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Enhancing junior secondary students' learning outcomes in basic science and technology through PhET: A study in Nigeria

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Abstract
A computer-based simulation is a viable approach for integrating the basics of science and technology in Junior Secondary. This study examined the impact of PhET on students' academic performance as well as students' motivation toward Basic Science and Technology. The study also investigates how PhET influence students' attitudes toward Basic Science and Technology. The study adopted the pre-test, post-test, and non-equivalent control group design. We randomly selected the study population from junior secondary two (JSII) students in private and public schools who are studying Basic Science and Technology. Quantitative data were collected and analyzed using a statistical approach such as the mean, standard deviation, and t-test. Students' post-test academic performance improved significantly ($t160 = 36.28$, $p < 0.05$) as a result of teaching Basic Science and Technology with PhET. According to the findings PhET had a substantial effect on the motivation of Basic Science and Technology students ($t160 = 29.32$, $p < 0.05$). Furthermore, the results demonstrated that PhET affected students' attitudes toward Basic Science and Technology ($t160 = 65.36$, $p < 0.05$). This study contributes to the body of knowledge by providing empirical evidence to support the integration of PhET in the teaching of Basic Science and Technology in Nigeria and other similar contexts. The findings suggest that PhET can be an effective pedagogical tool for improving learning outcomes in science and technology education, particularly in developing countries where resources and infrastructure may be limited.

Keywords Computer-Based Interactive Simulation (CBIS) · Simulation-based learning · STEM Education · Simulation-based education (SBE) · Basic Science and Technology · Nigeria

Extended author information available on the last page of the article

1 Introduction

Educators and researchers in the field of education are continuously seeking ways to enhance students' learning outcomes. In today's digital culture, much of this effort is focused on integrating digital technology into subject domains to create engaging learning experiences. One effective instructional approach is Computer-Based Interactive Simulation (CBIS), which provides a situated and authentic form of practice and motivation for learning without the physical constraints and dangers associated with real-world scenarios (Almasri, 2022; Toksoy & Bulu, 2022). CBIS offer numerous learning affordances that can positively influence students' attitudes and behaviors across different domains and educational levels (Hallinger & Wang, 2020; Havola et al., 2021; Morin et al., 2020). Therefore, simulations remain relevant in the teaching and learning process due to their potential in improving learning outcomes, practice, and fostering learner interests. Extensive literature exists on the use of simulation-based approaches across various fields, such as medicine, construction engineering, and vocational education (Korayem et al., 2022; Lee et al., 2020; Mai et al., 2020; Meier et al., 2022).

At the K-12 level, CBIS have been widely applied to various subjects. For instance, studies have investigated the use of CBIS in senior school chemistry and their impact on the performance of female students relative to males (Oladejo et al., 2021a, b). Other research has explored the effects of CBIS on students' academic performance and perceptions of organic chemistry in secondary schools (Nsabayezu et al., 2023). Additionally, CBIS have been employed to introduce physics concepts to 10th-grade students (Toksoy & Bulu, 2022). This study aims to contribute to the existing literature by examining the impact of CBIS as an instructional strategy for teaching basic technology topics to grade 8 students in Nigeria. CBIS used for this study is called PhET Interactive Simulation. This is an innovative educational technology tool developed at the University of Colorado Boulder. It allows students to explore complex scientific and mathematical concepts in a virtual environment, promoting active learning in STEM subjects. The simulations are free, interactive, and available online, providing widespread accessibility.

While previous studies have focused on specific subjects like social studies, basic science, and chemistry, this study specifically explores the potential of PhET to improve students' motivation, attitude, and performance towards basic science and technology. Understanding basic science and technology is crucial for young learners as it serves as a foundation for further studies in STEM fields. The study's findings can contribute to the existing knowledge on the use of CBIS as an effective pedagogical approach to enhance learning outcomes in basic science and technology education. In summary, this study addresses the problem of enhancing students' learning outcomes in basic science and technology through the use of CBIS. The literature indicates the potential of simulations in improving learning and practice across various subjects and educational levels. However, there is a need to investigate the impact of CBIS specifically on students' motivation, attitude, and performance in basic science and technology. This study's novelty lies in its focus on a specific subject and its potential to contribute to the existing body of knowledge on the effectiveness of computer simulations in educational contexts.

The specific research questions that guide this study are:

1. How does PhET impact students' academic performance in Basic Science and Technology?
2. To what extent do PhET influence students' motivation to learn Basic Science and Technology?
3. What is the attitude of students toward Basic Science and Technology after learning through PhET intervention?

In the following section, we review the literature on the impact of CBIS on Nigerian students' learning outcomes in Basic Science and Technology Education.

2 Literature review

This literature review examines the impact of Computer-Based Interactive Simulation (CBIS) on Nigerian students' learning outcomes in Basic Science and Technology education. The review is structured into four main sections: Basic Science and Technology in K-12, Simulation-Based Learning (SBL) theory and practice, Computer-Based Interactive Simulation (CBIS) and Learning Outcomes, and key features of PhET Interactive Simulation. Through a synthesis of existing literature, the review aims to provide insights into the theoretical foundations and practical applications of SBL and CBIS, specifically with the use of PhET CBIS, in enhancing students' motivation, attitude, and learning outcomes in Basic Science and Technology education.

By examining the latest research findings and best practices in the field, the review intends to provide a comprehensive overview of the effectiveness and potential of PhET CBIS as an innovative approach to teaching and learning Basic Science and Technology in Nigeria (Aliyu, & Aliyu, 2023).

2.1 Basic science and technology in Nigerian schools

The Basic Science and Technology Curriculum (Revised 2012) provides the contents and additional learning experiences that foster the acquisition of functional skills for job creation and wealth generation, reducing poverty in communities and the nation at large (Igbokwe, 2015). The curriculum is learner-centered and problem-solving oriented, encouraging student–teacher and student–student interaction. It also promotes group work, pair work, and interaction with resource materials. The Basic Science and Technology Curriculum aligns with the STEM approach, which integrates science, technology, engineering, and mathematic (Igbokwe, 2015). English (2016) advocates for a greater emphasis on STEM integration in K-12, as well as equitable representation of the four disciplines in STEM learning studies. STEM teaching methods have been widely acknowledged as important in the K-12 classroom setting (Tawbush et al., 2020). Science is the most well-documented topic in K-12 STEM literature in India and Italy, while technology and mathematics receive more attention in Singapore. Student-centered teaching practices are more prevalent in Italy and Singapore, while India primarily utilizes student-centered teaching approaches (Tawbush et al., 2020).

2.2 Simulation-based learning (Theory and practice)

Simulation-Based Learning (SBL) has gained considerable attention as a pedagogical approach that enhances learning outcomes in different fields (Levin & Flavian, 2022). SBL involves creating a simulated environment that replicates real-life situations and allows learners to practice and develop their skills in a safe and controlled setting. SBL is rooted in experiential learning principles, emphasizing learning through direct experience and reflection (Kolb, as cited in McLeod, 2017). SBL aligns with Kolb's experiential learning theory by providing learners with an opportunity for active experimentation in a safe environment.

SBL has been extensively used in healthcare for training medical students, nurses, and physicians (Nikdel & Jenney, 2023; Skedsmo et al., 2023). Simulation-based medical education (SBME) improves learners' knowledge, skills, confidence, and patient outcomes (Pal et al., 2023). In engineering, SBL is utilized for training students in areas such as process control, design, and optimization (Dai & Ke, 2022). It offers a cost-effective and safer alternative to real-world testing, allowing students to design and test systems and processes in a simulated environment (Nowparvar, 2022). SBL provides immediate feedback, enabling students to refine their designs and processes in real time. In business, SBL has been employed for training and development, particularly in leadership, decision-making, and teamwork (Chatpinyakoop et al., 2022). Business simulations create a risk-free environment where learners can practice and develop their skills. They have been shown to improve decision-making, teamwork, and leadership abilities (Yasin et al., 2022). SBL is an effective pedagogical approach that allows learners to engage in active experimentation in a safe and controlled environment. Its application in healthcare, engineering, and business has demonstrated positive results in improving learning outcomes (Levin & Flavian, 2022; Pal et al., 2023; Dai & Ke, 2022; Chatpinyakoop et al., 2022).

2.3 Computer-Based Simulation (CBS) and learning outcomes

Computer-Based Simulation (CBS) complements standard teaching methods and has been shown to have a beneficial influence on skill and knowledge acquisition (Ravert, 2002). CBS or simulation-based learning in higher education and professional development provides effective ways to support professional learning and development (Duchatelet et al., 2022). Fischer et al. (2022) suggest that simulation-based learning can benefit from utilizing a variety of methodological techniques and analyzing different process indicators and learning outcomes. CBS has been found to significantly improve learning outcomes in physics, biology, and chemistry (Ben Ouahi et al., 2021; Rehman et al., 2021; Simanjuntak et al., 2021; Swandi et al., 2018; Akhigbe & Ogufere, 2020; Olumide, 2019; Nkemakolam et al., 2018; Uzezi & Deya, 2020). CBS enhances academic achievement, motivation, retention, and attitude among students. It has been particularly effective in bridging the gender gap in attitudes and achievements in biology (Akhigbe & Ogufere, 2020; Olumide, 2019). CBS instructional techniques can improve learners' academic performance in chemistry, with no significant difference in gender performance (Nkemakolam et al., 2018; Uzezi & Deya, 2020). Using a combination of simulation approaches may be the most effective strategy to achieve intended learning objectives (Korayem et al., 2022).

In conclusion, research indicates that using Computer-Based Simulation (CBS) packages in education is advantageous and improves students' learning outcomes. CBS has shown positive effects on academic achievement, motivation, retention, and attitudes in various subjects. As such, CBS, along with Simulation-Based Learning (SBL) approaches, has the potential to enhance Basic Science and Technology education (Nsabayezu et al., 2023; Pal et al., 2023; Chatpinyakoop et al., 2022; Fischer et al., 2022; Akhigbe & Ogufere, 2020).

2.4 Key features of PhET interactive simulation

PhET Interactive Simulations is a widely recognized and extensively used platform that offers a diverse range of interactive simulations for science and mathematics education (Lopes & Soares, 2023). These simulations are designed to provide students with hands-on, inquiry-based learning experiences that promote a deeper understanding of scientific concepts and principles.

The following key features of PhET Interactive Simulations contribute to their effectiveness in enhancing students' motivation, attitude, and learning outcomes in Basic Science and Technology education:

User-Friendly Interface: PhET simulations have a user-friendly interface that allows students to easily interact with the virtual environment. The simulations are designed with intuitive controls and visual representations that make it accessible for students of different age groups and proficiency levels (Byrne, 2020; Lin, 2020).

Realistic and Engaging Simulations: PhET simulations are known for their high-quality graphics and realistic representations of scientific phenomena (see Fig. 1). These simulations create an immersive learning experience that captures students' attention and engages their curiosity (Penn et al., 2019). The interactive nature of the simulations enables students to manipulate variables, conduct experiments, and observe the outcomes in real time, fostering a sense of active participation in the learning process.

Customizable Parameters: PhET simulations often allow users to customize various parameters within the simulation to explore different scenarios and observe the corresponding changes (Alhadlaq, 2023). This feature encourages students to investigate cause-and-effect relationships, make predictions, and test hypotheses, promoting critical thinking and problem-solving skills.

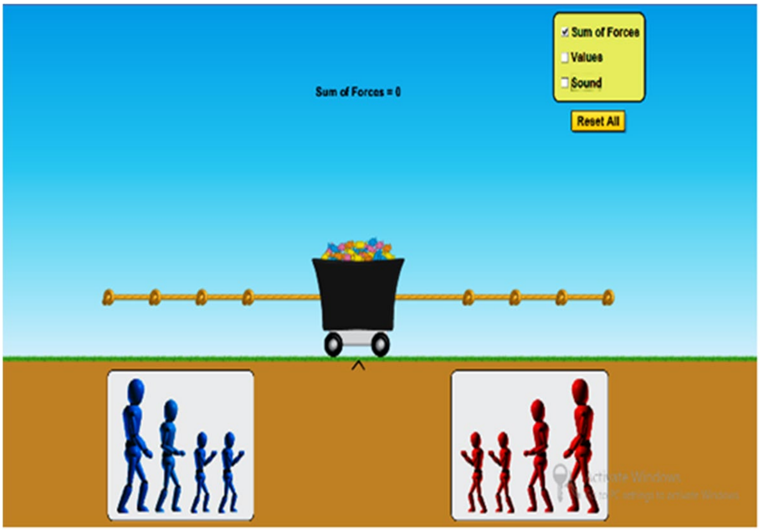

Fig. 1 PhET interactive simulations

Instant Feedback and Guided Exploration: PhET simulations provide immediate feedback to students based on their interactions within the simulation (Loeblein & Perkins, 2023). This instant feedback helps students understand the consequences of their actions and facilitates self-correction and reflection. Additionally, many simulations offer guided exploration activities or prompts that scaffold students' learning and encourage them to delve deeper into the underlying scientific concepts (So et al., 2019).

Accessibility and Availability: PhET simulations are freely accessible online, making them readily available to educators and students (Salame & Makki 2021). This accessibility ensures that students from diverse backgrounds and geographical locations can benefit from these interactive learning tools. Furthermore, the simulations are compatible with various devices and operating systems, allowing for flexibility in their usage (Inayah et al., 2021).

In summary, PhET Interactive Simulations offer a range of key features that make them effective tools for enhancing students' learning outcomes in Basic Science and Technology education. With their user-friendly interface, realistic simulations, customizable parameters, instant feedback, and accessibility, PhET simulations provide an engaging and interactive learning environment that supports inquiry-based exploration and deep understanding of scientific concepts.

3 Research design, context and methodology

3.1 Research context of the study

In this study, the effectiveness of a Computer-Based Interactive Simulation (CBIS) developed by PhET Interactive Simulations was investigated in the context of Basic

Science and Technology (BST) education in Nigeria. The research took place in Oluyole Local Government Area, involving four secondary schools (two private and two public) with equipped computer laboratories. In Oluyole local government area, there are a total of 26 junior secondary schools offering Basic Science and Technology (BST). From this pool, a sample was taken, consisting of 1 complete sort out from each one of four randomly selected secondary schools. The sample comprised intact classes totaling 162 students, divided into an experimental group taught with CBIS (79 students) and a control group taught using traditional methods (83 students). The intervention consisted of sixteen 1-h lectures and activities covering topics such as Force, Friction, Speed, Velocity, and Motion. For reference, please refer to Figs. 2 and 3, which provide examples of the interface used in the PhET Interactive Simulation for Friction and Force. Overall, the research aimed to evaluate how the CBIS intervention affected students' learning outcomes, attitudes, and intrinsic motivation in the context of BST education.

3.2 Research methodology of the study

This study employed a pre-test, post-test, and non-equivalent control group design to assess the impact of the PhET on Basic Science and Technology (BST) education. The distribution of participants into experimental and control groups as presented in Table 1 below.

Table 1, the sample was categorized into one experimental group and one control group. Participants in the experimental group were taught using the PhET while those in the control group were taught using the conventional method (no treatment).

Research Instruments used are:

1. Basic Science and Technology Achievement Test (BTAT): The BTAT was developed by the researchers to measure students' achievement in basic science and

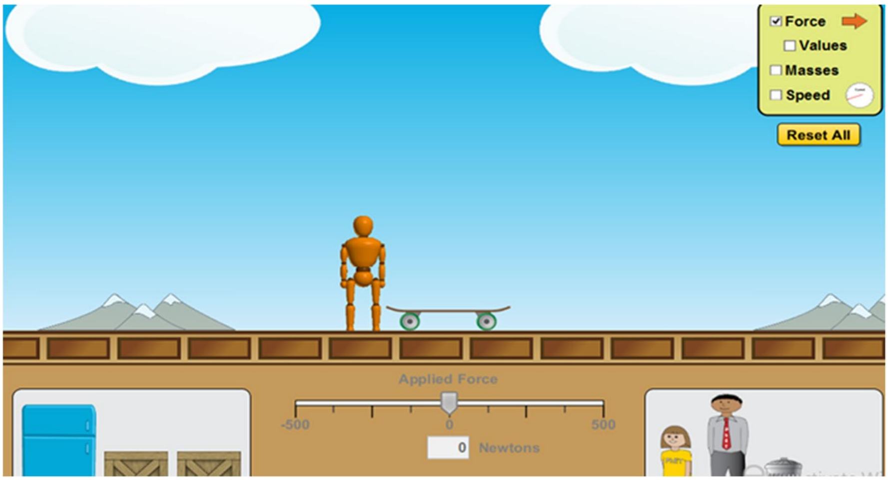

Fig. 2 Interface of PhET interactive simulation (Friction)

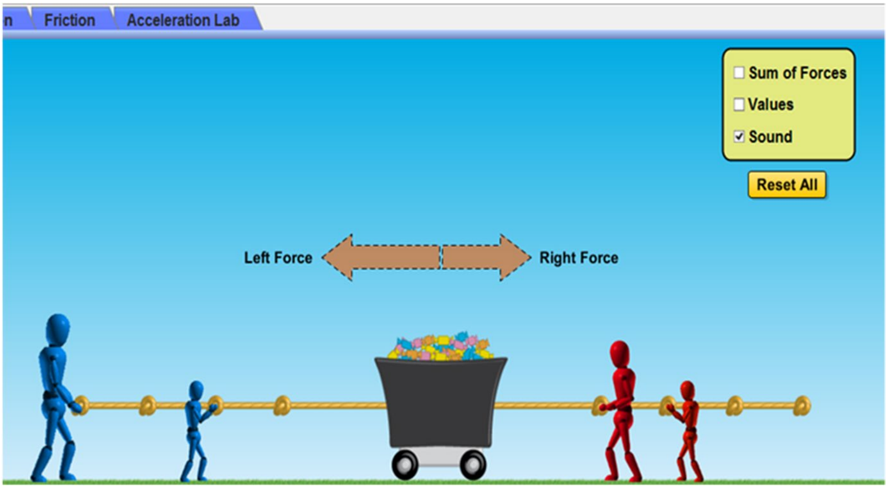

Fig. 3 Interface of PhET interactive simulation (Force)

Table 1 Distribution of samples to control and experimental groups

	PRETEST	TREATMENT	POSTTEST
EXPERIMENTAL	Basic Science and Technology Achievement Test and Student's Attitude towards Basic Science and Technology	PhET	Basic Science and Technology Achievement Test, Student's Attitude towards Basic Science and Technology and Student's Intrinsic Motivation Inventory towards Basic Science and Technology
CONTROL	Basic Science and Technology Achievement Test and Student's Attitude towards Basic Science and Technology	No Treatment	Basic Science and Technology Achievement Test, Student's Attitude towards Basic Science and Technology and Student's Intrinsic Motivation Inventory towards Basic Science and Technology

technology. It consisted of ten multiple-choice items, drawn from standardized past questions from the Basic Education Certification Examination (BECE). The Basic Education Certificate Examination (BECE) is a national exam in Nigeria for students completing junior secondary education (grades 7–9). Administered by NECO, it assesses proficiency in core subjects like Math, English, Science, and Social Studies, marking a crucial milestone in a student's education. The research instrument underwent rigorous validation. Experts in Science curriculum development and Special Education from Oyo State Ministry of Education, Ibadan, along with lecturers specializing in tests and measurement from Obafemi Awolowo University, Ile-Ife, collaborated in the process. This iterative exchange led to corrections and refinements, ensuring the instrument's suitability and standardization.

2. Student's Attitude towards Basic Science and Technology (SABST): The SABST was adapted from Aladejana and Aderibigbe (2007) rating of an attitude scale, which was designed to assess students' attitudes toward basic science and technology. It was a 20-item Likert-type questionnaire divided into two sections. The first section collects on respondents' demographical information, while the second section contained attitude-related items.
3. Student's Intrinsic Motivation Inventory towards Basic Science and Technology (SIMIBST): The SIMIBST instrument was adapted from Ryan and Deci (2000), and comprised of twenty items used to measure students' intrinsic motivation toward basic science and technology.

The internal consistency and reliability of the research tools for factor analysis was determined by analyses carried out in this study. The findings, which are shown in Table 2, include the Cronbach's Alpha values and Kaiser–Meyer–Olkin (KMO) coefficients for each instrument.

Basic Science and Technology Achievement Test instrument's computed Cronbach's Alpha score was $\alpha = 0.871$, suggesting a high degree of internal consistency across the ten multiple-choice questions used to gauge students' proficiency in basic science and technology. Furthermore, this test's KMO coefficient was 0.881, indicating good sufficiency for factor analysis. Also, Student Attitude Towards BST Questionnaire survey measured students' attitudes toward basic science and technology with strong internal consistency, as indicated by its Cronbach's Alpha coefficient of $\alpha = 0.867$. Moreover, the questionnaire's KMO coefficient was 0.936, indicating excellent suitability for factor analysis. In addition, student's intrinsic motivation assessment showed a good degree of internal consistency in measuring students' intrinsic motivation towards fundamental science and technology, as indicated by the Cronbach's Alpha rating of 0.908. With a KMO value of 0.830, factor analysis was found to be adequately enough for this inventory. The reliability and validity of the instruments used in this study are supported by these results, which also demonstrate the high level of internal consistency shown in all of the measures and their high fit for factor analysis.

Table 2 Results Cronbach's α and Kaiser–Meyer–Olkin (KMO)

Research Instrument	Cronbach's Alpha (α)	KMO Coefficient
Basic Science and Technology Achievement Test	0.871	0.881
Student's Attitude towards BST Questionnaire	0.867	0.936
Student's Intrinsic Motivation Inventory	0.908	0.830

3.3 Data collection in the study

In this study, data collection was conducted using various instruments to gather information from both the experimental and control groups at different stages of the treatment. The instruments used included the Student's Attitude towards Basic Science and Technology (SABST) questionnaire, Basic Science and Technology Achievement Test (BTAT), and Student's Intrinsic Motivation Inventory towards Basic Science and Technology (SIMIBST).

During the pre-treatment phase, in the first week, both the experimental and control groups completed the SABST questionnaire to assess their attitudes towards Basic Science and Technology. Additionally, the BTAT and SIMIBST were administered to determine the participants' previous knowledge and intrinsic motivation in the subject.

The treatment phase involved training the experimental group on how to use and navigate through the PhET. This training took place between the second and fourth weeks of the study. The PhET focused on teaching the topics of Force, Motion, Friction, and Speed, which were part of the Junior Secondary School curriculum. Meanwhile, the control group received instruction on the same topics using conventional teaching methods during the same weeks.

To assess the impact of the intervention, mid-treatment assessments were conducted in the fourth and sixth weeks. During these assessments, the experimental group completed the SABST and SIMIBST instruments once again to measure any changes in their attitudes and intrinsic motivation towards Basic Science and Technology after using the PhET. The BTAT was also administered to evaluate the experimental group's performance in the subject.

Post-treatment assessments took place during the sixth and eighth weeks. Both the experimental and control groups were given the BTAT to examine their performance after the treatment. These assessments aimed to measure the retention of knowledge and skills in Basic Science and Technology.

The data collected from the various instruments were collated, and analyzed using SPSS 20.0 to assess the impact of the PhET intervention on students' attitudes, intrinsic motivation, and academic performance in Basic Science and Technology.

4 Result

4.1 Impact of PhET on students' academic performance in basic science and technology

We analysed the respondents to understand how PhET impact students' academic performance and presented the results.

As presented in Table 3, the result found that students who were taught using PhET exhibited a pre-test mean score of 20.50 with a corresponding standard deviation of 11.97. Conversely, students taught through the conventional method achieved a pre-test mean score of 16.99, coupled with a standard deviation of 6.19. This suggests that the PhET group not only demonstrated a higher average score but also displayed a greater spread of scores as indicated by the larger standard deviation. These findings imply potential differences in the effectiveness and variability of learning outcomes between the two instructional approaches.

Similarly, Table 4, it has been found that the students that were not exposed to any of PhET had a post-test mean score of 23.19 and a standard deviation of 8.96, while those taught using PhET had a post-test mean score of 76.96 and a standard deviation of 12.02. This contrast in both mean scores and standard deviations between the two groups indicates a substantial difference in post-test performance.

In Table 5, the result found that pre-test t-test analysis indicated a statistically significant difference between the PhET and Control groups, with $t(160) = 2.60$, $p < 0.05$. This suggests that there was a meaningful distinction in the pre-test scores of students exposed to the PhET method compared to those taught using the conventional approach.

Similarly, in Table 6, the study found that the post-test t-test analysis revealed an even more substantial disparity between the two groups, with a highly significant t-statistic of $t(160) = 36.28$, $p < 0.05$. This indicates a profound divergence in post-test performance, further underscoring the effectiveness of PhET.

Overall, the results demonstrate that PhET simulations significantly improved post-test performance in Basic Science and Technology compared to the conventional method. This suggests a substantial positive impact, indicating a potential shift in educational practices. These results strongly support the effectiveness of PhET in enhancing student performance.

Table 3 Pre-test mean scores and standard deviation of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D
1	PhET	79	20.50	11.97
2	CONTROL	83	16.99	6.19

Table 4 Post-test mean scores and standard deviation of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D
1	PhET	79	76.96	12.02
2	CONTROL	83	23.19	8.96

Table 5 Calculated pre-test t-test scores of performance of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D	t	df	P	95% Confidence Interval	
								Lower Bound	Upper Bound
1	PhET	79	20.50	11.97	2.60	160	0.11	0.80	6.04
2	CONTROL	83	16.99	6.19					

Table 6 Calculated post-test t-test scores of performance of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D	t	df	P	95% Confidence Interval	
								Lower Bound	Upper Bound
1	PhET	79	79.76	12.02	36.28	160	0.000	50.73	56.62
2	CONTROL	83	23.19	8.96					

4.2 Influence of PhET on students' motivation to learn basic science and technology

As presented in Table 7, the result found that students that were exposed to PhET possessed very good motivation toward Basic Science and Technology. The students were rated on a scale of 5. There are four items in each of the five subscales that made up the motivational inventory. The subscales are Procedural Skill Rating (PSR), Interest (IE), Perceived Choice (PC), Effort/Importance (EI), and Value/Usefulness (VU). Each of the subscales has a total score of 20. Therefore, the motivation inventory had a total score of 100.

The students that were taught using PhET had an overall mean score of 76.38 and a standard deviation of 5.49 while those taught using the conventional method had a mean score of 48.12 and a standard deviation of 6.89. In a breakdown, for PSR, those that were taught using PhET had a mean score of 15.29 and a standard deviation of 2.59 while those that were taught using the conventional method had a mean score of 9.06 and a standard deviation of 3.81. The mean and standard deviation of the students that were taught using PhET in IE was 15.19 and 2.49 respectively while those that were taught using the conventional method had a mean score of

Table 7 The mean and standard deviation and calculated t-test scores of students' motivation towards Basic Science and Technology for both experimental and control Group

Motivation Sub-Scales	Group	N	$\bar{X}$	S.D	t	Df	P
Procedural Skills Rating (PSR)	PhET	79	15.29	2.59	11.16	160	0.000
	CONTROL	83	9.06	3.81			
Interest/Enjoyment (IE)	PhET	79	15.19	2.49	13.77	160	0.000
	CONTROL	83	9.11	3.04			
Perceived Choice (PC)	PhET	79	14.85	2.99	10.43	160	0.000
	CONTROL	83	10.16	2.99			
Effort/Importance (EI)	PhET	79	15.49	2.79	13.35	160	0.000
	CONTROL	83	9.65	3.17			
Value/Usefulness (VU)	PhET	79	15.58	2.65	6.29	160	0.000
	CONTROL	83	10.78	5.95			
OVERALL MOTIVATION	**PhET**	**79**	**76.38**	**5.49**	**29.32**	**160**	**0.000**
	CONTROL	**83**	**48.12**	**6.89**			

9.11 and a standard deviation of 3.04. The mean of the students exposed to PhET in PC was 14.85 while the standard deviation was 2.99. Those that were taught using the conventional method had a mean of 10.16 and a standard deviation of 2.99. The mean of the EI of those taught using PhET was 15.49 and a standard deviation of 2.79 while the students that were taught using the conventional method had a mean of 10.78 and a standard deviation of 5.95. Those that were exposed to PhET in VU had a mean score of 15.58 and a standard deviation of 2.65 while those that were taught using the conventional method had a mean score of 10.78 and a standard deviation of 5.95. In terms of overall motivation, students exposed to the PhET approach displayed a remarkable mean score of 76.38, accompanied by a relatively low standard deviation of 5.49. In contrast, students taught using the conventional method exhibited a significantly lower mean score of 48.12 and a higher standard deviation of 6.89. The PhET package increased Basic Science and Technology students' motivation toward the subject.

4.3 Students attitude toward basic science and technology after learning through PhET intervention

As shown in Table 8, the study found that the impact of PhET intervention on students' attitudes towards Basic Science and Technology. Initially, no significant disparities were noted in entry-level behavior between the PhET and conventional instruction groups. This is evidenced by comparable mean scores of 24.67 (PhET) and 18.29 (Conventional) with corresponding standard deviations of 8.07 and 7.78, respectively ($p = 0.76$). However, at the post-test stage, a remarkable shift in attitudes became evident. The control group displayed a mean score of 17.69, along with a standard deviation of 8.17. In contrast, the experimental group exhibited a substantially higher mean score of 85.58, accompanied by a standard deviation of 8.75. This marked contrast in post-test results highlights a profound and statistically significant differentiation between the two instructional approaches. These findings strongly suggest that PhET intervention plays a pivotal role in positively influencing students' attitudes towards Basic Science and Technology.

The pre-test t-test analyses in Table 9 found that there wasn't a significant difference between the PhET and Control groups, $t(160) = -0.27$, $p < 0.05$. This suggests that there was a meaningful distinction in the pre-test attitude of students exposed to the PhET method compared to those taught using the conventional approach.

However, the pre-test t-test result in Table 10 found a highly significant result of $t(160) = 65.36$, $p < 0.05$. This finding demonstrates a substantial difference at the

Table 8 Mean and standard deviation of the attitude of students taught using PhET and those taught using conventional method towards Basic Science and Technology

S/N	TEST	GROUPS	N	$\bar{X}$	S.D
1	Pretest	PhET	79	24.67	8.07
		CONTROL	83	18.29	7.98
2	Post-test	PhET	79	85.58	8.75
		CONTROL	83	17.69	8.17

Table 9 Calculated pre-test t-test scores of attitude of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D	T	df	P	95% Confidence Interval	
								Lower Bound	Upper Bound
1	PhET	79	24.67	8.07	-0.27	160	0.76	-2.305	1.748
2	CONTROL	83	18.29	7.98					

Table 10 Calculated post-test t-test scores of attitude of students exposed to PhET and conventional method

S/N	GROUPS	N	$\bar{X}$	S.D	T	df	P	95% Confidence Interval	
								Lower Bound	Upper Bound
1	PhET	79	85.58	8.75	65.36	160	0.000	58.90	63.30
2	CONTROL	83	17.69	8.17					

0.05 level of significance, favoring the experimental group. It can be inferred that the implementation of PhET had a profound and statistically significant impact on the attitudes of students who were exposed to this instructional package, as compared to those taught through conventional methods.

Overall, the results of the study show a significant impact of PhET intervention on students' attitudes towards Basic Science and Technology. Initially, no notable disparities were observed in entry-level behavior between the PhET and conventional instruction groups. However, at the post-test stage, a remarkable shift in attitudes became evident. The experimental group, taught using PhET, exhibited a substantially higher mean attitude score compared to the control group. The t-test analyses further confirmed a highly significant difference, favoring the PhET group. These findings underscore the pivotal role of PhET intervention in positively influencing students' attitudes towards Basic Science and Technology, suggesting a promising avenue for enhanced educational learning outcomes.

5 Discussion

The findings of this study provide valuable insights into the impact of PhET on students' academic performance, motivation, and attitudes toward Basic Science and Technology in elementary classrooms. The study employed a pre-test, post-test, and non-equivalent control group design, and the data were analyzed using statistical measures such as mean, standard deviation, and t-test.

We discovered that students taught using PhET demonstrated significantly higher pre-test mean scores compared to those taught through conventional methods. Additionally, the PhET group exhibited a wider spread of scores, indicating greater variability in performance. This suggests that PhET may lead to both higher average performance and increased variability in understanding. The post-test results further confirmed the effectiveness of PhET, with the experimental group displaying a substantially higher mean score compared to the control group. The t-test analyses provided strong evidence of the statistical significance of these differences, indicating that PhET significantly enhanced students' academic performance in Basic Science and Technology. This aligns with prior research findings. For example, a study by Srisawasdi et al. (2019), Yunzal & Casinillo (2020) found that computer simulations improved students' conceptual understanding and academic achievement in science. Another study by Wei et al. (2020) demonstrated that interactive simulations enhanced students' problem-solving skills and academic performance.

In addition, the motivational inventory encompassing subscales such as Procedural Skills Rating (PSR), Interest/Enjoyment (IE), Perceived Choice (PC), Effort/Importance (EI), and Value/Usefulness (VU) provided a comprehensive evaluation. The results clearly demonstrated that students exposed to PhET exhibited notably higher motivation scores across all subscales, as well as in overall motivation, compared to those taught using conventional methods. These findings strongly suggest that PhET positively impacted students' motivation towards the subject. This finding is consistent with research conducted by Diwakar et al. (2023); Ng et al. (2021) which showed that simulation-based learning environments enhanced students' intrinsic motivation and engagement in science education. Additionally, the study by Hussein et al. (2019) indicated that computer simulations increased students' motivation and interest in science learning.

Lastly, the pre-test results showed no significant differences in attitudes between the PhET and conventional instruction groups, indicating an even starting point. However, at the post-test stage, a remarkable shift in attitudes became evident. The experimental group, taught using PhET, displayed a substantially higher mean attitude score compared to the control group. The t-test analyses confirmed a highly significant difference, further emphasizing the positive influence of PhET on students' attitudes. This finding is in line with previous research conducted by Yu et al. (2021), which demonstrated that computer simulations positively influenced students' attitudes towards science. Furthermore, a study by Fawaz et al. (2019); AlBalawi et al. (2022); Banda et al. (2023) showed that simulation-based learning environments improved students' attitudes and perceptions of science. In summary, the findings of this study corroborate existing literature on the benefits of PhET in science and technology education.

The studies reviewed collectively underscore the significant positive impact of PhET simulations on various facets of teaching and learning. Firstly, Wieman et al. (2008) concluded that PhET enhances overall student learning. This finding indicates a consensus among the studies regarding the effectiveness of PhET in improving student comprehension and retention of subject matter. Adams (2010) further emphasized that PhET simulations are not only educational but also engaging, making the learning process more interactive and stimulating for students. This aspect of engagement is crucial in maintaining student interest and motivation, potentially leading to more effective learning outcomes. Haryadi and Pujiastuti's study in 2020 delved into the development of science process skills through PhET simulation software-based learning. Their findings highlighted that PhET not only aids in content understanding but also contributes to the cultivation of critical thinking and problem-solving abilities. This suggests that PhET has a broader impact on students' cognitive development beyond mere subject knowledge. Moving on, Salame and Makki's research in 2021 explored the effects of PhET simulations on students' attitudes and learning in the context of general chemistry II. Their study concluded that PhET simulations significantly influence students' attitudes towards the subject, indicating a positive shift in their overall disposition and engagement with the material. This finding suggests that PhET simulations have the potential to foster a more positive learning environment. Similarly, Rahayu and Sartika (2020) provided insights into the motivational aspect of learning with PhET interactive simulations. Their study demonstrated that the use of PhET led to an increase in students' motivation levels and their understanding of science concepts. This suggests that PhET not only impacts knowledge acquisition but also plays a role in enhancing students' overall learning experience. Lastly, the study conducted by Ndihokubwayo et al. (2020) in an African setting offers valuable insights into the applicability of PhET in diverse educational contexts. Their research showed that PhET simulations, coupled with YouTube videos, effectively improved the learning of optics in Rwandan secondary schools. This demonstrates the adaptability and effectiveness of PhET in different regional settings.

In conclusion, the collective findings of these studies affirm the substantial positive effects of PhET simulations on teaching and learning. The software not only enhances content understanding but also fosters engagement, critical thinking, positive attitudes, and motivation among students. This body of research underscores the versatility and efficacy of PhET in enriching educational experiences across various contexts.

In summary, the findings of this study corroborate existing literature on the benefits of PhET in science and technology education. The integration of PhET in the classroom improved students' academic performance, motivation, and attitudes towards Basic Science and Technology. These findings are consistent with studies emphasizing the positive impact of computer simulations on learning outcomes, motivation, and attitudes in science education (Srisawasdi et al., 2019; Yunzal & Casinillo, 2020; Diwakar et al., 2023; Ng et al., 2021; Yu et al., 2021; Fawaz et al., 2019; AlBalawi et al., 2022; Banda et al., 2023).

The results of this study provide valuable insights for educators, policymakers, and curriculum developers, supporting the use of PhET as an effective pedagogical tool in science and technology education. By integrating PhET, educators can enhance students' academic performance, motivation, and attitudes towards science and technology subjects. Policymakers and curriculum developers can consider the adoption and implementation of PhET in educational settings to promote more engaging and effective learning experiences in science and technology education. Overall, this study contributes to the existing body of knowledge by providing empirical evidence and aligning with previous research on the benefits of PhET in science and technology education.

6 Conclusion

This study provides compelling evidence supporting the effectiveness of PhET in improving students' learning outcomes in Basic Science and Technology in Oluyole Local Government, Oyo State, Nigeria. The findings of this study are in line with the arguments made by Nassar and Tekian (2020) regarding the benefits of computer simulations in teaching operative skills. The study also reinforces the growing recognition of simulation-based education in dentistry, as highlighted by the work of Leung et al. (2021). However, it is important to acknowledge the limitations and areas for improvement in this study. Firstly, the study was conducted in a specific geographical area and may not fully represent the diverse contexts and populations in Nigeria. Replicating the study in different regions would provide a more comprehensive understanding of the effectiveness of PhET in Basic Science and Technology education.

Additionally, while the study focused on academic performance, motivation, and attitudes, there are other factors that could influence students' learning outcomes, such as individual differences, teaching strategies, and classroom dynamics. Future studies could explore these factors and their interaction with PhET to gain a more nuanced understanding of their impact on learning outcomes. Furthermore, the study primarily relied on quantitative measures to assess learning outcomes and attitudes. Including qualitative methods, such as interviews or focus groups, could provide deeper insights into students' experiences and perceptions of using PhET. Combining both quantitative and qualitative approaches would yield a more comprehensive understanding of the impact of PhET on students' learning.

Lessons learned from this study emphasize the importance of integrating technology, such as PhET, into educational practices to enhance student engagement and learning outcomes. However, successful implementation requires adequate training and support for teachers to effectively incorporate PhET into their instructional strategies. Providing ongoing professional development opportunities for teachers and addressing any potential barriers to implementation should be considered. For future work, it would be beneficial to explore the long-term effects of PhET on students' learning outcomes and retention of knowledge. Additionally, investigating the impact of PhET on different student populations, such as students with diverse learning abilities or cultural backgrounds, would provide valuable insights into the applicability and effectiveness of PhET across various contexts.

In conclusion, while this study demonstrates the positive impact of PhET on students' learning outcomes in Basic Science and Technology, further research is needed to expand our understanding of the benefits and challenges associated with its implementation. By addressing the identified limitations, incorporating qualitative methods, and exploring diverse populations, future studies can contribute to the ongoing improvement and optimization of PhET as an educational tool.

Appendix

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BASIC SCIENCE AND TECHNOLOGY ACHIEVEMENT TEST (BTAT)

1.) For all materials the frictional force is always?
(a) perpendicular to the direction of motion
(b) along the direction of motion
(c) opposite to the direction of motion
(d) None of these.

2.) If F and R are the limiting force and normal reaction, then coefficient of static friction is
(a) *F/R* (c) *FR*
(b) *R/F* (d) F^2R.

3.) For all materials the coefficient of friction is always?
(a) less than one
(b) greater than one
(c) equal to one
(d) none of these.

4.) When a body is moving along an inclined plane, the direction of frictional force is always
(a) perpendicular to the direction of motion
(b) along the direction of motion
(c) opposite to the direction of motion
(d) none of the above

5.) A block of iron weighing 28 kg can be just pulled along a horizontal force of 12 N. Find the coefficient of friction.
(a) 3/7 *(b)* 7/3 *(c)* 0.3 *(d)* 0.7.

6.) Viscosity is closely similar to
(a) Density
(b) Velocity
(c) Friction
(d) Surface tension.

7.) ……………… is the change of pos0ition of an object over time?
(a) Speed
(b) Velocity
(c) Motion

(d) None of the above

8.) When an object A from a state of rest moves through a vertical straight line, this is known as?

(a) Speed
(b) Motion
(c) Velocity
(d) Friction

9.) Ms-1 means ……………………?
(a) Speed
(b) Velocity
(c) Friction
(d) Acceleration

10.) Friction is the force resisting the relative motion of solid surface,
(a) True
(b) False
(c) All of the above
(d) None of the above

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Declarations

Competing interests The authors declare that they have no competing interests.

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