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Effects of Physics Education Technology (PhET) Simulations On Students' Attitude and Achievement in Electricity Concepts in Colleges of Education in North-Central, Nigeria

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ABSTRACT
This study investigated the Effects of Physics Education Technology (PhET) Simulations on Students' Attitude and Achievement in Electricity Concepts in Colleges of Education in North-Central, Nigeria. Four research questions and hypotheses guided the study. The research design employed was quasi-experimental design of pre-test, post-test non-equivalent groups design. The population of the study was made up of 143 NCE 1 students. Multi-stage sampling technique was used to select 70 NCE 1 students comprising both experimental (35) and control (35) groups. The research instruments used for data collection were Electricity Achievement Test (EAT) and Electricity Attitude Questionnaire (EAQ). The instruments were validated and subjected to reliability test and coefficients of 0.80 and 0.85 were obtained for EAT and EAQ using Kuder-Richardson formula 21 (K-R21) and Cronbach's Alpha respectively. Data collected were analyzed using mean rank for research questions one and three and frequency counts, mean and standard deviation for research questions two and four. Mann-Whitney U test was used to test hypotheses one and three, while ANCOVA was used to test hypotheses two and four at 0.05 level of significance. Based on the findings, it was recommended among others that PhET simulations be incorporated into the teaching of Electricity concepts to improve students' attitude and achievement. The findings suggests that physics lecturers receive training to effectively implement simulation-based instruction and also support the continued use of PhET for both male and female students, as it enhances learning outcomes for all learners with only slight gender differences.
Keywords: PhET Simulations, Students' Attitude, Achievement, Electricity Concepts, Colleges of Education.

1. INTRODUCTION

Simulations are technological advances used in instructional media which have the capacity to aid students, especially at the tertiary level, to grasp new concepts faster and better in engineering related disciplines. The uses of simulations can activate multiple skills in science learners such as observing, measuring, predicting, controlling variables, formulating hypotheses and interpreting results (Mahdi,

Laafou & Mohamed, 2018). According to Mbonyiryivuze, Yadav and Amadalo (2022), incorporating technology into teaching and learning has benefits which can enhance attitude in science related subjects. Additionally, Batuyong and Antonio (2018), explained that PhET simulation is a very effective educational tool for use in teaching and studying physics because it raises students' achievement in the subject. PhET simulations are essential to fast-developing conceptual knowledge to increase learning and compensate for the lack of actual laboratories in classrooms (Banda & Nzabahimana, 2021).

The creation of interactive simulation software made it possible to visualize and explore electric circuits and electromagnetic phenomena in virtual settings, enabling students to interact with abstract electricity concepts in a practical way, complementing traditional classroom teaching and laboratory experiments. With scientific development and technological revolution, simulation technology and the use of its models such as virtual reality, artificial intelligence and others have arisen, and the need to take advantage of it to develop education and solve its problems and serve the learner and the teacher is already reflected in the improvement of the efficiency of the educational process (Droui & Hajjami, 2014).

Simulations offer an interactive and appealing interface enabled with functions of repeated manipulations and observations. These properties of the simulations help learners to repeat the videos or the experimental simulations a couple of times; hence, they develop a concrete understanding of the scientific phenomenon being exhibited by the simulation (Bozkurt & Ilik 2010; Otrel-Cass, Renken, Peffer, Girault & Chiocarriello 2016; Lin, Wu, Kao, Wu & Hsu, 2019). Banda and Nzabahimana (2021), noted that dynamic simulations help educators to facilitate the learning of physics concepts that are challenging, abstract and help students develop skills in virtual laboratory experimentation. A closer look has to be given to the immense importance of learning through simulations and manipulation in education, particularly in Science, Technology, Engineering and Mathematics (STEM) fields (Podolefsky, Rehn & Perkins 2013; Hensberry, Whitacre, Findley, Schellinger & Wheeler 2018; Whitacre, Hensberry, Schellinger & Findley 2019).

Since many of the students are now technology savvy through various outlets of technology such as cell phones, computers, video games, they can be better engaged through simulations on the computer since it provides a different outlet than the traditional forms of learning such as a textbook (Couch, 2014). While the effects of simulations in education have widely been researched and evaluated, it is important to understand why teachers adopt these learning techniques in their classrooms and how they are applied while teaching (Price, Perkins, Holmes & Wieman 2018).

According to Ndihokubwayo et al., (2020), attitude is generally considered a set of psychological ideas where a person feels favorable or unfavorable about an object or person. Although, attitude is based on individual perceptions, it can be changed in the presence of new information. A clear understanding of students' attitudes toward using simulations can help develop better teaching tools and methods. Students' attitudes toward using interactive simulations also influence their performance in learning physical science. How students think and perceive their learning is a critical characteristic of teachers' pedagogy. Students can point out the things they don't understand, along with the way they prefer to learn and the methods they like to use. Therefore, it is essential to know how students perceive interactive simulations in teaching physical science activities and experiments. Thus, students' attitudes toward the usage of interactive simulations must be studied to ascertain its efficacy in physical science learning.

Chong et al., (2012) and Roll et al., (2014) indicate that students' attitudes towards using simulations as a pedagogical tool in physical science teaching are very positive. PhET interactive simulations appear to have a significant positive impact on students' attitudes and perception toward learning since according to Ndihokubwayo et al., (2020), PhET simulations appear to encourage and build an understanding of abstract concepts. In addition, PhET simulations provide learning opportunities not available in a classical laboratory (Perkins et al., 2014). This could lead to improved academic achievement.

Achievement in Electricity concepts is the measurable outcome of learning, typically assessed through tests, conceptual inventories or practical problem-solving tasks. High achievement indicates not just recall but deep conceptual understanding and the ability to apply principles in novel situations. Studies have demonstrated that using PhET interactive simulations significantly improves students' achievement in

physics topics, including electrodynamics and electrostatics (Najib, Md-Ali, & Yaacob, 2022; Uwambajimana & Minani, 2023). The field of academic achievement is very wide-ranging and covers a broad variety of educational outcomes, the definition of academic achievement depends on the indicators used to measure it and gender may be one of such indicators.

Gender is a socially constructed concept that defines roles, behaviors and identities assigned to individuals based on perceived sex differences (World Health Organizations, 2023). In education particularly in science, technology, engineering and mathematics (STEM) gender shapes learners' access, engagement and achievement. Physics, and more specifically electricity as a concept, has historically been perceived as male-dominated, leading to gendered disparities in motivation, confidence and performance (UNESCO, 2022). Historically, societies have organized gender roles along binary lines (male/female), which has influenced access to power, opportunities and resources (Connell, 2021). Today, gender is increasingly recognized as a spectrum, encompassing non-binary, transgender and gender-nonconforming identities (UNESCO, 2022).

Technology-mediated learning tools, like PhET Interactive Simulations, offer opportunities to address gender gaps in science education, physics education in particular. PhET simulations, when integrated thoughtfully and inclusively, serve as powerful tools to promote gender equity in physics education. By making abstract electricity concepts more accessible and engaging, they can help mitigate gender disparities and foster higher achievement levels for all students, especially girls who have been historically underrepresented in the field.

Chukwuyenum et al., (2022), in a Nigerian secondary school context, found that gender-sensitive teaching strategies incorporating PhET simulations significantly improved girls' achievement in physics, especially in electricity concepts. Gender disparities in physics achievement particularly in electricity concepts are shaped by both societal influences and instructional practices. PhET simulations offer an inclusive, engaging and effective pedagogical tool for addressing these disparities. By visualizing abstract phenomena, fostering self-paced learning and supporting collaborative inquiry, PhET simulations can significantly enhance the achievement of both male and female learners. For female students, especially, these tools can serve as equalizers helping to close the gender achievement gap and promote greater representation in physics education.

Physics is challenging to study because students tend to view some of the laws and concepts as abstract (Guido, 2018). This may have resulted to the decline in the percentage of Colleges of Education students choosing physics as their core course due to their level of exposure at the secondary school level. Reports from National Commission for Colleges of Education (2024), on students' enrollment, show that there is a decrease in the number of students enrolling in Physics Education in Colleges of Education in Nigeria due to lack of interest in physics and poor performance of students in physics at their secondary school stage. This poses a great task to educators in physics to reinvent the wheel of teaching by developing exciting and meaningful ways to facilitate learning. When used efficiently, simulation-based learning strategies can overcome the problems of motivation and academic achievement in physics.

While traditional teaching methods (lectures, textbooks, static diagrams) are common in Colleges of Education, these methods may not adequately support students' conceptual understanding of Electricity concepts. Abstract notions such as voltage, resistance and charge are difficult to visualize in conventional classrooms. This gap contributes to persistent low motivation and substandard academic outcomes among student-teachers. Nigeria's educational system suffers from a lack of resources at all stages of education (UNICEF Nigeria, 2015). In spite of this, teachers continue to use the conventional method to teach students, concentrating on their cognitive dimension. Studies have shown that the bulky nature of the curriculum makes teachers employ the conventional method (Amponsah, 2020; Amponsah, Boateng & Mohammed; Amponsah & Ochonogor, 2016b) to enable them finish the syllabus on time instead of innovative strategies like the use of Simulations in teaching and learning physics. Thus, integrating PhET interactive simulations in physics classes may be one of the remedies for correcting poor academic achievement and lack of motivation towards physics, particularly electricity concepts by students of

Colleges of Education in the North Central part of Nigeria. Specifically, the objectives of the study were to:

i. find out the difference between the mean attitude scores of students taught Electricity concepts in physics using PhET simulations and those taught using conventional teaching method.

ii. find out the difference between the mean achievement scores of students taught Electricity concepts in physics using PhET simulations and those taught using conventional teaching method.

iii. find out the difference between the mean attitude scores of male and female students taught Electricity concepts in physics using PhET simulations and those taught using conventional teaching method.

iv. find out the difference between the mean achievement scores of male and female students taught Electricity concepts in physics using PhET simulations and those taught using conventional teaching method.

Research Questions

The following research questions were raised to guide the conduct of this study:

1. What is the difference between the mean attitude scores of students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?
2. What is the difference between the mean Achievement scores of students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?
3. What is the difference between the mean attitude scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?
4. What is the difference between the mean Achievement scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?

Hypotheses

H_{01} There is no significant difference between the mean Attitude scores of students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

H_{02} There is no significant difference between the mean Achievement scores of students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

H_{O3} There is no significant difference between the mean Attitude scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

H_{O4} There is no significant difference between the mean Achievement scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

2. MATERIALS AND METHODS

This study employed quasi-experimental design. Specifically, the study applied the pre-test, post- test non-equivalent control groups design. The population of this study comprised one hundred and forty-three (143) NCE 1 students studying physics in public Colleges of Education in North-Central, Nigeria. A sample size of 70 students were drawn through multi-stage sampling technique. At the first stage of sampling, simple random sampling technique was used to select three states located at the North-Central part of Nigeria. At the second stage of sampling, random sampling technique was used to select four public Colleges of Education from the population. At stage three of sampling, to obtain a more robust and representative sample and to ensure that the sample reflects variations across multiple schools rather than relying on a single institution per group, the researcher selected **four Colleges of Education**, assigning **two institutions to the experimental group** and **two to the control group.** There were 35 students in experimental group and 35 in control group. The instruments used for data collection were Electricity Achievement Test (EAT) and Electricity Attitude Questionnaire (EMQ). The instruments were validated by three physics lecturers in Colleges of Education within the study area. The test items were constructed in line with the learning objectives and cognitive levels as specified in the table of specification. A pilot test was conducted using one intact class of thirty (20) physics students in a College

of Education that was not part of the sampled Institutions selected for this study. The reliability of EAT and EAQ were determined using Kuder-Richardson formula 21 (K-R21) and Cronbach Alpha respectively. Lesson plans were prepared separately for both experimental and control groups. Those in experimental group were taught Electricity concepts using Physics Education Technology (PhET) Simulations while those in control group were taught using conventional method of teaching. Data collected were analyzed using mean rank for research questions one and three and frequency counts, mean and standard deviation for research questions two and four. Mann-Whitney U test was used to test hypotheses one and three, while ANCOVA was used to test hypotheses two and four at 0.05 level of significance.

3. RESULTS

Research Question 1: *What is the difference between the mean Attitude scores of students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?*

Table 1: Mean Rank Attitude Scores of Students in Experimental and Control Group

Groups	N	Mean Rank	Mean Difference	Sum of Ranks
Experimental	35	24.68	8.80	290.50
Control	35	15.88		181.50
Total	**70**			

Table 1 shows mean rank attitude scores of students in both experimental and control group. The mean rank scores of students taught Electricity concepts using PhET Simulations is 24.68 and sum of ranks is 290.50 while those taught Electricity concepts using conventional method of teaching is 15.88 and sum of ranks is 181.50. The difference between the mean rank is 8.80 in favour of experimental group. The result implies that students in experimental group had higher mean attitude score than those in control group.

Research Question 2: *What is the difference between the mean Achievement scores of students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?*

Table 2: Mean Achievement Scores of Students in Experimental and Control Group

Groups	N	Pre-test		Post-test		Mean gain
		$\bar{x}$	SD	$\bar{x}$	SD	
Experimental	35	11.54	3.457	17.83	2.953	6.29
Control	35	10.61	2.611	11.76	2.538	1.15

Table 2 shows that the experimental group has a pre-test mean score of 11.54, a post-test mean score of 17.83 and mean gain of 6.29 while the control group has a pre-test mean score of 10.61, a post-test mean score of 11.76 and mean gain of 1.15. The experimental group has a higher mean gain than control group as the difference in mean gain is 5.14. This shows that the experimental group taught Electricity concepts using PhET Simulations have higher achievement score than those taught with conventional teaching method.

Research Question 3: *What is the difference between the mean attitude scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?*

Table 3: Mean Rank Attitude Scores of Male and Female Students in Experimental Group

Groups	N	Mean Rank	Mean rank Difference	Sum of Ranks
Male	27	17.55	0.66	169.50
Female	8	16.89		169.00
Total	**35**			

Table 3 shows mean rank attitude scores of students in experimental group. The mean rank scores of male students are 17.55 and sum of ranks is 169.50 while that of their female counterparts is 16.89 and sum of ranks is 169.00. The slight difference in the mean rank is 0.66 in favour of male students.

Research Question 4: What is the difference between the mean Achievement scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional teaching method?

Table 4: Mean Achievement Scores of Male and Female Students in Experimental Group

Variables	N	Pre-test		Post-test		Mean gain
		$\bar{x}$	SD	$\bar{x}$	SD	
Male	27	10.46	2.739	14.84	1.759	4.38
Female	8	9.69	1.584	13.61	2.438	3.92

In table 4, the mean achievement scores of male students taught Electricity concepts using PhET Simulations is 10.46 and 14.84 for the pre-test and post-test respectively, and mean gain score is 4.38 while the mean achievement scores of female students taught Electricity concepts using PhET is 9.69 and 13.61 for the pre-test and post-test respectively and mean gain score is 3.92. This implies that male students achieved slightly higher than the female students.

Test of Hypotheses

H_{01} There is no significant difference between the mean Attitude scores of students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

Table 5: Summary of Mann Whitney U Test Results of Attitude Scores of Students in Experimental and Control Group

Groups	N	Mean Rank	Sum of Ranks	Mann Whitney U	Z	Sig.	Remark
Experimental	35	24.68	290.50				
Control	35	15.88	181.50	78.500	-2.284	.000	Sig.

Table 5 reveals Mann-Whitney U test of attitude scores of students taught Electricity concepts using PhET Simulations and those taught using conventional teaching method. The results indicate a statistically significant difference between the attitude scores of students in experimental and control groups ($z = -2.284$; $p < .05$). This implies that the null hypothesis two is not accepted.

H_{02}: There is no significant difference between mean achievement scores of students taught Electricity concepts in physics using PhET Simulations and those taught using Conventional Teaching Method.

Table 6: Analysis of Covariance (ANCOVA) of Respondents' Scores in Achievement Test (Method*Gender)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	124.581[a]	4	31.145	18.501	.000	.747
Intercept	87.589	1	87.589	52.030	.000	.675
PRET	22.392	1	22.392	13.301	.001	.347
	45.275	1	45.275	26.894	.000	.518
GENDER	2.706	1	2.706	1.608	.216	.060

GENDER	.061	1	.061	.036	.850	.001
Error	42.086	65	1.683			
Total	3580.000	70				
Corrected Total	166.667	69				

a. R Squared = .747 (Adjusted R Squared = .707
b. Computed using alpha = .05

Results in Table 6 shows there is a significant difference in treatments (PhET and Conventional Teaching methods) on students' achievement in Electricity concepts ($F_{(1,25)}$ = 26.894; $p < 0.05$). Hence, null hypothesis two is not accepted. To determine the mean achievement difference between the two groups, table 6 shows a difference of $\bar{x}$=5.14 in favour of the experimental group. This implies that there is a significant difference in the mean achievement scores of students taught Electricity concepts with PhET Simulations and those taught using Conventional Teaching Method.

H_{O3} There is no significant difference between the mean Attitude scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

Table 7: Summary of Mann Whitney U Test Results of Attitude Scores of Male and Female Students in Experimental Group

Groups	N	Mean Rank	Sum of Ranks	Mann Whitney U	Z	Sig.	Remark
Male	27	14.27	167.50				
Female	8	14.18	167.00	90.000	-.897	.428	Not Sig.

Table 7 shows the results of the Mann Whitney U test of attitude scores of male and female students in experimental group. The results yielded no statistically significant difference in the mean attitude scores of male and female students ($z = -.897$, $p > .05$). Therefore, the null hypothesis five is accepted.

H_{O4} There is no significant difference between the mean Achievement scores of male and female students taught Electricity concepts in physics using PhET Simulations and those taught using conventional teaching method.

Result in table 6 shows no significant difference between the mean achievement scores of male and female students taught Physics (Electricity concepts) using PhET Simulations ($F_{(1,120)}$ = .036; p = .850). Therefore, null hypotheses six is accepted.

4. DISCUSSION

The result revealed a statistically significant difference in the attitude scores between the experimental and control groups. This implies that students in experimental group had higher mean attitude scores than those in control group.

This indicates that the intervention or treatment applied to the experimental group influenced their attitude scores. This is supported by Ziya'ulhaq and Bello (2021), who found out that Simulations can improve Students' Performance and Attitudes. The result of the study is also contrary to that of Mei and Kah (2023), who found out that PhET Interactive Simulation negatively impacts students' attitudes towards physics inquiry learning during the full virtual online lessons.

The result also shows that the experimental group taught Electricity concepts in physics using PhET Simulations have higher achievement scores than those taught with conventional teaching method. The findings indicate that there was a significant difference between the two teaching methods on students' achievement in Electricity concepts. This is in line with Uğur, Abdillahi and Kutalmış (2017), whose findings revealed that interactive simulations integrated 5E teaching model caused significantly better acquisition of scientific concepts related to content taught and relatively higher positive attitudes towards physics than traditionally based instruction. Another finding in support of the result revealed that Alex, Ezekiel and Adams (2020), found out that there was a statistically significant difference in academic achievement between the control and experimental groups.

The findings indicate that there was no statistically significant difference between the mean attitude scores of male and female students. The result disagrees with findings of Ayasrah, Alarabi, Al Mansouri, Fattah and Al-Said (2024), in their study, enhancing secondary school students' attitudes towards physics by using computer simulations whose findings demonstrated a statistically significant difference between experimental and control groups in students' attitudes toward scientific inquiry, enjoyment of science lessons and career interest in physics/science. Furthermore, results showed a significant difference in attitudes perceived in these scales, with males having a more significant effect size than female students in all three scales.

The findings indicate that there was no significant difference in the mean achievement scores between male and female students who were taught Electricity concepts using PhET simulations. Which is contrary to the findings of Pember and Achor (2017), whose findings revealed that there was a significant difference in the mean Practical Physics achievement. On the basis of gender there were no significant differences both for the two groups in practical achievement.

CONCLUSION

The findings of this study underscore the effectiveness of the PhET Simulations over the conventional method of teaching towards improving students' attitude and achievement in Electricity concepts. PhET Simulations proved to augment students' attitude and achievement further confirming its potential as a transformative instructional strategy. It was also concluded that gender does not have a significant effect on students' attitude and achievement in learning Electricity concepts. Hence, it is highly recommended for instruction at the Tertiary level and at other levels of Education. This highlights the importance of innovative teaching Strategies in improving Physics education outcomes among Colleges of Education students in Nigeria.

RECOMMENDATIONS

The following recommendations were made based on the findings:

1. Physics lecturers should make regular use of PhET simulations when teaching Electricity concepts, as the tool has been shown to boost students' motivation and achievement.
2. Colleges of Education should organize capacity-building workshops to help lecturers learn how to apply PhET simulations effectively in classroom instruction.
3. Since PhET simulations benefit both male and female students equally, lecturers should ensure that all learners have the same opportunities to engage with the simulations.

REFERENCES

Alex K., Ezekiel N. & Adams 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 Implication in Education* ISSN 2520-7504 (Online) *4* (4), 126-138.

Amponsah S. & Ochonogor C. E. (2016b). The impact of Simulation-based learning on student engagement and understanding. *International Journal of Educational Research, 12*(1), 33.

Amponsah, K.D. (2020). Examining the effectiveness of simulation-based lessons in improving the teaching of high school physics: Ghanian Preservice Teachers' Experiences''. *Schrodinger: Journal of Physics Education*, 5(3), 56.

Banda, H. J. & Nzabahimana, J. (2021). Effect of integrating physics education technology simulations on students conceptual understanding in physics: A review of literature. *Physical Review Physics Education Research, 17*(2), 45-51.

Batuyong, C. T. & Antonio, V. V. (2018). Exploring the effect of PhET® interactive simulation-based activities on students' performance and learning experiences in electromagnetism. *Asia Pacific Journal of Multidisciplinary Research*, *6*(2), 121- 131.

Bozkurt E. & Ilik A. (2010). The effect of computer simulations over students' beliefs on physics and physics success. *Procedia Social and Behavioral Sciences,* 12(9), 654.

Chong, C. K., Go, Y. H., Koay, Y. Y. & Lee, C. H. (2012). Perception and expectations towards the PhET photoelectric effect simulation in learning and teaching: Similarities and differences between female and male students. In Physics Education Research Conference Proceedings *1*(1064), 59-62.

Connell, R. (2021). *Gender and Power: Society, the Person and Sexual Politics*. Polity Press, *6*(9), 45.

Couch, A. S. (2014). The impact of virtual simulations on student comprehension of mechanics. LSU Master's Theses. 151.

Droui, M., & Hajjami, A. (2014). The impact of simulation-based learning on the development of educational practices in light of technological advancements. *International Journal of Innovation and Applied Studies*, *9*(3), 1357–1365.

Guido, R. M. D. (2018). *Attitude and Motivation towards Learning Physics* [Preprint]. arXiv. https://doi.org/10.48550/arXiv.1805.02293

Hensberry K. K., Whitacre I., Findley K., Schellinger J. & Wheeler M.B. (2018). Engaging students with mathematics through play. *Mathematics Teaching in the Middle, 24*(3). https://doi.org/10.29333/iji.2022.15116a

Lin, Y., Wu, W. H., Kao, H. S., Wu, Y. T. & Hsu, Y. S. (2019). The effects of computer simulation in science education: A meta-analysis. Computers & Education, *142*(6), 98.

Mahdi, M. A., Laafou, M. & Mohamed, A. (2018). The use of computer simulation in teaching and learning physics: A case study of Moroccan secondary schools. *International Journal of Innovation and Applied Studies*, *22*(3), 479–487.

Mbonyiryivuze, A., Yadav, L. L. & Amadalo, M. M. (2022). Physics Students' Conceptual Understanding. *A Journal of Science Education, 63*(10), 77-82.

Mei E. N. & Kah H. C. (2023). The Effect of Using PhET in Changing Malaysian Students' Attitude to Learning Physics in a Full Virtual Environment. *Journal of Social Sciences & Humanities, 31*(2): 545 – 560.

Najib, M. N. M., Md-Ali, R., & Yaacob, A. (2022). Effects of PhET Interactive Simulation Activities on Secondary School Students' Physics Achievement. *South Asian Journal of Social Sciences and Humanities, 3*(2), 73–78.

National Commission for Colleges of Education (2024). Minimum standards for Nigerian Certificate in Education (NCCE), *6*(9), 4.

Ndihokubwayo, K., Uwamahoro, J. & Ndayambaje, I. (2020). Effectiveness of PhET Simulations and YouTube Videos to Improve the Learning of Optics in Rwandan Secondary Schools. *African Journal of Research in Mathematics, Science and Technology Education*, *0*(0), 1–13.

Otrel-Cass, K., Renken, M., Peffer, M. E., Girault, I. & Chiocarriello, A. (2016). Inquiry-based science education and problem-based learning: Motivation, objectives, and challenges relevant to computer simulations. *Simulations as scaffolds in science education*. Springer Briefs in Educational Communications and Technology.

Pember, S. T. & Achor, E. E., (2017). Computer-Simulated Experiments and Senior Secondary Students' Achievement in Practical Physics in Nigeria. *Journal of the International Centre for Science, Humanities & Education Research, 3(*2), 1- 17, https://ssrn.com/abstract=3236597

Podolefsky N. S, Rehn D. & Perkins K. K. (2013). Affordances of play for student agency and student-centered pedagogy. *AIP Conference Proceedings. 1513*(1):306.

Price, A., Perkins, K., Holmes, N. & Wieman, C. (2018). How and why do high school teachers use PhET interactive simulations? Paper presented at Physics Education Research Conference, Washington, DC. Retrieved fromhttps://www.compadre.org/Repository/document /ServeFile.cfm?ID=14842&DocID=4989.

Roll, I., Marker, R. & Negron, M. (2014). Enhancing students' attitude toward simulation-based learning: Evidence from interactive classroom implementations. *Journal of Science Education and Technology*, *23*(4), 578‑590

Uğur S., Abdillahi H., Kutalmış G. (2017). Effects of the 5E Teaching Model Using Interactive Simulation on Achievement and Attitude in Physics Education. *International Journal of Innovation in Science and Mathematics Education*, *25*(3), 32-40.

UNESCO, (2022). *Cracking the Code: Girls' and Women's Education in STEM*. Paris.

UNICEF Nigeria (2015). *Education, learning and protection in Nigeria: Situation and resource constraints*. UNICEF Nigeria. Retrieved from UNICEF website (2015 report).

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*, *6*(7), 876-912.

Whitacre I, Hensberry K, Schellinger J. & Findley K. (2019). Variations on play with interactive computer simulations: Balancing competing priorities. *International Journal of Mathematical Education in Science and Technology, 50*(5):665–681.

WHO (2023). *Gender and Health.* https://www.who.int

Ziya'ulhaq, S. & Bello, I. (2021). The Effectiveness of Simulations in Supplementing Traditional Physics Laboratory Experiments, Students' Performance and Attitudes towards Simulations. *Zaria Journal of Educational Studies (ZAJES)*, *21*(1), 20–29. Retrieved from https://zarjes.com/ZAJES/article/view/433