https://doi.org/10.1088/1742-6596/2165/1/012038

Arifin, S., Razali, F. B., & Rahayu, W. (2023). Integrating PHET interactive simulation to enhance students' mathematical understanding and engagement in learning mixed fraction. Al Ibtida Jurnal Pendidikan Guru MI, 10(2), 241. https://doi.org/10.24235/al.ibtida.snj.v10i2.15056

B**in-Hady et al. (2020).** Journal Education and Social Research. Retrieved from Google Scholar: http//www.googlescholar.com

Bunterm, T., Lee, K., Ng, C., & Rattanavongsa, J. (2014). The effectiveness of inquiry-based learning using a PhET simulation on students' understanding of static electricity. Procedia - Social and Behavioral Sciences, 116, 2951–2956. https://doi.org/10.1016/j.sbspro.2014.01.682

Chamberlain, et al. (2021). Interdisciplinary Journal of Environmental and Science Education . Retrieved from Google Scholar : https://www.ijese.com/

Diana Kozlova, Marcel Pikhart. (2021). ScienceDirect . Retrieved from Google Scholar : sciencedirect.com

Diab, H., Daher, W., Rayan, B., Issa, N., & Rayan, A. (2024). Transforming science education in Elementary Schools: The Power of PHET Simulations in Enhancing Student Learning. Multimodal Technologies and Interaction, 8(11), 105. https://doi.org/10.3390/mti8110105

Eleo, M. C., & Manguilimotan, Y. B. (2024). Physics education technology (phet) interactive simulations as teaching aid in enhancing students' performance in physics. EPRA Int. J. Multidiscip. Res. IJMR, 60-64.

ESpinosa et al. (2020). Journal Educational and Social Reasearch. Retrieved from Google Scholar: http:www.googlescholar.com

Fernandes et al., 2018; . (2018). Journal Education and Social Research . Retrieved from Google Scholar : http://ww.w.googlescholar.com

Florida E. Doloksaribu, Triwiyono Triwiyono. (2021). International Journal on Studies in Education . Retrieved from Google scholar : https://d1wqtxts1xzle7.cloudfront.net/

Galle. (2020, September). Turkish Science Education . Retrieved from Google Scholar : www.turkishscienceeducation.com

Haryadi and Pujiastut. (2020). Journal of Physics . Retrieved from Google Scholar : https://iopscience.iop.org/

Jumman Sani, Md Mostafa Kamal, Tapan Kumar Biswas. (2024, May). International Journal for Multidisciplinary Research (IJFMR). Retrieved from Google Scholar: http://www.googlescholar.com

Lourida, K., Anastasopoulou, E., Tsagri, A., & Avramidi, E. (2024). The impact of ICT on education. Technium Social Sciences Journal, 58, 48–55. https://doi.org/10.47577/tssj.v58i1.12345

Konstantina Lourida, et.al . (2024, June). HeinOnline . Retrieved from Google Scholar : heinonline.org

Mayer, R. E. (2009). Multimedia learning (2nd ed.). Cambridge University Press.

Moore, et,al. . (2021). Interdisciplinary Journal of Environmental and Science Education . Retrieved from Google Scholar : https://www.ijese.com/

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., & LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. The Physics Teacher, 44(1), 18–23. https://doi.org/10.1119/1.2150754

Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. Computers & Education, 58(1), 136–153. https://doi.org/10.1016/j.compedu.2011.07.017

Telefonica. (2023, July 15). Telefonica . Retrieved from Google : https://www.telefonica.com/

Wieman, C. E., Adams, W. K., & Perkins, K. K. (2008). PhET: Interactive simulations for teaching and learning physics. The Physics Teacher, 44(1), 18–23.

Zuzana, Alena . (2017, September). International Journal of Learning and Teaching. Retrieved from Google Scholar: internationaljournalof learningteaching.com

Doloksaribu, F. E., & Triwiyono, T. (2021). *The reconstruction model of science learning based PhET-Problem Solving*. *International Journal on Studies in Education (IJonSE), 3*(1), 37–47. ejournal.undiksha.ac.id+11academia.edu+11link.aps.org+11Anastasopoulou, E., Tsagri, A., Avramidi, E., & Lourida, K. (2024). *The impact of ICT on education*. *Technium Social Sciences Journal, 58*, 48–55. searchworks.stanford.edu+3researchgate.net+3scispace.com+3

Budiarti, I. S., Boy, B. Y., & Lumbu, A. (2021). *Analysis of students' scientific problem solving skills in learning using PhET simulation in 3T region*. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK), 7*(2), 59–76. pdfs.semanticscholar.org+1ojs.uho.ac.id+1

Halmuniati. (2022). *Pengaruh model pembelajaran problem solving dibantu media simulasi PhET terhadap kemampuan pemecahan masalah fisika*. *Jurnal Penelitian Pendidikan Fisika, 7*(4). journal.uinjkt.ac.id+10ojs.uho.ac.id+10neliti.com+10

Taqwa, M. R. A., & Rivaldo, L. (2019). *Pembelajaran problem solving terintegrasi PhET: Membangun pemahaman konsep listrik dinamis*. *Jurnal TSCJ*. neliti.com

Wieman, C. E., Perkins, K. K., & Adams, W. K. (2008). *PCAST report: Scientific teaching*. *Science*, 332(6039), 978–979. *(Referenced for active learning pedagogies)*

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press. *(Theoretical foundation for visualizations and simulations)*

Zacharia, Z. C., & Olympiou, G. (2011). *Physical versus virtual manipulative experimentation in physics learning*. *Learning and Instruction, 21*(3), 317–331. *(Supports real-world connections and cognitive engagement)*