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Using PhET Interactive Simulations to Improve the Learners' Performance in Science

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Abstract

In the science section of the 2018 Programme for International Student Assessment (PISA), the Philippines came in last out of all the participating countries. Through a classroom-based research methodology, the study aimed to determine the effectiveness of using Physics Education Technology (PhET) to enhance learners' performance in science in grade 10. Thirty-three pupils from a public school in Ozamiz City were chosen by purposive sampling in the academic year 2023–2024. Both qualitative and quantitative approaches were used in the study; data were gathered through interviews and a test created by the researcher. To understand the results thoroughly, statistical analysis was conducted using Minitab and HyperResearch, utilizing methods such as mean, standard deviation, t-test, and theme analysis. The study aimed to achieve the following objectives: Determine the learners' performance before using PhET interactive simulations; Determine the learners' performance before using PhET interactive simulations; Identify significant difference in learners' performance before and after using PhET interactive simulation; and explore other observed developments among the learners after the use of PhET interactive simulation. The findings revealed an outstanding improvement in the learners' overall performance following the integration of PhET interactive simulations into science learning. Therefore, the PhET interactive is an effective tool for improving the learners' performance in science. This supports a recommendation that PhET simulations can be effectively incorporated to enhance students' understanding of scientific concepts.

Keywords: academic performance, motivation, PhET, self-learning, simulation.

1. Introduction

The science curriculum was implemented in the Philippines with the goal of developing persons with scientific literacy, promoting responsible decision-making, and the ability to apply scientific knowledge to community challenges (Dela Cruz, 2022). A scientific attitude toward science education promotes twenty-first-century learning and lays a solid basis for students' academic success. Science education at the secondary level serves as a foundation for upper secondary education (Choudhary et al., 2019). However, according to the most recent findings of the Programme for International Student Assessment (PISA) 2018, the Philippines placed last among participating nations where science was one of the topics assessed.

Students were discouraged from learning science because they lost interest and acquired a negative attitude toward it (Solis-Foronda & Marasigan, 2021). Similarly, pupils had trouble grasping the topic and connecting past material to a new one since their instructor was not devoted to scientific education (Solis-Foronda & Marasigan, 2021).

Poor performance in STEM subjects is due to psychological factors, including poor attitudes, high achievement anxiety, low interest, and motivation, lack of enjoyment, low task value and self-efficacy, and others that rapidly increase during high school years (Ekatushabe et al., 2021). Furthermore, motivation and interest affect students' learning, especially in Physics, a subject learners perceive as abstract (Kwarikunda et al., 2020). Moreover, boredom during learning activities has the potential to impede attention, motivation, learning, and, eventually, achievement (Ekatushabe et al., 2021).

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More than 25% of participants said that learning physics was dull (Mbonyiryivuze et al., 2021). Around 39% believe that physics is unrelated to real-world experience (Mbonyiryivuze et al., 2021). A considerable proportion of individuals expressed negative attitudes toward physics because of the amount of work necessary to study (Mbonyiryivuze et al., 2021). It also revealed that participants' general physics problem-solving abilities were low (Mbonyiryivuze et al., 2021).

In contrast to student- and teacher-led activities, students thought collaborative functions were the most beneficial. More specifically, learning performance in physics was favorably correlated with male students' impression of collaborative functions and positively correlated with female students' view of student-led functions. However, according to Zhao and Shi (2020), the impression of teacher-led functions by both male and female students negatively influenced their success in physics learning.

Students showed an acceptable degree of technology readiness but a high level of science knowledge. Additionally, the study found an important connection between students' related to technology preparedness and specific abilities in group projects and creative thought. Additionally, it is recommended that teaching methods that include group projects and encourage critical thinking be incorporated into all curriculum areas and activities (Fideli & Aliazas, 2022).

However, there appears to be a practical knowledge gap in the prior research and a lack of rigorous research in the prior literature. Some of these unexplored aspects are lacking in the practice of science education for Grade 10 students. The field of science education for Grade 10 is ripe for an investigation of practical focus research on using Physics Education Technology (PhET) interactive simulation to improve grade 10 students' performance in science (Miles, 2017).

Thus, this study is based on John Dewey's philosophy of learning. Students learn best when they have experience. Thus, providing an interactive simulation to pupils will assist Grade 10 students in improving their scientific performance during the school year 2023-2024 at one of Ozamiz City's public schools. This allows students to control the simulation and improve their critical thinking abilities. As a result, action research was done to increase grade 10 students' scientific performance through the use of PhET interactive simulations.

2. Research Methods

2.1. Research Design

The study used action research by design. Action research is a type of study that teachers may utilize to address problems and enhance their professional practices independently (Zuber-Skerritt, 2021). Action research is a systematic inquiry strategy used by teachers to enhance and improve their practices (Whitehead, 2020). This action research methodology was found acceptable since it intended to increase Grade 10 science achievement through the use of PhET interactive simulations.

2.2. Research Setting

The study was conducted at the junior high school, specifically at the Grade 10 level, at a certain public secondary school in Ozamiz City. It was a complete secondary school catering to learners from Grade 7 to Grade 12.

2.3. Respondents of the Study

The *study* participants consisted of 2 students from Misamis University, selected using a snowball purposive sampling method. Initially, there were ten participants who decided to participate in the photovoice study. However, following the orientation session where they learned about the photovoice method, they opted to withdraw their participation. The selection of participants was based on specific criteria, including: (1) enrollment at Misamis University for the academic year 2022-2023, (2) being a victim of the flood that occurred between December 2022 and January 2023, which included those who were evacuees or experienced property loss, and (3) willingness to participate in the study. Prior to conducting the interviews, the researchers ensured that all the aforementioned criteria were fully met.

2.4. Data Collection

This action research gathered quantitative data. The student's performance in science among Grade 10 learners was assessed using a researcher-made instrument, such as test questions.

2.4.1. Pre-Implementation Phase

The researcher conducted a background investigation on emerging students' problems regarding their performance in science. The researcher read previous related studies that provided a wider perspective on the problem. The researcher started crafting the research proposal, developed lesson plans, created pre- and post-tests, and created a prototype intervention. Eventually, the researcher sought permission from the Superintendent of the Division of Ozamiz City and authorization from the principal and cooperating teacher to conduct research at a secondary school in Ozamiz City.

2.4.2. Implementation Phase

During the implementation phase, information was obtained through pre-testing the participants, having the researcher provide a targeted intervention for a certain period of time, monitoring the participants' behavior and manner, and administering the post-test assessment. Data collection, counting, analysis, and interpretation are all included in this step. In order to determine if the intervention had a meaningful impact at this point, the data needed to be evaluated.

2.4.3. Post-Implementation Phase

The post-implementation stage included drawing conclusions, providing recommendations, proofreading, editing, and finalizing the research study. It also involved properly disseminating the research results to a certain group of people.

2.5. Ethical Considerations

In any research study, the protection of human subjects by the application of suitable ethical norms is essential. Because of the extensive duration of the research process, ethical questions are especially important in qualitative studies (Arifin, 2018). Letters asking for consent to participate in the study were sent to the participants. The study's participants' anonymity and confidentiality were preserved by withholding their names and identities throughout the data collecting, analysis, and reporting phases. After being made aware of the purpose of their involvement in the study, participants were required to sign an informed consent form.

All data were handled confidentially, and participants' identities were not reflected in any part of the paper. Student participation in this research project was invitational, and consent was sought from both parents and students. Interested participants were asked to sign consent forms, which specified the nature of their participation and their ability to discontinue their involvement in the research at any time.

The study maintained confidentiality and anonymity by refraining from mentioning the school and participant/respondent identity in any part of the paper. Copyright issues were addressed by citing the works of the original authors in the final report. Additionally, the final report underwent a plagiarism test before submission and publication to ensure 95 percent originality.

2.6. Data Analysis

With the use of Anaconda, Jupyter, and Minitab statistical software, the following tools were utilized:

Frequency and percentage were used to provide a descriptive overview of the various aspects related to the study.

Mean and standard deviation were used to determine the learners' performance before and after using the PhET interactive simulation.

T-test was used to explore the significant difference in learners' performance before and after using PhET interactive simulation.

Thematic analysis was used to explore other improvements observed among the learners after the use of PhET interactive simulations with the aid of HyperReseacrh software.

3. Results and Discussion

3.1. Learners' Performance Before Using Phet Interactive Simulation

Table 1 presents the performance of learners before the implementation of the PhET Interactive Simulation. The overall findings indicate that all students did not meet the expectations. Specifically, 33 students (100.00%) were categorized as not meeting the expectations (M = 8.27; SD = 2.45).

The data clearly shows that before the use of PhET Interactive Simulation, the learners' performance was significantly below the expected level. With 100% of the students falling into the "Did not Meet the Expectations" category, it is evident that there was a pervasive issue with understanding or retaining the material. The mean score of 8.27, which is far below the lowest satisfactory threshold of 18, underscores the magnitude of the challenge. The relatively high standard deviation of 2.45 suggests some variability in the scores, indicating that while all students were underperforming, some were closer to the threshold than others.

The findings suggest a critical need for intervention to improve learner performance. Educators and school administrators should consider integrating PhET Interactive Simulations as a potentially effective tool to enhance understanding and retention. The current performance levels indicate that traditional teaching methods may not be sufficient for the learners to grasp the material fully.

Most items that purport to measure school engagement inquire about academic performance (Jimerson et al., 2003). The importance of academic performance will never be overlooked, and nor should it ever be overlooked. It is also time to shift focus toward ensuring and understanding how to best support students to attain non-academic success (Chung & McKenzie, 2020). The importance of academic performance is not only in achieving educational and learning goals but also necessary for transformation (Anierobi et al., 2022).

To address these gaps, it is recommended that educators receive training on how to effectively incorporate PhET simulations into their lesson plans. Additionally, it might be beneficial to supplement these simulations with other interactive and engaging teaching methods, such as group discussions, hands-on activities, and frequent formative assessments to gauge and support student progress. Regular feedback sessions also help in identifying specific areas where students struggle and require additional support. By adopting a more interactive and supportive approach, it is anticipated that learners' performance and retention levels will significantly improve.

Table 1. Learners' Performance Before Using Phet Interactive Simulation

Learners' Performance	Frequency	Percentage	M	SD
Did not Meet the Expectations	33	100.00	8.27	2.45

Note Scale: 26-30 (Outstanding); 23-25 (Very Satisfactory); 21-22 (Satisfactory); 18-20 (Fairly Satisfactory); 1-17 (Did not Meet the Expectations)

3.2. Learners' Performance After Using Phet Interactive Simulation

Table 2 presents the performance of learners after the implementation of the PhET Interactive Simulation. The learners' overall performance improved significantly (M = 22.36; SD = 6.95).

Thirteen students, representing 39.39%, achieved outstanding performance, indicating that the PhET interactive simulations were highly effective in improving their understanding and knowledge in science. Eleven students, or 33.33%, were satisfactory, suggesting they showed solid improvement, though not at the same level as those who were outstanding. Seven students, making up 21.21%, did not meet expectations, highlighting the need for additional support. One student each, accounting for 3.03%, fell into the very satisfactory and fairly satisfactory categories. This indicates that while the PhET interactive simulations had a positive impact on many students, there remains a portion who require further instructional support.

The data indicates a substantial improvement in learner performance following the use of the PhET Interactive Simulation. A notable 39.39% of students achieved outstanding results, highlighting the effectiveness of the interactive tool in enhancing comprehension and retention. The mean score of 22.36 reflects an overall shift towards higher performance levels, as opposed to the pre-simulation scores where all students were below expectations. The reduction in the percentage of students who did not meet expectations, from 100% to 21.21%, further underscores the positive impact of the simulation. The increased standard deviation of 6.95 suggests a wider range of performance levels, indicating that while many students benefited significantly, others still struggled, albeit at a lower proportion than before.

The findings suggest that the integration of PhET Interactive Simulations had a markedly positive effect on learner performance. This improvement should encourage educators and school administrators to continue using and possibly expand the use of such simulations in their curriculum.

An interactive simulation is a helpful tool for improving student understanding (Samitra et al., 2023). Students become enthusiastic and active in learning because students learn with the help of audio-visual media to improve learning outcomes (Samitra et al., 2023). PhET Interactive Simulations is a widely recognized and extensively used platform that offers a diverse range of interactive simulations for science and mathematics education (Olugbade et al., 2024). These simulations are designed to provide students with hands-on, inquiry-based learning experiences that promote a deeper understanding of scientific concepts and principles. Significant increase of students' concept understanding and also the implementation of PhET simulation achieved very positive responses (Inayah & Masruroh, 2021).

To address the gaps were some students still did not meet expectations, it is recommended that additional support mechanisms be put in place. These could include targeted tutoring sessions, personalized learning plans, and further interactive resources to cater to diverse learning needs.

Moreover, professional development for teachers on best practices for implementing these simulations could help maximize their effectiveness. Encouraging collaborative learning activities and providing regular feedback can also help identify and support students who are still facing challenges. By fostering a more interactive and supportive learning environment, it is anticipated that overall student performance will continue to improve, ensuring that all learners can benefit from the enhanced educational tools.

Table 2. Learners' Performance After Using Phet Interactive Simulation

Learners' Performance	Frequency	Percentage	M	SD
Outstanding	13	39.39	29.00	0.81
Very Satisfactory	1	3.03	25.00	-
Satisfactory	11	33.33	21.63	0.50
Fairly Satisfactory	1	3.03	20.00	-
Did not Meet the Expectations	7	21.21	11.14	3.29
Overall Performance	33	100.00	22.36	6.95

Note Scale: 26-30 (Outstanding); 23-25 (Very Satisfactory); 21-22 (Satisfactory); 18-20 (Fairly Satisfactory); 1-17 (Did not Meet the Expectations)

3.3. Significant Difference in the Learners' Performance Before and After the Use of Phet Interactive Simulation

Table 3 presents the significant difference in learners' performance before and after using the PhET Interactive Simulation. The analysis revealed that the difference in performance before and after using the PhET Interactive Simulation was highly significant ($t = 12.08$, $p = 0.00$).

Before using the PhET Interactive Simulation, the mean score of the students was 8.27. However, after using the simulation, the mean score increased to 22.36. The t-value of 12.08 and a p-value of 0.00 indicate that the observed difference in mean scores is statistically significant. This means the likelihood of observing such a difference by chance alone is extremely low. Overall, these findings suggest that the PhET Interactive Simulation had a substantial positive impact on learners' performance and significantly improved their learning outcomes. The highly significant improvement in learner performance after using the PhET Interactive Simulation has important implications for educators and school administrators. This evidence strongly supports the continued and expanded use of interactive simulations in the curriculum to enhance student understanding and retention of material.

Simulation learning can support students with low understanding and cannot construct abstract concepts (Olympiou et al., 2013). The existence of simulation learning helps abstract understanding to be easily understood. That is because animated media can provide a comprehensive experience from concrete to abstract. Animation media can also embed basic concepts that are true, real, and precise. Besides that, it can generate motivation and stimulate students to study well (Salam et al., 2020). It is in line with the thinking Sihombing et al. (2021) that better student learning motivation, and better student understanding of concepts.

To build on this success, it is recommended that schools provide training for teachers on effectively integrating PhET simulations into their teaching practices. Additionally, incorporating other interactive and engaging instructional methods alongside simulations can further support student learning. Regular assessments and feedback sessions can help identify any remaining areas where students may struggle, allowing for targeted interventions.

Overall, the findings suggest that adopting interactive educational tools like PhET simulations can lead to significant improvements in student performance, making it a valuable addition to the educational strategies employed by schools.

Table 3. Significant Difference in the Performance of Learners Before and After the Use of Phet Interactive Simulation

Variables	**Mean Score**		**Test Statistics**	
	(Pretest	**Post-test)**	**(t-value**	**p-value)**
Before and after using PhET simulation	8.27	22.36	12.08	0.000

Ho: There is no significant difference in the performance of learners before and after the use of Phet interactive simulation

*Note: Probability Value Scale: **p<0.01 (Highly Significant); *p<0.05 (Significant); p>0.05 (Not Significant)*

3.4. Other Developments Observed Among the Learners After the Use of Phet Interactive Simulation

The study analyzed the distinguished effects upon the implementation of PhET interactive simulation. Participants of the study have presented individual experiences and feelings on the implementation of this simulation. The researchers utilized the responses of 7 participants and analyzed the results for important meaning in search of emergent themes to classify the responses. The three (3) emerging themes mentioned in the study revealing the participants' experiences and feelings in the use of PhET interactive simulations are as follows: 1) Building Concepts; 2) Increasing motivation to learn more in science subjects;3) Enhancing self-directed learning.

3.5. Building Scientific Concepts

Building concepts using PhET interactive simulations refers to an educational approach where students engage with dynamic, virtual simulations to explore and understand complex scientific and mathematical ideas. It involves an interactive element where students manipulate variables and observe outcomes to deepen their comprehension of the subject matter. This is highlighted in the responses of the participants:

"I have learned that PhET interactive simulations have been helpful to me and many other students in understanding scientific concepts in general, and particularly complex concepts, due to the animations that illustrate what is happening." (P4)

"PhET simulation enhanced my understanding of scientific concepts, particularly complex topics, by providing hands-on virtual experiences that allow me to explore and experiment in engaging way." (P6)

"PhET interactive simulations have improved my understanding of scientific concepts, especially complex topics, because they allow me to explore and manipulate variables in a virtual environment. By actively engaging with the simulations, I can observe outcomes in real-time, which enhances my comprehension of the concepts being simulated." (P7)

Furthermore, participants also stated how PhET simulations make things easier for them to understand. This is commonly experienced by most of the participants, as revealed in the answers of participants 1, 2, and 5.

"PhET simulations have helped me understand science better by making learning more interactive and fun, like a game." (P4)

"The help of PhET simulations enhanced my understanding, and I was able to grasp topics that are difficult to understand because of the PhET simulations." (P2)

"By using the PhET simulations, I can easily understand the topic, especially the difficult ones." (P5)

In light of technological and scientific progress, education must prepare tools and methods that keep pace with this scientific and technological development (Abbas & Abdullah, 2022). PhET virtual media can train process skills to get the result of product cognitive and positive response of learners. The learning by using PhET would make learners more active, and more interested learning uses PhET simulation due to learners can use PhET software animation and also can give a learning experience as well as playing (Gani et al., 2020).

Integrating PhET interactive simulations into education can effectively enhance students' understanding of complex scientific and mathematical concepts. These simulations provide a hands-on, engaging experience that allows students to explore and experiment in a virtual environment. The positive responses from participants indicate that PhET simulations not only make learning more interactive and fun but also facilitate a deeper comprehension of difficult topics.

3.6. Increasing Motivation to Learn More in Science Subjects

PhET interactive simulations serve as dynamic tools that not only enhance understanding but also ignite students' enthusiasm for scientific exploration. Through engaging virtual experiences, these simulations not only elucidate complex scientific concepts but also inspire curiosity, thereby fostering a deeper desire to delve into the realms of science. The answers of participants support this:

"Using PhET simulations has increased my motivation in science because they are engaging and make me feel like I'm experiencing the concepts rather than just reading about them.” (P1)

" The effectiveness of the simulations in raising student motivation led to better learning outcomes for me in science.” (P3)

“The use of PhET simulations in class has significantly increased my interest and motivation in science. Learning becomes more engaging and interactive as participants connect. I can now actively participate in experiments instead of solely relying on reading and listening to teachers' explanations.” (P4)

“Using PhET simulations has increased my interest and motivation in the subject, as the applications have made learning more enjoyable and accessible. Using PhET simulations is fun.” (P6)

“Since using PhET simulations, my interest and motivation in the subject have increased. It makes learning more engaging and enjoyable. The ability to interact with the simulations has made the learning process more meaningful.” (P7)

Motivation is a crucial aspect of learning since it dictates how motivated or energetic a person is to accomplish a job (Banda & Nzabahimana, 2023). Teachers have struggled to figure out what makes a learner genuinely interested in learning. Many elements influence one’s willingness to put effort into the learning process. These variables include a student’s personality and talents, the qualities of specific learning activities, the surroundings, rewards, and the instructor’s behavior (Slavin, 2018). It is a fact that all students are motivated in very different ways in the classroom. Students’ motivation towards learning also ensures that students are engaged in activities; hence, meaningful learning is achieved. Using media can improve the motivation of learning of learners because it can concentrate on improving of the concept understanding learners (Gani et al., 2020).

The responses from participants underscore the effectiveness of PhET simulations in increasing motivation and improving learning outcomes. Students express how the interactive nature of the simulations makes learning more engaging and enjoyable, leading to enhanced motivation to explore scientific concepts further. Additionally, the simulations enable active participation in experiments, providing a hands-on approach that enhances comprehension and retention.

Understanding the importance of motivation in learning, educators must recognize the diverse factors that influence students' willingness to engage in the learning process. By incorporating dynamic tools like PhET simulations, teachers can create an environment that promotes active learning and meaningful engagement. These simulations cater to different learning styles and preferences, thereby enhancing the overall learning experience for students.

3.7. Enhancing Self-directed Learning

PhET interactive simulations are more than just educational tools; they represent a gateway to self-directed learning for students. By providing dynamic, hands-on experiences, PhET simulations empower learners to take control of their own learning journey. This interactive approach fosters curiosity, encourages exploration, and allows students to delve deeply into scientific concepts at their own pace. The answers of participants support this:

" It boosts my confidence in learning on my own by providing a fun way to explore and understand new topics and lessons like having my personal science teacher." (P1)

" Using PhET interactive simulations greatly improves my ability to learn independently. These simulations engage us students, not just me, with visualizations, encourage experimentation, provide immediate feedback, offer a safe learning environment, allow for customization, and bridge theoretical concepts with real-world applications. (P2)

"PhET interactive simulations have improved my ability to learn independently by providing a self- learning environment where I can explore and experiment on my own. These simulation helped and boosted my confidence on exploring new topics and understanding complex concepts." (P6)

Self-directed learning entails individuals taking initiative and responsibility for their own learning. You are free to set goals and define what is worth learning (Loeng, 2020). Exploration of the simulations under no guidance or with open conceptual questions promotes students to explore the simulations where they gain physical insight into the phenomena via their own questioning (Adams, 2010). Engaged exploration with simulations in the no guidance or open conceptual question condition provides only enough guidance to require students to explore via their own questioning (Adams, 2010).

Self-directed learning, characterized by individuals taking initiative and responsibility for their learning, is facilitated through the interactive nature of PhET simulations. Students are free to set goals, explore topics of interest, and gain insights through their own questioning and exploration.

The implications suggest that PhET simulations not only enhance understanding but also cultivate essential skills such as critical thinking, problem-solving, and self-motivation. By promoting self-directed learning, PhET simulations contribute to the development of lifelong learners who are curious, adaptable, and empowered to pursue knowledge independently.

4. Conclusion

4.1. Summary

The study was conducted to improve grade 10 students' performance in science with the use of PhET interactive simulations during the academic year 2023-2024 in a certain secondary public school in Ozamiz City. The research utilized a classroom-based action research design, selecting 33 students through purposive sampling. A researcher-made test was used for data collection, and the analysis included calculating the mean, and standard deviation, and conducting a t-test. Specifically, the objectives of the study were to: (1) determine the learners' performance before using PhET interactive simulation; (2) determine the learners' performance after using PhET interactive simulation; (3) identify significant difference in learners' performance before and after using PhET interactive simulation; and (4) explore other observed developments among the learners after the use of PhET interactive simulation.

4.2. Findings

The following were the key findings of the study:

1. All of the learners' performance before the use of PhET interactive simulation did not meet the expectations.
2. The learners' performance improved significantly after using the PhET interactive simulation, with the overall performance falling into the satisfactory category.
3. The study revealed that the difference in performance before and after using the PhET interactive simulation was highly significant.
4. After the use of PhET interactive simulations, several developments among the learners were identified. PhET interactive simulations helped build scientific concepts, increased motivation to learn more in science subjects, and enhanced self-directed learning.

4.3. Conclusions

Based on the findings, the following conclusions are drawn:

1. The challenging nature of traditional teaching methods contributes to students finding it difficult to understand science concepts. This difficulty leaves students struggling and potentially disinterested in the subject matter. Additionally, the initial lack of engagement indicates a need for more interactive and supportive educational tools.
2. PhET interactive simulations facilitate a better understanding and engagement with science content. Using PhET interactive simulations helps students grasp complex scientific concepts.
3. PhET interactive simulations play a crucial role in science education, suggesting that it is an effective tool for improving the academic performance of learners in science.
4. PhET simulations cultivate learners' vital skills and positive attitudes in learning science, enriching the educational experience. By engaging with interactive interfaces and manipulating virtual objects, learners enhance their digital literacy while interpreting visual representations of scientific concepts.

4.4. Recommendations

Based on the finding and conclusions, it is recommended that:

1. Science teachers create interactive activities where PhET simulations can be effectively incorporated to enhance students' understanding of scientific concepts.
2. Teachers also facilitate reflective discussions where students can share their experiences with PhET simulations, discuss their observations, and reflect on how these simulations have enhanced their understanding of scientific concepts.
3. School principals ensure that the school has the necessary technology infrastructure and equipment to support the implementation of PhET simulations in classrooms.
4. Students take the initiative in exploring additional PhET simulations outside of classroom assignments to further enhance their scientific knowledge and skills.
5. Students provide constructive feedback to teachers about their experiences with PhET simulations to help improve their integration and effectiveness in the classroom.
6. Future researchers may research the effectiveness of PhET simulations in other subjects.

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