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Gender as a Predictor of Students' Performance in Physics Education Technology Simulation of Chemistry Content as Community Service in Secondary Schools

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ABSTRACT

This study investigated gender as a predictor of students' performance in Chemistry using Physics Education Technology simulations as a form of community service in secondary schools. A quasi-experimental design with pre-test, post-test, and control groups was employed, involving selected Senior Secondary Chemistry students. Participants were taught Chemistry concepts through interactive simulations, while a control group received conventional instruction. The results showed that both male and female students improved comparably in performance. This occurred because the simulations provided visual and engaging experiences that enhanced understanding of abstract concepts regardless of gender. The findings imply that technology-supported strategies can reduce persistent challenges in Chemistry education and promote inclusive opportunities. This also represents community service in education, as accessible simulations support schools with limited laboratory facilities, ensuring equitable learning experiences that strengthen student success and contribute to broader social development.

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1. INTRODUCTION

Student performance is central to the evaluation of educational systems because it reflects the extent to which teaching and learning objectives are achieved (Kumar *et al*., 2021). Academic achievement determines future employment, social mobility, and national development. Performance is understood as observable and measurable behavior that reflects achievement in a given context (Rilwanu *et al*., 2019), while in schools, it is commonly represented by grades and continuous assessments (Anwer, 2019). Academic performance, therefore, serves as both an outcome of learning and an indicator of institutional effectiveness (York *et al*., 2019).

Low academic performance has been identified as a persistent concern globally, particularly in developing countries (Fernandes *et al*., 2019). In Nigeria, research has documented long-standing underachievement in secondary and tertiary institutions (Stone, 2021). Poor results in national examinations are viewed not only as individual shortcomings but also as systemic failures that hinder educational quality and economic growth (Kumar *et al*., 2021; Minh & Van Hoi, 2023). Studies confirm a strong relationship between academic achievement and socioeconomic development, since performance reflects the knowledge and skills needed for national productivity (Dodd *et al*., 2021).

Student outcomes are shaped by both individual and environmental factors. Variables such as intelligence, prior achievement, interest, and motivation interact with teacher quality, school climate, and availability of resources to determine performance (Kim & Kutscher, 2021; Fryer & Leenknecht, 2023). Research further shows that differences in learning strategies and socioeconomic background complicate achievement patterns, making it insufficient to rely on single-factor explanations (Rodríguez-Hernández *et al*., 2020; Gultom & Oktaviani, 2022).

Historical evidence indicates that Nigerian students have consistently struggled with public examinations. Only 32.36% of candidates passed the West African School Certificate Examination in 1960, with performance declining further in later years. More recent records from the Kwara State Ministry of Education revealed that in 2018, only 49.24% of candidates achieved the required five credits for secondary school completion.

Table 1 illustrates the performance of students in Chemistry across four consecutive years of the West African Examinations Council. The table shows that Chemistry pass rates fluctuated between 57.74 and 62.68%, while up to 42.26% of students consistently scored below the credit level. These results highlight persistent weaknesses in Chemistry learning, particularly in basic topics such as acids, bases, and chemical equations. The implications extend to career progression, as students failing to achieve credit passes are excluded from science-related fields, contributing to national shortages in STEM manpower (Ibe *et al*., 2021; Nnanna & Chukwunazo, 2021).

Table 1. Statistics of Students' Academic Performance in WAEC Chemistry (2015–2018) (Ibe *et al*., 2021).

Year	Total Sat	Credit Passed (A1–C6)	% Pass	Below Pass (D7–F9)	% Below Pass
2015	680,357	412,323	60.6	268,034	39.4
2016	706,873	408,122	57.74	298,751	42.26
2017	704,494	441,576	62.68	262,918	37.32
2018	728,998	451,614	61.95	277,384	38.05

The causes of low performance in Chemistry include ineffective teaching methods, inadequate laboratory facilities, overcrowded classrooms, and insufficient instructional resources (Olufemioladebinu *et al*., 2018; Nnoli & Nwafor, 2023). Even when infrastructure is

available, the role of teacher quality remains decisive. Teachers directly shape engagement and comprehension, and no nation can surpass the quality of its teaching workforce (Kim *et al*., 2018). Studies consistently affirm a positive association between teacher competence and student achievement, particularly in science subjects that require conceptual clarity (Fauth *et al*., 2019).

Given these challenges, digital innovations such as Physics Education Technology simulations provide new opportunities. Simulations enable students to visualize abstract concepts and experiment with variables interactively, thereby improving comprehension and retention (Ajijolajesu *et al*., 2019). Beyond their pedagogical value, simulations serve as a form of community service in education because they provide access to quality learning resources for schools with limited laboratory facilities. By making instruction more inclusive, these tools help reduce disparities across socioeconomic and gender groups.

While evidence suggests that simulations enhance learning outcomes, the role of gender as a predictor of performance remains debated. Some studies report no significant gender differences in science learning when technology is integrated (Ajijolajesu *et al*., 2019)

, yet others note variations depending on context and subject. In Nigeria, where gender disparities in education persist, examining whether simulations support equitable outcomes is particularly relevant (Ononye & Obiakor, 2020).

The main purpose of this study is to investigate whether gender predicts students' performance in Chemistry when taught through Physics Education Technology simulations in secondary schools. Specifically, the study aims to:

(i) Determine the performance of senior school Chemistry students in a simulation-based learning environment.
(ii) Examine the difference in performance between pretest and posttest scores of students taught Chemistry with simulations.
(iii) Investigate differences in male and female pretest performance in Chemistry when taught using simulations.
(iv) Determine the influence of gender on posttest performance in a simulation learning environment.

The following research questions guided the study:

(i) What is the performance of senior school Chemistry students in a simulation-based learning environment?
(ii) What is the difference between the pretest and posttest scores of students taught Chemistry with simulations?
(iii) What is the difference between male and female pretest performance in Chemistry when taught using simulations?
(iv) Does gender influence the posttest performance of senior school Chemistry students in a simulation environment?

The following null hypotheses were tested at the 0.05 level of significance:

(i) H01: There is no significant difference between the male and female pretest performance of Chemistry students taught with simulations.
(ii) H02: There is no significant influence of gender on the posttest performance of senior school Chemistry students in a simulation learning environment.

The novelty of this study lies in presenting simulation-based learning as both an instructional strategy and a form of community service. By framing technology as a tool for equity, the research highlights how accessible digital resources can support schools with limited facilities while ensuring that both male and female students benefit equally. The impact of the findings extends to teachers, curriculum planners, and policy makers,

demonstrating that simulations can bridge gender gaps, address persistent performance problems, and contribute to the broader educational community.

2. METHODS

The research design that was adopted is a quasi–experimental pre-test, post-test, and control group design. The design adapted a non-randomized sample where the researcher cannot randomly assign subjects; hence, intact classes were used. The population of the study consists of all senior school students in Kwara State, Nigeria, enrolled in Chemistry classes. The target population for this study is senior secondary school One (S.S.S. I) students of Chemistry in Kwara State. The rationale for selecting S.S.S. I Chemistry Student am hinged on the selected topics taught using PhET Simulation of Chemistry content, and due to the willingness of S.S.S I chemistry students to learn using the PhET simulation, because they have been perceiving chemistry as a subject that is too abstract and volatile coming from their J.S.S. The sample for this was drawn from S.S.S. I Chemistry student in Kwara State. Purposive sampling techniques were adopted to select two intact classes from two separate schools that served as both experimental and control groups accordingly.

Based on the National Policy on Education, a ratio of 1:40 is recommended for teacher-student classroom interaction. Therefore, the sample size for this study was 80 S.S.S. I Chemistry Students with 40 Chemistry students in each of the groups (Experimental and Control). Then, Stratified Sampling was employed to categorize students' performance in the first term examination results and four strata. These strata were tailored along **Table 2**.

Table 2. Scoring Range of Kwara State Senior Secondary School Chemistry Students in four Strata.

Score Range	Remark
1-49	Low
50 – 69	Average
70 – 100	High

Thereafter, proportional Sampling was adopted to select the 40 participants in each of the schools that constituted both the experimental and control groups. The instruments that were used for data collection in this study are two. The first instrument was the PhET simulation, the second instrument was the Chemistry Performance Test (CPT). The research instruments were validated by showing the draft copies of the instruments to the seven experts, four lecturers from the department of science education of Al-Hikmah University, Ilorin, Nigeria, and three senior secondary school Chemistry teachers from Government Day Senior Secondary School, Adeta, Ilorin (GL 10), Hikhi-Wanu Nasirdeen Senior Secondary School, Kuntu Ilorin (GL 12), and Ilorin West Senior Secondary School, Osin Aremu, Kwara State (GL 12). The experts were required to examine the contents of the instruments to ascertain their suitability for the category of students under investigation.

The observations, suggestions, and comments made by the experts were corrected in the final draft copies of the instruments and which were used for a pilot study outside the locale to determine the reliability of the instrument, and a reliability test was carried out for the instrument using Cronbach's Alpha. The reliability test result of 0.79 was obtained. Afterward, the researcher and two other research assistants that have already been trained by the researcher administered the pre-test assessments to both the experimental and control groups to measure their initial understanding of chemistry content, which included Matter, Atom, Molecules, and Chemical Equation. Immediately after the administration of the

pretest, the researcher introduced the PhET simulations into the chemistry content for the experimental group. The teaching of control group also took place after the exposure of experimental group to the PhET simulation of Chemistry contents which both experimental and control groups lasted for six weeks.

We conducted post-test assessments on both groups (experimental and control groups) to measure the impact of PhET simulations on learning outcomes. The responses were subjected to both inferential and descriptive statistics. Research questions were answered using mean, frequency count, and standard deviation. While all research hypotheses were tested using a t-test.

3. RESULTS AND DISCUSSION

The demographic data on gender in the study evaluation of PhET simulations of Chemistry content on senior school students' performance in Kwara State reveals an equal number of male and female participants (**Table 3**). Both the pretest and posttest included 40 male and 40 female students, each making up 50% of the group. This even distribution indicates that the study took steps to include both genders equally, ensuring that the results are free from gender bias in evaluating the PhET simulation's effectiveness. Additionally, there was no dropout in the posttest, with all participants completing the study, which adds to the credibility of the findings.

Table 3. Gender of the Participants

Pretest		%	Posttest		%
Male	**Female**	**Total**	**Male**	**Female**	**Absent**
40	40	80	40	40	0
50.0%	50.0%%	100%	50.0%	50.0%	0.0%

Table 4 shows the evaluation of senior school students' performance in Chemistry content using PhET simulations reveals generally strong outcomes. The mean score of 30.60, out of a possible 40 marks, reflects a solid average performance across the group. Scores varied from 20 to 38, with most students scoring above 30. While the standard deviation of 5.688 indicates some variability in scores, the majority of students' results were concentrated at the higher end of the scale. Impressively, 60% of the students achieved scores between 33 and 38, indicating that a substantial number of students demonstrated a high level of understanding of the Chemistry content presented through PhET simulations. A small portion of students scored in the lower range (20-26), suggesting that while a few students faced challenges, the overall trend in performance was positive. These findings suggest that PhET simulations were highly effective in supporting students' comprehension and retention of Chemistry concepts, as reflected in the strong performance by the majority of participants.

These findings are consistent with previous research highlighting the effectiveness of PhET simulations in enhancing student performance. PhET simulations positively influenced students' performance and retention in physics concepts like the kinetic theory of gases and gas laws, with those using simulations showing superior results compared to those who did not. This suggests that simulations can significantly improve students' grasp and retention of complex concepts. Computer simulations significantly boosted secondary school students' performance in science subjects, supporting the effectiveness of simulations in achieving better learning outcomes (Ouahi *et al*., 2021). Previous research (Ajijolajesu *et al*., 2019) further supports these findings, demonstrating that interactive simulations enhance students' achievement and interest in Chemistry, without significant gender differences in

performance. This aligns with the observed results in Kwara State, where PhET simulations fostered high engagement and understanding among students of both genders. The standard deviation of 5.688 indicates some variability in individual performance, which is consistent with broader studies on educational technology. The use of technology in education can produce varied levels of student engagement and motivation, emphasizing the need for customized approaches to meet diverse learning needs (Erdem, 2019).

Table 4. Performance of senior school Chemistry students in a PhET simulation learning environment.

Scores	Frequency	Percent
20	1	2.5
21	1	2.5
22	1	2.5
23	1	2.5
24	3	7.5
25	6	15.0
26	3	7.5
30	1	2.5
31	1	2.5
33	3	7.5
34	5	12.5
35	4	10.0
36	4	10.0
37	4	10.0
38	2	5.0
Total	40	100.0
Mean	30.60	
Std. Deviation	5.688	
Minimum	20	
Maximum	38	

The data in **Table 5** illustrates the variation between pretest and posttest scores for students who engaged with PhET simulations in Chemistry. The findings reveal a marked improvement in student performance following the integration of PhET simulations. The pretest mean score for the experimental group was 17.15, with a standard deviation of 4.167, indicating that students initially performed at a moderate level. However, after the PhET simulations were introduced, the mean posttest score increased to 30.60, with a standard deviation of 5.688. This reflects a substantial enhancement in students' understanding and performance as a result of the simulation. Furthermore, the rise in the minimum score from 9 in the pretest to 20 in the posttest further confirms the positive impact of PhET simulations on students' learning outcomes. Likewise, the maximum score advanced from 32 in the pretest to 38 in the posttest, suggesting that even the highest-performing students experienced gains. Overall, these results indicate that PhET simulations greatly improved students' grasp of Chemistry concepts, as evidenced by the significant increase in posttest scores. These results align with prior research advocating for the integration of interactive technology in education to boost student engagement and performance.

The data provided in **Table 6** evaluates whether there is a significant difference between the pretest performance of male and female Chemistry students who were exposed to PhET simulations. Male students had a mean score of 16.35 with a standard deviation of 4.196, while female students achieved a slightly higher mean score of 17.95 with a standard deviation of 4.084. Despite this minor difference in performance, the t-value of -1.283 and a

significance level of 0.215 indicate that this difference is not statistically significant. As the p-value exceeds the 0.05 threshold, the null hypothesis is accepted, meaning there is no significant difference in the pretest performance of male and female students. This suggests that both genders exhibited similar levels of performance before the intervention. Previous research (Ajijolajesu *et al*., 2019) further supports these findings, demonstrating that interactive simulations enhance students' achievement and interest in Chemistry, without significant gender differences in performance. This aligns with the observed results in Kwara State, where PhET simulations fostered high engagement and understanding among students of both genders. The standard deviation of 5.688 indicates some variability in individual performance, which is consistent with broader studies on educational technology.

Table 5. Difference in performance between pretest and posttest scores of students in the PhET simulation of Chemistry content.

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest Experimental	40	9	32	17.15	4.167
Posttest Experimental	40	20	38	30.60	5.688
Valid N (listwise)	40				

Table 6. t-test of significant difference between the male and female pretest performance of Chemistry students in PhET simulation.

	MEAN	Std. deviation	Std. Error Mean	N	df	t	Sig. (2-tailed)	Decision
Male	16.35	4.196	0.938	20	19	-1.283	0.215	Accept
Female	17.95	4.084	0.913	20				

The analysis from **Table 7** examines the potential influence of gender on the performance of senior school Chemistry students in a PhET simulation learning environment in Kwara State. The findings reveal that male students had a mean score of 29.25 with a standard deviation of 6.265, while female students achieved a slightly higher mean score of 31.95 with a standard deviation of 4.828. Although there is a noticeable difference in the average performance between the two genders, the t-value of -1.811 and a significance level of 0.086 indicate that this difference is not statistically significant at the standard 0.05 level. Consequently, the results do not provide sufficient evidence to reject the null hypothesis, which suggests that gender does not play a significant role in determining students' performance in the PhET simulation learning environment for Chemistry. Both male and female students demonstrated similar levels of performance in this setting in Kwara State. The research by some researcher (Ajijolajesu *et al*., 2019) further supports these findings, demonstrating that interactive simulations enhance students' achievement and interest in Chemistry, without significant gender differences in performance.

This aligns with the observed results in Kwara State, where PhET simulations fostered high engagement and understanding among students of both genders. The standard deviation of 5.688 indicates some variability in individual performance, which is consistent with broader studies on educational technology. Additionally, the discussion resonates with empirical studies emphasizing the benefits of simulations in supporting cognitive processes essential for learning complex scientific concepts. Students in the experimental group using simulations outperformed those in the control group, a pattern that mirrors the results of this study (Ouahi *et al*., 2021). The improved understanding and skill acquisition facilitated by the PhET

simulations suggest that such tools are crucial in addressing the learning challenges often associated with abstract Chemistry concepts.

The analysis also places the findings within the broader context of student performance in Chemistry, particularly concerning historical trends in public examination results in Nigeria. Data from WAEC (2015-2018) highlight ongoing difficulties in achieving high performance in Chemistry, with many students struggling to meet the required standards. The improvement observed in this study underscores the potential of PhET simulations to address these challenges by offering a more interactive and engaging learning experience that enhances understanding of complex Chemistry topics. Moreover, the discussion considers the pivotal role of teachers in effectively utilizing PhET simulations.

Table 7. t-test of significant influence of gender on the performance of senior school Chemistry students in the PhET simulation learning environment.

	MEAN	Std. deviation	Std. Error Mean	Df	t	Sig. (2-tailed)	Decision
Male	29.25	6.265	1.401	19	-1.811	0.086	Accept
Female	31.95	4.828	1.080				

4. CONCLUSION

The study explored the role of gender as a predictor of students' performance in PhET simulations for Chemistry content in secondary schools across Kwara State. Results indicated that gender had no significant effect on students' performance, as both male and female participants achieved similar outcomes. The equal gender representation among participants reinforced the credibility of the findings by eliminating potential gender bias. Overall, the PhET simulations proved to be highly effective in improving students' grasp of Chemistry concepts. There was a marked increase in posttest scores compared to pretest results, with the average posttest score significantly higher. Most students performed well, with a large portion scoring in the higher range, underscoring the effectiveness of PhET simulations in promoting engagement and deeper understanding. The analysis of the hypotheses confirmed no statistically significant difference in performance between male and female students in both the pretest and posttest stages. This outcome supports existing research showing that interactive simulations such as PhET can enhance academic performance without creating gender-based disparities.

Recommendations are in the following:

(i) Further research should investigate the performance of senior school Chemistry students in a broader range of interactive simulation environments beyond PhET, such as virtual labs and other educational technologies, to compare their effectiveness in promoting students' understanding of Chemistry concepts across various regions.

(ii) Future studies should explore the long-term impact of PhET simulations on students' academic performance by examining the retention of Chemistry knowledge over an extended period.

(iii) Additional research should be conducted to examine the pretest performance of male and female students in other science subjects, using different simulation tools, to determine if gender differences in pretest performance persist across diverse contexts or if this trend is unique to Chemistry.

(iv) Future studies should explore the influence of gender on students' performance in PhET simulations in various educational settings, such as rural versus urban schools or mixed

versus single-gender schools, to determine whether contextual factors mediate the relationship between gender and academic outcomes in science simulations.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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