JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website:www.jriiejournal.com ISSN 2520-7504 (Online) Vol.9, Iss.3, 2025 (pp. 961 - 976)

Exploring the Effectiveness of PhET Simulations on Students' Performance in Electromagnetic Induction within Selected Secondary Schools of Nyamasheke District, Rwanda

Alexandre Ndayisaba & Gabriel Janvier Tugirinshuti
African Centre of Excellence Innovative Teaching and Learning Mathematics and Science (ACEITLMS), University of Rwanda-College of Education Remera Campus, Rwanda (UR-CE)
Email: alexndayisaba05@gmail.com
https://orcid.org/0009-0004-5899-7488

Abstract: *Electromagnetic induction is a challenging and abstract topic in physics. Students demonstrate poor performance in electromagnetic induction studies due to the lack of demonstration of its complexity and its abstract nature. The PhET simulation was used to measure its effectiveness on students' performance. The targeted population was made up of all the senior three-day students in 78 day schools of the Nyamasheke District, Western Province, Rwanda. A total of 160 participants participated in the data collection. 156 were senior three students from 4 schools, 156 students were selected through the multistage sampling technique and assigned to two groups: 78 students in the control group and 78 students in the experimental group as an intact class. A quasi-experimental design with a mixed-methods approach was used. The results reveal that an independent samples t-test gave a t-value equals to -17.789 and the p-value of 0.000 with a degree of freedom equivalent to 137.397 from the p-value of 0.000, which is less than the alpha value($\alpha=0.05$) this shows that there were statistically significant differences between the experimental and control groups in favor of the experimental group.*

Keywords: *PhET simulation, Learning academic performance, Electromagnetic induction, Physics, Rwanda*

How to cite this work (APA):

Ndayisaba, A. & Tugirinshuti, G. J. (2025). Exploring the Effectiveness of PhET Simulations on Students' Performance in Electromagnetic Induction within Selected Secondary schools of Nyamasheke district, Rwanda. *Journal of Research Innovation and Implications in Education, 9*(3), 961 - 976**.** **https://doi.org/10.59765/67grp4**.

1. Introduction

One of the main factors contributing to students' difficulty in grasping science concepts is the absence of models or visual representations for abstract ideas (Uwambajimana et al., 2023b). Teachers need to address this real-world problem in the context of a physics classroom. One tactic to raise students' interest and raise their academic performance in science is to use simulation-based activities. To help students gain a tangible grasp of scientific phenomena illustrated through simulations, simulation tools can be used to play back movies or simulations of their research. Simulation facilitates teachers' instruction of difficult and abstract physics concepts and helps students hone their experimental skills (Falloon, 2020).

The primary issue examined in this research is how effective PhET Simulations are in improving students' performance in electromagnetic induction at selected secondary schools in Nyamasheke District. This inquiry is essential for comprehending the potential of PhET simulations to enhance student outcomes in electromagnetic induction within secondary education. The objective of this study was to provide empirical data and practical insights that would guide educational stakeholders, such as teachers, policymakers, and curriculum designers.

Quality Education is the key foundation of the development of the country. According to Rampasso (2019), the main objective of the 2030 Sustainable Development Goals (SDGs), Goal 4, is high-quality education, aiming to ensure that all individuals have access to inclusive and fair education and promoting chances for continuous learning for everyone (Boeren, 2019). Every nation is working to improve the standard of education, particularly in the sciences, to support its social and economic advancement. School children are expected to acquire science through practice, study, experimentation, and observation to explain natural phenomena (Darling-Hammond et al., 2020)

To promote quality education, the world has noticed a broadening of information and communication technology's (ICT) application in the classroom. The US government utilized ICT to enhance its economic productivity, encouraging EU countries to leverage the ICT sector. In Africa, research was conducted in Zimbabwe over the years. The government of Zimbabwe, through the Ministry of Primary and Secondary Education, has been encouraging schools to embrace and utilize ICTs in their teaching and learning activities.

Furthermore, research conducted in Rwanda has indicated a strong commitment from the government to invest in Information and Communication Technology (ICT) and its integration across various levels of education. According to (Buheji, 2023), Rwanda has adopted a strategy of basing its economy on its people as the main source of development and with much emphasis on technology. The Rwandan government has demonstrated its commitment by integrating ICT tools into every department, a step considered crucial for promoting a knowledge-based society. This dedication is especially important because ICT encourages science and technology education, giving students the skills they need for a variety of career options (Tugirinshuti et al., 2022)

1.1 Statement of the Problem

Physics instruction and learning in secondary schools and learning of Physics in secondary schools should be characterized by active student engagement, comprehensive understanding of concepts, and accurate utilization of technological tools to explore the abstract concept (Kedir, 2020). Teachers should use both theory and practice while teaching physics; they should employ innovative pedagogical approaches that seamlessly integrate technology into the curriculum(Niyonsaba et al., 2022). Technology in the form of interactive simulations is one tool that can and is being utilized to make sure that students acquire conceptual knowledge in science, especially +in physics, and enhance their participation (Banda & Nzabahimana, 2021)

Presently, the instruction and acquisition of physics knowledge in high schools in Nyamasheke District, located in the western province, face challenges in providing adequate resources and innovative teaching methods for science education(Nyoman et al., 2025). Many schools in Nyamasheke district lack laboratory equipment, students almost study only theory instead of practice, using traditional teaching methods led by teachers, such as lecturing, demonstrating, and utilizing chalkboards and chalks, which remained prevalent in classroom settings (Nsabayezu et al., 2023).

Electromagnetic induction is among the abstract physics topics that require the use of teaching methods that engage learners and bring learners' interest toward learning. The integration of technology in educational settings presents opportunities for enhancing student learning experiences and outcomes (Uwayezu & Uzabakiriho, 2024). For a long time, physics was one of the most difficult and despised subjects due to problems with the subject and ineffective teaching strategies. Because physics concepts are so relevant to our everyday lives, teaching physics calls for a range of methods and techniques (Uwambajimana et al., 2023a). But some of the issues that make students believe that physics is extremely difficult include several abstract physics ideas (Mbonyiryivuze et al., 2021)

According to (Uwambajimana & Minani, 2023), without the interactive and visual aids provided by PhET simulations, students may struggle to grasp abstract electromagnetic induction concepts. This could lead to shallow understanding and misconceptions about the main topics such as electromagnetic induction, Faraday's law, Lenz's law, Direct Current generator. Traditional teaching methods that rely solely on textbooks and lectures may fail to capture students' interest and engagement. As a result, students may become disinterested in the subject matter, leading to decreased motivation to learn and participate in class activities (Rone et al., 2023)

Electromagnetic induction concepts often have real-world applications in various fields such as engineering, physics, and technology. According to Gholam,(2019), without hands-on experience using simulations to explore electromagnetic phenomena, students may encounter a problem in linking theoretical knowledge to practical applications, due to a lack of their capability to solve real-world problems. However, despite the widespread adoption of simulations, there exists a notable gap in understanding their effectiveness, particularly in the domain of electromagnetic education. Thus, this seeks to explore the effectiveness of PhET simulations on students' performance in electromagnetic induction.

The following are the questions that guided the researcher to conduct this study

1. What are the mean scores of students taught electromagnetic induction using PhET?
2. What are the attitudes of students and teachers regarding the use of PhET simulations in teaching electromagnetic induction compared to traditional teaching methods?
3. What are the challenges to effectively implementing PhET simulation into teaching and learning of electromagnetic induction, and how could the identified challenges be addressed?

2. Literature Review

The research provides insight into earlier research by a number of researcher, which is relevant to the current study. This section highlights two primary elements of the presentation of pertinent literature were theoretical and empirical reviews. Under theoretical review, prevailing concepts like motivation, types of motivation, and their impact in teaching and learning activities, the Self Determination theory of motivation, Faraday's law of electromagnetic induction, Lenz's law, direct current generator (DC), and PhET simulations were discussed.

2.1 Theoretical Review

This section emphasizes examining, summarizing, and talking about theories and conceptual frameworks that are pertinent to the subject of my study. This section of theoretical review highlighted the motivation of the study, the type of Motivation and its impact in teaching and learning, Self-Determination theory of Motivation, Physics as a subject, Faraday's law of electromagnetic induction, Lenz's law, Direct Current Generator (DC).

2.1.1 Motivation

Motivation is commonly defined as the internal process that initiates, directs, and sustains goal-directed behavior. It reflects the reasons individuals engage in particular actions and persist in them (Cook & Artino, 2016). According to Kambara (2021) motivation concerns energy, direction, persistence, all aspects of activation and intention**.** Researchers emphasize that motivation can be intrinsic (driven by interest or enjoyment) or extrinsic (driven by outcomes or rewards).

Intrinsic motivation refers to motivation that comes from within the learner**,** driven by personal interest, curiosity, or the inherent satisfaction of the task itself (Leandro & Umana, 2021). In learning intrinsic motivation is highly effective in promoting deep learning**,** critical thinking**,** and long-term retention**.** Learners who are intrinsically motivated are more likely to engage in meaningful learning activities and persist through challenges.(Aubret et al., 2019).

Extrinsic motivation refers to the drive to perform a task or engage in an activity due to external rewards or pressures, such as grades, praise, competition, or fear of punishment (Adamma et al., 2018). In educational contexts, teachers frequently employ extrinsic motivators to encourage student participation, discipline, and performance. While it may not always foster deep learning, extrinsic motivation remains a powerful tool, especially when carefully designed and integrated with learner-centered approaches.

Extrinsic motivators in teaching include tangible rewards (e.g., certificates, prizes), social rewards (e.g., praise, recognition), and institutional pressures (e.g., grades, academic expectations). Teachers may also use behavioral reinforcement strategies such as token economies, point systems, or competitions to encourage certain behaviors or performance (Tsang & Zhang, 2022). In many cases, extrinsic motivation helps learners who might not otherwise engage with a topic to begin participating

A Self-Determination Theory (SDT) is a motivation Theory that was first developed by Eduard Deci and Richard Ryan in the 1980s. This theory is a well-established theory of motivation and personality that explains how people are driven to grow, change, and act based on intrinsic and extrinsic motivations**.** SDT proposes that human or student motivation is deeply influenced by fulfillment of the three basic psychological needs, which are Autonomy, the need to feel the one's behavior and goal, Competence, the need to gain mastery and effectiveness in one's activities the last is relatedness, the need to feel connected, valued and cared for by others. When these three needs are satisfied, individuals are more likely to be intrinsically motivated, that is, they engage in activities because they find them interesting or enjoyable, not just because of external rewards.

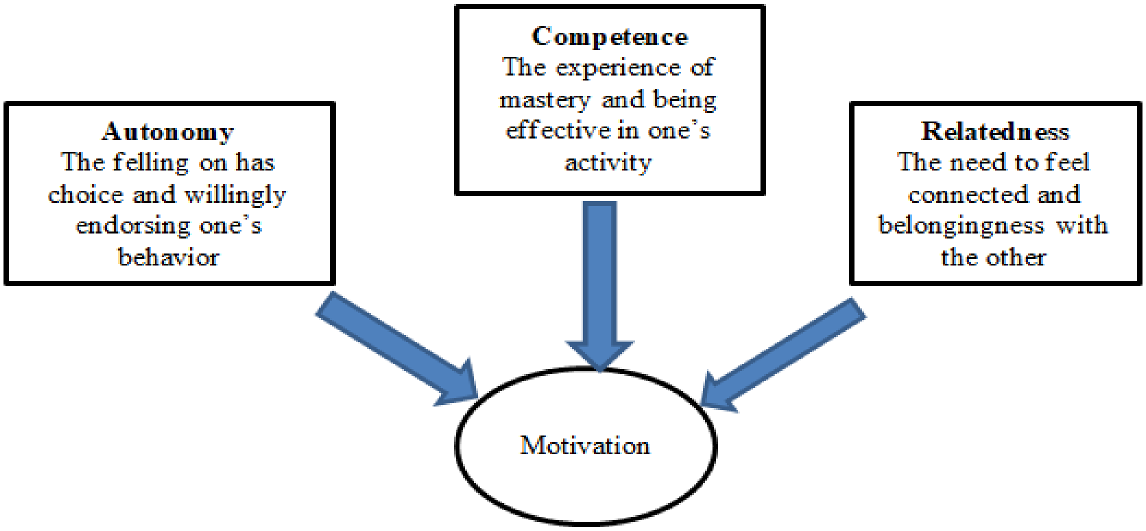

Figure 1: Self-Determination Theory of Motivation (SDT)

In order for a student to stay engaged and benefit from the course materials, attention is a crucial component of motivation. To grab and hold students' attention, the teacher needs to use a variety of instructional techniques. Since this is the only way to guarantee that the teaching and learning process is relevant, a teacher must provide the instructional materials in a way that enables students to comprehend how and why these contents apply to their lives.

Faraday's law of electromagnetic induction.

Electromagnetic induction is the process where a voltage (or electromotive force) is produced across an electrical conductor when it's exposed to a changing magnetic field or when it's moved through a stationary magnetic field.

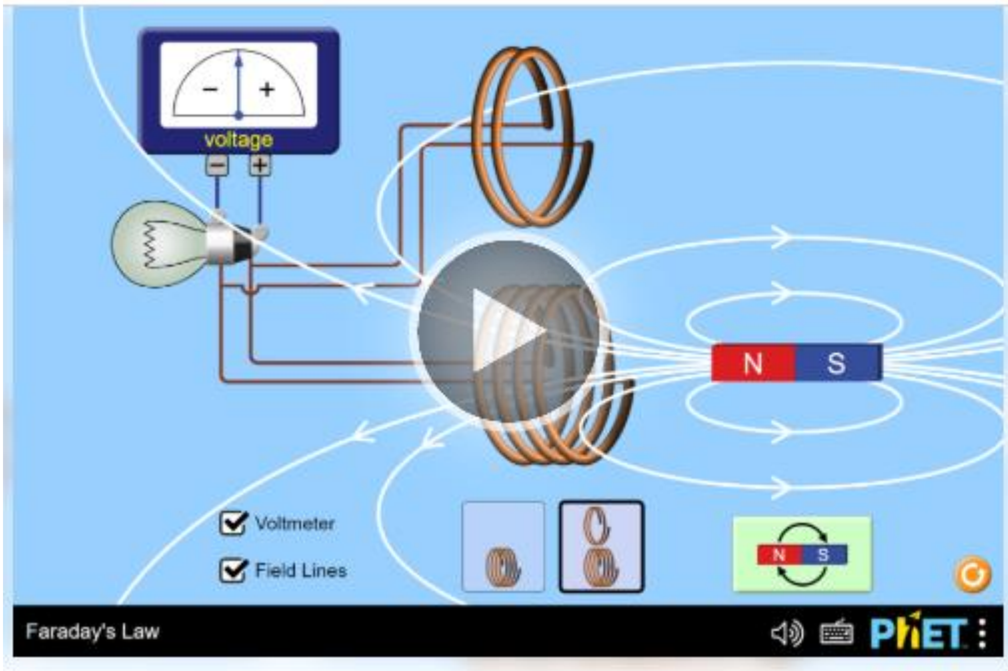

Figure 2: Faraday's law of electromagnetic induction

According to Al-khalili & Al-khalili (2015), electromagnetic induction is a process whereby an electric current can be induced to flow through a conductor that experiences a changing magnetic field.

Lenz' Law

Lenz's law, first introduced by Heinrich Lenz in 1834, is a fundamental concept in electromagnetic induction that describes the direction of an induced current resulting from a changing magnetic field. According to Lenz, the induced current will always flow in such a way that its magnetic field opposes the change in the magnetic flux that produced it(Hoe et al., 2024).Lenz's Law is mathematically embedded within Faraday's Law of Electromagnetic Induction, where the induced electromotive force (emf) is given by the negative rate of change of magnetic flux. The negative sign represents Lenz's Law and highlights the law's oppositional nature:

$\in_{ind} = -N\frac{d\emptyset}{dt}$

$\in_{ind}$ is the induced emf

$\frac{d\emptyset}{dt}$ is the rate of change of magnetic flux through the circuit.

This formulation provides a quantitative basis for understanding how electromagnetic induction works in real systems (Everett & Chave, 2019).

Numerous studies and physics texts have emphasized the significance of Lenz's Law in explaining phenomena such as electromagnetic braking, eddy currents, and transformer operation. Tural & Tarakçı (2017) explain that the opposition caused by induced currents plays a critical role in resisting mechanical motion, a principle used in braking systems of electric trains. Similarly, Lenz's Law explains the slowing down of a magnet falling through a conductive tube, where eddy currents are induced to oppose the motion, converting kinetic energy into thermal energy.

Recent educational research also highlights the importance of conceptual understanding of Lenz's Law in physics instruction. According to Ogegbo & Ramnarain, (2022), learners often struggle with the abstract nature of electromagnetic concepts, and visual tools such as PhET simulations can help in reinforcing the oppositional aspect of Lenz's Law by providing interactive learning environments. The law is not only central in physics education but also serves as a design principle in modern electrical engineering. Applications in devices like induction cooktops, generators, and metal detectors rely on the principles governed by Lenz's Law to function effectively (Shetye et al., 2021).

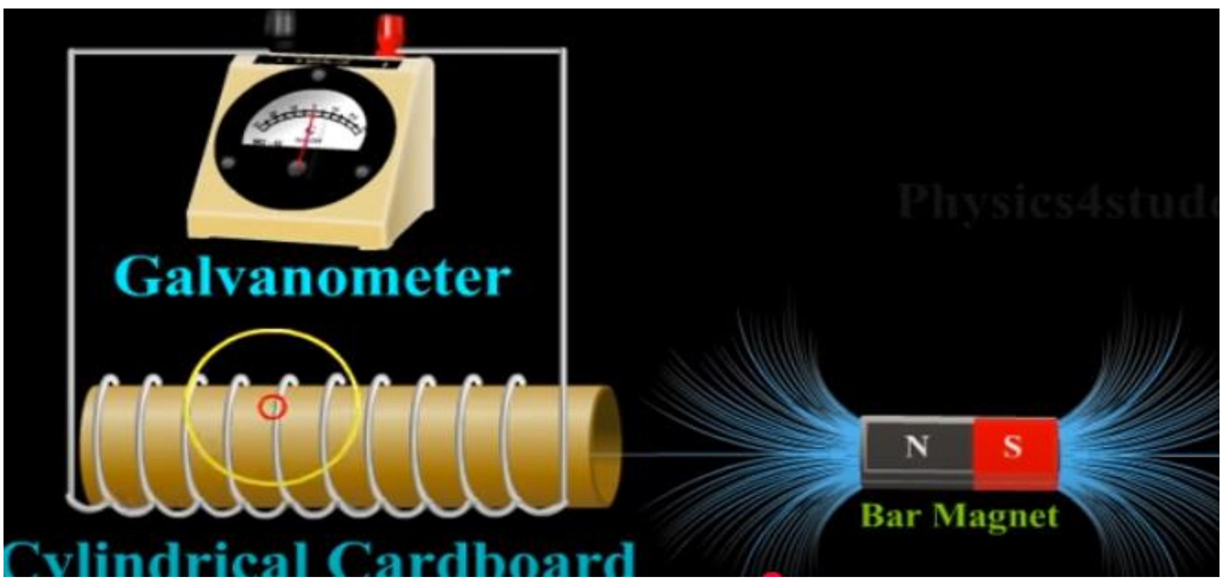

Figure 3: Demonstration of Lenz's law

As Lenz's law states that when the magnet moves from the coil, the electric current is induced in the opposite of the change that causes it. Once the magnet enters the coil above the needle of the galvanometer will deflect in the opposite direction to the magnet. The diffraction of the needle proves that the electrical current is induced.

Direct Current Generator (DC)

A DC generator is a device that converts mechanical energy into direct electrical energy using the principle of electromagnetic induction**.** According to Erol & Önder (2021), the fundamental structure of a DC generator includes an armature winding, field magnets, a commutator, and brushes.

Advances in education technology have improved how DC generators are taught. Simulation platforms such as PhET and MATLAB Simulink are widely used in engineering programs to help students visualize magnetic flux, emf generation, and commutation in DC machines (Abbasian, 2024).

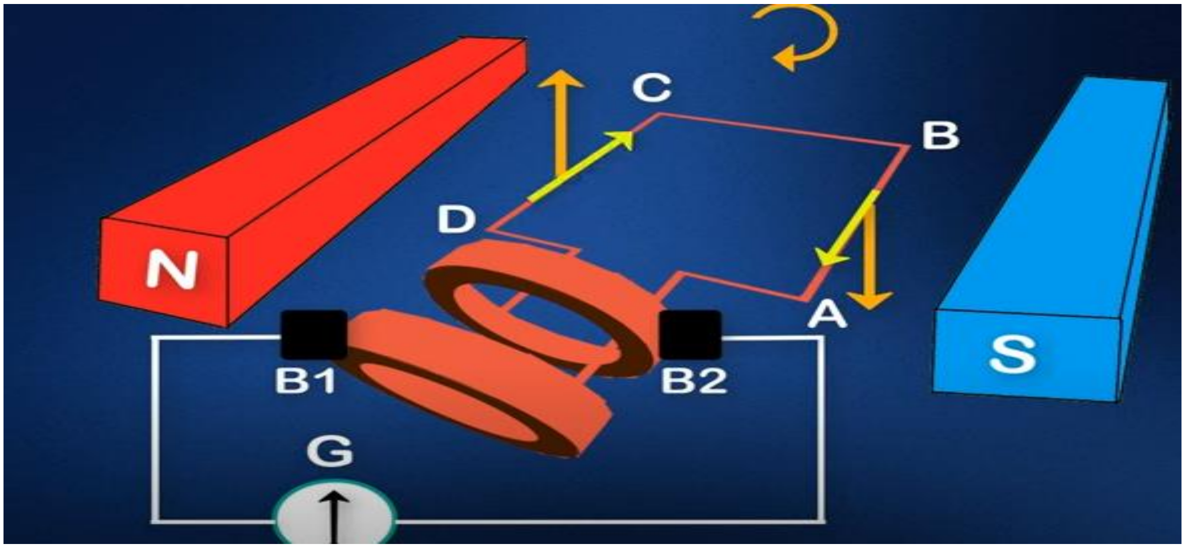

Figure 4:Direct Current Generator (DC)

PhET Simulation

PhET (Physics Education Technology) simulations are interactive, research-based digital tools developed by the University of Colorado Boulder to enhance conceptual understanding in science and mathematics through inquiry-based learning. Since their inception, PhET simulations have been widely adopted in physics education due to their ability to visualize abstract concepts and engage students in active learning environments (Pranata, 2024). Recent studies affirm the effectiveness of PhET simulations in improving student engagement, conceptual understanding, and academic performance in subjects such as electricity, magnetism, and mechanics. According to Salame & Makki (2021), PhET simulations provide implicit scaffolding, allowing students to explore concepts at their own pace while receiving indirect guidance that promotes deeper cognitive processing.

PhET tools are aligned with constructivist learning theories, which emphasize student-centered learning through exploration and interaction. In a comparative study, Drastisianti et al.,(2024) found that students using PhET simulations outperformed those who received traditional instruction, especially in understanding dynamic concepts like electric circuits and motion.

2.2 Empirical Review

An empirical review in research is part of the literature review that focuses on studies based on actual data, observations, or experiments, rather than theories or abstract concepts. It involves analyzing and summarizing previous empirical studies

Effectiveness of PhET Simulations in Teaching and Learning Sciences

The use of technology in education has completely changed how people teach and learn, especially in the sciences (Mystakidis & Christopoulos, 2022). One prominent technological tool that has garnered significant attention is PhET simulations. PhET, short for Physics Education Technology, provides interactive simulations designed to facilitate hands-on exploration of scientific concepts, (Kibiwott & Njoroge, 2024)in quasi-experimental research conducted he realized that through the use of simulation, studying physics can be enjoyable, understanding physics concepts can be practical, and grasping physics principles can be straightforward and uncomplicated. (Taibu & Mataka, 2021) observed that simulations also offer a dynamic and engaging learning environment.

In addition, the PhET simulation provided to the students acts as a stimulus so that they can readily investigate the relevant chapter of electromagnetic induction and develop their critical thinking abilities to the fullest. It is a learning tool that matches real-world tasks or occasions, like skateboarding games. Tuyizere & Yadav (2023), however, the researchers highlight a notable gap in the challenge of the effective implementation of PhET simulation.

Impact of PhET simulation on Learners' motivation in teaching and academic achievement.

Susilawati et al.,(2022) observed that the experimental group's motivation had changed somewhat as a result of the PhET simulation learning. Since motivation is a multifaceted phenomenon, researchers emphasized the need to expand the parameters of motivation to include factors related to active learning strategies.

3. Methodology

3.1 Research Design

From a pragmatic point of view, this study employed a quasi-experimental design with a nonequivalent pretest and posttest control group. After purposive selection of four schools, two schools were randomly assigned to the control group and two schools to the experimental group. Students studied electromagnetic induction in both the experimental and control groups for an equal time of 20 teaching periods (equal to five weeks). However, students in the experimental group studied using PhET simulations, while those in the control group studied using the existing teaching methods characterized by chalk and talk.

3.2 Sampling

A purposive sampling method was used to select four schools in the Nyamasheke district. To choose such schools, high standards for laboratory equipment, qualified teaching personnel, and infrastructure (such as electricity, ICT labs, and internet connectivity) were required. Considering the sample criteria prescribed above, four schools were selected, resulting in 158 students (80 males and 76 females). In four selected schools, two were randomly assigned to the experimental group, with 78 students, and two schools had 78 students in the control group.

Table 1: Sampled participants

Schools as strata	Physics teachers		Senior three students		Total
	Male	Female	Male	Female	
A	1	-	26	20	47
B	1	-	20	19	40
C	-	1	28	16	45
D		1	6	21	28
Total	2	2	80	76	160

Source: Field data (2025)

3.3 Data Collection Tools

The triangulation method was used during data collection.

Questionnaire

Closed-ended questionnaires were used to measure students' performance during teaching and learning electromagnetic induction using the PhET simulation. Pretest and posttest questionnaires were distributed to both control and experimental groups.

Focused Group Discussion

Four physics teachers from four schools selected randomly were interviewed in focused group discussion, to measure their attitude toward the effectiveness of PhET simulation in teaching and learning electromagnetic induction, focused group discussion was also used to measure the challenge of effective implementation of PhET simulation into teaching and learning of electromagnetic induction, and how could the identified challenges be addressed.

3.4 Data Analysis

Data were analyzed and discussed objectively with the aid of figures, tables, and graphs where necessary. Data retrieved from the questionnaires, observation, and focused group discussion were analyzed thematically.

Validity and Reliability

To determine whether research instruments were reliable and would gather data and assess the intended outcomes, revised instruments were developed and administered to a pilot study in two phases. The first phase was to measure the reliability of the pretest, and the last was to measure the reliability of the post-test on 20 items, using Cronbach's alpha coefficient

Table 2: Reliability statistics for pretest

Cronbach's Alpha	N of Items
0.886	20

Table 3: Reliability statistics for post-test

Cronbach's Alpha	N of Items
0.772	20

Both values of Cronbach's Alpha on both pretest and posttest were greater than the necessary value of 0.70, which means that the questionnaire used was reliable

4. Results and Discussion

Table 4: Distribution of participants in two groups by Gender

Variable (students)		**Control Group (N)**	**Experimental Group (N)**	**Total**	**%**
	Male	43	37	80	51.3%
Gender	Female	35	41	76	48.7.%
	Total	78	78	156	100%

From the above table, we have a fairly equal representation of the respondents by gender. Male participants were 80 students (representing 51.3% of the total sample), of which 43 students were in the control group and 37 students were in the experimental group. Female participants were 76 female participants (representing 49.4% of the total sample), of which 35 female students were in the control group and 41 female students were in the experimental group. The control group had 78 students, and the experimental group had 78 students in total.

Table 5: The difference between the pre-test scores of the control group and the experimental group

Group	N	Minimum score	Maximum score	Mean score	Standard deviation
Control group	78	8	52	34.08	10.948
Experimental Group	78	14	52	34.54	9.896

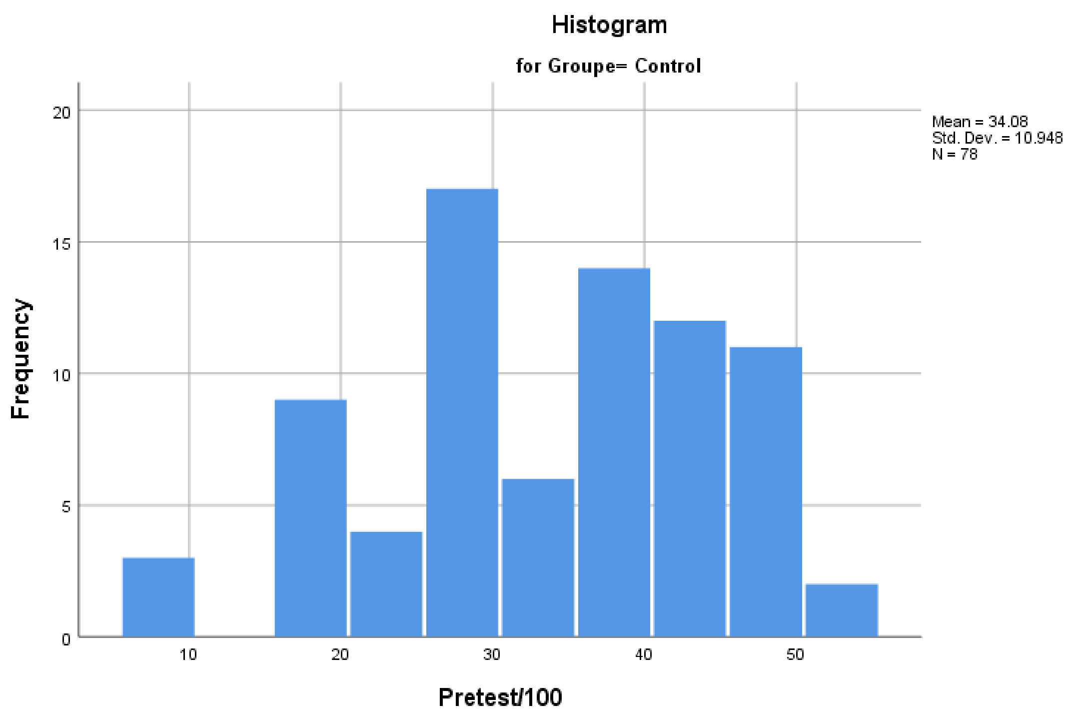

Figure 5:Pre-test scores of students in the control group

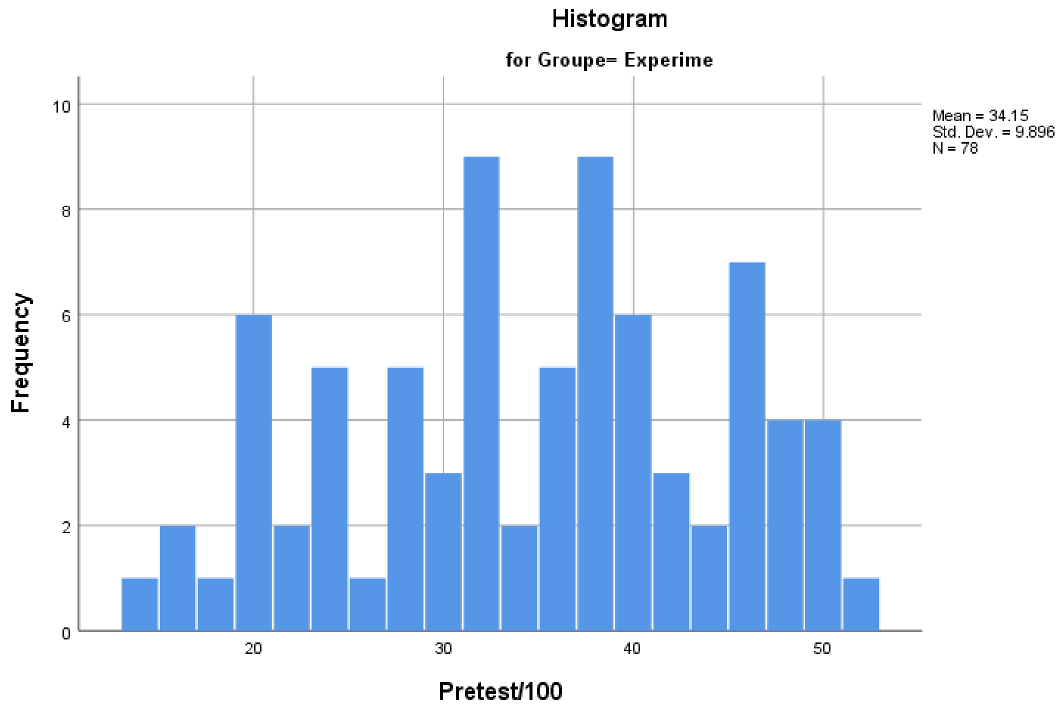

Figure 6:Pre-test scores of students in the experimental group

The academic performance of students in the control group in the pre-test is different from the academic performance of students in the experimental group since, for the experimental group, the range of marks is from 14 to 52 out of 100 marks, the mean score is 34.15 marks, and the standard deviation is 9.896 marks.

Table 6: Compares the post-test scores of students from the control group to the scores of students from the experimental group

Group	N	Minimum score	Maximum score	Mean score	Standard deviation
Control group	78	25	64	49.63	8.336
Experimental Group	78	46	100	79.03	11.980

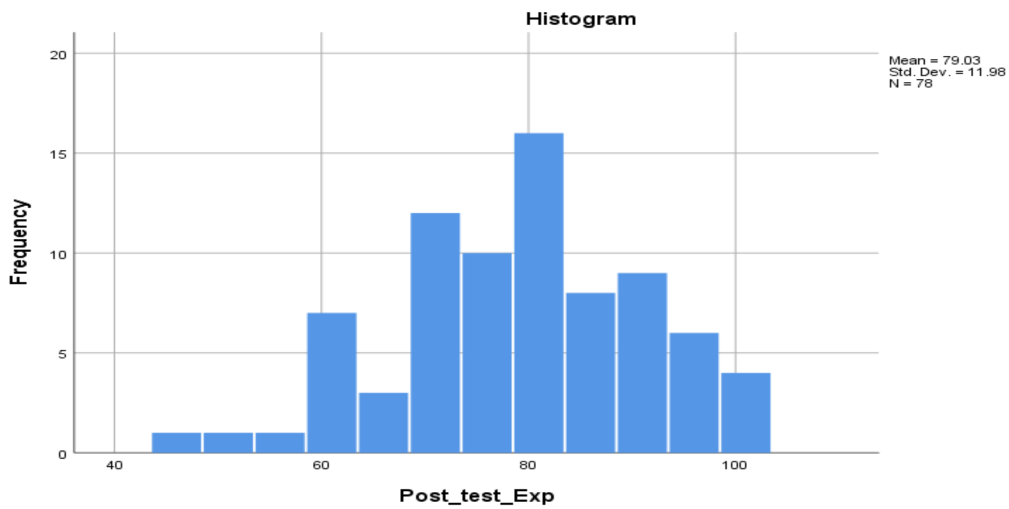

Figure 7:Post-test scores of students from the control group

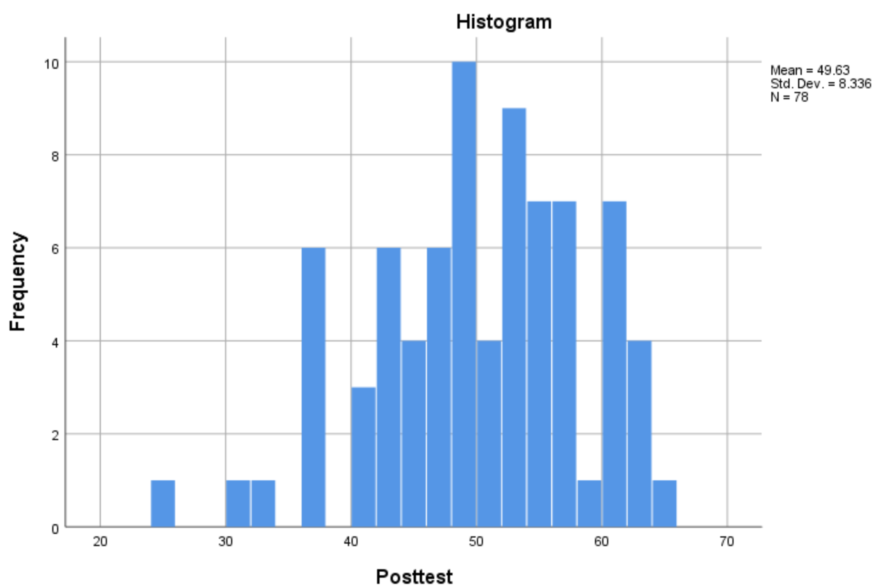

Figure 8:Post-test scores of students from the control group

From the table and the histogram above, the experimental group has scored higher than the control group. The range of scoring is from 46 to 100 out of 100 marks in the case of the experimental group, while it is from 25 to 64 out of 100 marks for the case of the control group. The post-test mean score for the experimental group (79.03 out of 100 marks) is greater than the mean score for the control group (49.63 out of 100 marks). It is important to note that 4 students from the experimental group have scored the maximum (100 out of 100 marks) in the post-test, while none from the control group have scored this maximum. The standard deviation of the post–test scores from the experimental group is 11.96 marks, while it is 8.336 marks for the control group

Table 7: Independent samples t-test results from a comparison of post-test mean scores between control and experimental groups.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Posttest	Equal variances assumed	7.714	.006	-17.789	154	.000	-29.397	1.653	-32.662	-26.133
	Equal variances not assumed.			-17.789	137.397	.000	-29.397	1.653	-32.665	-26.130

To test the significance of this difference, the results from an independent samples t-test give a t-value equal to −17.789 and the p-value of 0.000 with a degree of freedom equivalent to 137. 397. From the p-value of 0.000, which is less than the alpha value ($\alpha = 0.05$), we conclude that the difference between the post-test mean scores of controls and experimental groups is significant.

Table 8: Perception of students and teachers to use PhET simulations vs Traditional Teaching Method in Electromagnetic induction.

Students' views	SD	D	N	A	SA	Mean	Analysis
When teaching and learning electromagnetic induction, PhET facilities help students pay more attention.	0.0%	0.0%	7.1%	28.6%	64.3%	4.57	Positive
Compared to traditional teaching methods, PhET is more effective.	0.0%	0.0%	0.0%	35.7%	64.3%	4.64	Positive
The use of PhET improves the efficiency of constantly updating daily lessons.	0.0%	0.0%	0.0%	85.7%	14.3%	4.14	Positive
I feel at ease instructing students in electromagnetic induction in the classroom utilizing PhET facilities.	21.4%	35.7%	28.6%	14.3%	0.0%	2.36	Negative

I possess the instructional and learning abilities needed to implement PhET exercises in my classroom	0.0%	0.0%	0.0%	57.1%	42.9%	4.43	Positive
Overall % and mean	2.1%	24.6%	8.5%	35.6%	29.2%	3.57	Positive

Keywords **SA**-Strongly Agrees, **A**-Agree, **D**-Disagree, **SD**-Strongly Disagree, and **N**-Not Sure.

The findings in the table above showed that PhET simulation helps students pay more attention when studying and teaching electromagnetics. 28.6% of respondents agreed, 64.3% strongly agreed, 7.1% were not sure, 0.0% strongly disagreed, and 0% disagreed. Regarding the statement that PhET is more effective than traditional teaching methods, 0.0% of respondents disagreed, 0.0% strongly disagreed, 35.7% agreed, 64.3% strongly agreed, and 0.0% were not sure. On the subject, using PhET increases the effectiveness of continuously updating daily courses. Of the respondents, 0.0% was not sure, 85.7% agreed, 14.3% strongly agreed, 0.0% disagreed, and 0.0% strongly disagreed. Regarding the subject, I feel at ease instructing pupils in electromagnetic induction in the classroom using PhET facilities. Of those surveyed, 28.6% had no opinion, 14.3% agreed, 0.0% strongly agreed, 35.7% strongly disagreed, and 0.21.4% disagreed. I possess the teaching and learning abilities necessary to implement PhET activities in my classroom. 57.1% of respondents agreed, 42.9% strongly agreed, 0.0% strongly disagreed, 0.0% disagreed, and 0.0% were not sure. Results from table 8 indicated that most physics teachers thought PhET Simulation was a good way to teach electromagnetic induction.

To identify challenges to the effective implementation of PhET simulations in electromagnetic induction education and how to overcome those challenges.

Effective use of PhET simulations in electromagnetics education can have several advantages, such as helping students visualize abstract ideas and promoting active learning, but there are several challenges that institutions and teachers may encounter. The table below highlights those challenges.

Table 9: Challenges to the effective implementation of PhET simulations in electromagnetic education

	N = 4	
Challenges of effective implementation of PhET Simulation in teaching electromagnetic induction	**Number of responses**	**Percentage**
Poor internet Connectivity	3	75%
Using PhET simulations requires more training.	3	75%
Student-to-computer ratio	4	100%
Lack of innovation	2	5%
Insufficient funds allocated to Secondary schools	3	75%
Lack of enough training	3	75%

Source: Data Field 2025

From Table 9, teachers highlight that there was a notable number of students compared to the number of computers available, as it is noticed the student-to-computer ratio is 100%. 75 % of respondents answered that PhET simulations require more training, 75% of respondents replied that there is poor internet connectivity. 75% replied that they lack enough training on the use of PhET simulation in teaching and learning Electromagnetism induction

An important interview from the group discussion:

Some teachers do not employ PhET Simulation when teaching electromagnetic induction, depending on their age, whether they are in-service or pre-service. According to some educators, they are too old to become skilled with new digital tools and use them in the classroom.

Furthermore, important comments by the interviewees were also noted:

The last comment by interviewees was:

Despite the generally encouraging results, some teachers had trouble using PhET Simulation. According to the interview by teacher, navigating the simulation was the main source of difficulty. This indicates that mastering navigation requires time and additional instructional support. Additionally, some teachers suggested during Continuous Professional Development that science teachers should have training on it.

Overcoming the Challenges of Effective Implementation of PhET Simulation

To respond to this question, the interviewees were asked to suggest ways to overcome the challenges of effective implementation of PhET Simulation in teaching electromagnetic induction.

The interviewees (focused group discussion) provided the following answers:

- *To increase the student-to-computer ratio, the Rwanda Education Board should buy additional computers and other relevant ICT equipment.*
- *Free electromagnetic simulators should be downloaded by the schools.*
- *Every school needs to set up a schedule to access the computer lab or smart classroom. For teachers to receive self- training during CPD.*
- *Hiring personnel to oversee technical support services and holding workshops and seminars on the efficient use of PhET Simulation in teaching and learning electromagnetic*

5. Conclusion and Recommendations

5.1 Conclusion

The findings revealed that the PhET simulation showed a positive outcome on teaching and learning electromagnetic induction, and improved its conceptual clarity. Real-time variable manipulation and the depiction of abstract phenomena, both of which are frequently challenging to communicate through conventional chalk-and-talk methods, were made possible by the simulations. Deeper involvement and critical thinking were encouraged by these interactive experiences, which enhanced idea application and retention. When using simulations, students showed excitement and interest. They valued the visual depiction of otherwise invisible occurrences, the user-friendly interface, and the intuitive design. After engaging with the simulations, many students reported feeling more assured about their comprehension of electromagnetic concepts. The educational advantages of PhET simulations were also recognized by teachers. They saw that simulations improved their instructional strategies, enabled differentiation, and accommodated diverse learning preferences.

5.2 Recommendations

The study findings show that PhET simulation is more effective on students' performance in electromagnetic induction:

1. REB should incorporate ICT resource (mostly computer simulations as links with content) when creating physics curricula and publishing physics textbooks.
2. To enable the use of computer-aided instruction, such as computer simulations (PhET), in physics lessons, School leaders should set seminars or continuous development to the physics teachers, on the use of PhET simulation in teaching and learning physics.

Reference

Abbasian, M. (2024). Enhancing understanding of the rotating magnetic field in electric machines through active learning and visualization. *Engineering Reports*, *July*, 1–20. https://doi.org/10.1002/eng2.12976

Adamma, O. N., Ekwutosim, O. P., & Unamba, E. C. (2018). Influence of extrinsic and intrinsic motivation on pupils academic performance in mathematics. *SJME (Supremum Journal of Mathematics Education)*, *2*(2), 52–59. https://doi.org/10.35706/sjme.v2i2.1322

Al-khalili, J., & Al-khalili, J. (2015). *The birth of the electric machines : a commentary on Faraday (1832) ' Experimental researches in electricity ' Author for correspondence : 1832*.

Aubret, A., Matignon, L., & Hassas, S. (2019). *A survey on intrinsic motivation in reinforcement learning*. *Im*. http://arxiv.org/abs/1908.06976

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), 23108. https://doi.org/10.1103/PhysRevPhysEducRes.17.023108

Boeren, E. (2019). Understanding Sustainable Development Goal (SDG) 4 on “quality education” from micro, meso and macro perspectives. *International Review of Education*, *65*(2), 277–294. https://doi.org/10.1007/s11159-019-09772-7

Buheji, M. (2023). *OPTIMISING SOCIOECONOMIC RESILIENCESTRATEGIES- CASE STUDY OF RWANDA*. *December*. https://doi.org/10.17605/OSF.IO/ZFK9W

Cook, D. A., & Artino, A. R. (2016). Motivation to learn: an overview of contemporary theories. *Medical Education*, *50*(10), 997–1014. https://doi.org/10.1111/medu.13074

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791

Drastisianti, A., Dewi, A. K., & Alighiri, D. (2024). *International Journal of Pedagogy and Teacher Education Effectiveness of Guided Inquiry Learning With PhET Simulation to Improve Students ' Critical Thinking Ability and Understanding of Reaction Rate Concepts*. *8*(2), 235–252.

Erol, M., & Önder, E. B. (2021). Conceptual framework on teaching capacitors and inductors. *Momentum: Physics Education Journal*, *5*(2), 182–193. https://doi.org/10.21067/mpej.v5i2.5630

Everett, M. E., & Chave, A. D. (2019). On the physical principles underlying electromagnetic induction. *Geophysics*, *84*(5), W21–W32. https://doi.org/10.1190/geo2018-0232.1

Falloon, G. (2020). From simulations to real: Investigating young students’ learning and transfer from simulations to real tasks. *British Journal of Educational Technology*, *51*(3), 778–797. https://doi.org/10.1111/bjet.12885

Gholam, A. (2019). Inquiry-Based Learning: Student Teachers’ Challenges and Perceptions. *Journal of Inquiry & Action in Education*, *10*(2), 112–133.

Hoe, P. C., Francis, R., Asykin, A. S., Abdullah, M. A.-A. Bin, & Ahmad, M. A. Bin. (2024). Enhancing the Teaching and Learning Process of Faraday’s and Lenz’s Laws in Electromagnetic Induction using EM-Kit. *International Conference on Business Studies and Education (ICBE)*, *April*.

Kambara, H. (2021). Exploring Japanese Fourth Graders ’ Motivation to Read : A Mixed- Exploring Japanese Fourth Graders ’ Motivation to Read : A Mixed-Method Study ABSTRACT. *Literacy Research and Instruction*, *00*(00), 1–18. https://doi.org/10.1080/19388071.2020.1806416

Kedir, I. (2020). Secondary School Students’ Beliefs Towards Learning Physics and Its Influencing Factors. *Research on Humanities and Social Sciences*, *10*(7), 37–49. https://doi.org/10.7176/rhss/10-7-05

Kibiwott, D. K., & Njoroge, B. (2024). *Influence of Simulations on Students ' Achievement in Physics in Secondary Schools in Nandi East , Kenya*. *2*(2), 70–79.

Leandro, D. J. D. T., & Umana, D. M. V. (2021). The Impact of Transformational Leadership on the Self-Creative Efficacy and Intrinsic Motivation in FINTECH Organizations. *International Journal of Business and Management Research*, *9*(4), 448–456. https://doi.org/10.37391/ijbmr.090408

Mbonyiryivuze, A., Yadav, L. L., & Amadalo, M. M. (2021). Students’ attitudes towards physics in nine years basic education in rwanda. *International Journal of Evaluation and Research in Education*, *10*(2), 648–659. https://doi.org/10.11591/ijere.v10i2.21173

Mystakidis, S., & Christopoulos, A. (2022). Teacher Perceptions on Virtual Reality Escape Rooms for STEM Education. *Information (Switzerland)*, *13*(3), 1–13. https://doi.org/10.3390/info13030136

Niyonsaba, A., Nkurunziza, J. B., & Hakizimana, E. (2022). *Impacts of Collaborative Learning on Learners ' Academic Performance in Chemistry in Three Selected Secondary Schools of Nyamasheke District*. *18*(2), 0–1.

Nsabayezu, E., Uwihanganye, A., & Nsengiyumva, P. (2023). Examining Teachers’ and Students’ Perceptions on the Use of Science Kits to Improve Chemistry Performance in Lower Secondary Schools. *Journal of Classroom Practices*, *2*(2), 1–17. https://doi.org/10.58197/prbl/aori1073

Nyoman, N., Putu, S., & Nisrina, N. (2025). *Reimagining Physics Education : Addressing Student Engagement , Curriculum Reform , and Technology Integration for Learning*. *2*(1), 158–181.

Ogegbo, A. A., & Ramnarain, U. (2022). Teaching and learning Physics using interactive simulation: A guided inquiry practice. *South African Journal of*

Education, *42*(1), 1–9. https://doi.org/10.15700/saje.v42n1a1997

Pranata, O. D. (2024). Physics education technology (PhET) as a game-based learning tool: A quasi-experimental study. *Pedagogical Research*, *9*(4), em0221. https://doi.org/10.29333/pr/15154

Rone, N. A., Amor, N., Guao, A., Jariol, M. S., Acedillo, N. B., Balinton, K. R., & Francisco, J. O. (2023). Students' lack of interest, motivation in learning, and classroom participation: how to motivate them? psychology and education: a multidisciplinary journal Students' Lack of Interest, Motivation in Learning, and Classroom Participation: How to Motivate T. *Psych Educ*, *7*(March), 585. https://doi.org/10.5281/zenodo.7749977

Salame, I. I., & Makki, J. (2021). *Examining the Use of PhET Simulations on Students ' Attitudes and Learning in General Chemistry II*. *17*(4).

Shetye, K. S., Kumar, R. R., Klauber, C., Mao, Z., Overbye, T. J., Gannon, J., & Henderson, M. (2021). Development and electric grid applications of a magnetometer network. *IEEE Open Access Journal of Power and Energy*, *8*(December 2020), 77–84. https://doi.org/10.1109/OAJPE.2021.3054396

Susilawati, A., Yusrizal, Y., Halim, A., Syukri, M., Khaldun, I., & Susanna, S. (2022). Effect of Using Physics Education Technology (PhET) Simulation Media to Enhance Students' Motivation and Problem-Solving Skills in Learning Physics. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1157–1167. https://doi.org/10.29303/jppipa.v8i3.1571

Taibu, R., & Mataka, L. (2021). *CUNY Academic Works Using PhET Simulations to Improve Scientific Skills and Attitudes of Community College Students How does access to this work benefit you ? Let us know ! Using PhET Simulations to Improve Scientific Skills and Attitudes of*.

Tsang, Y., & Zhang, T. (2022). Advantages and Disadvantages of Using Tangible Rewards by Teachers with Chinese Young Students. *Proceedings of the 2021 International Conference on Social Development and Media Communication (SDMC 2021)*, *631*(Sdmc 2021), 1295–1301. https://doi.org/10.2991/assehr.k.220105.239

Tugirinshuti, G. J., Mugabo, L. R., & Banuza, A. (2022). *Teacher Pedagogical Beliefs and Resistance to the Effective Implementation of Video-Based Multimedia in the Physics Classroom*. *21*(5), 463–477.

Tural, G., & Tarakçı, D. (2017). Effects of physical models and simulations to understand daily life applications of electromagnetic induction. *Research in Science and Technological Education*, *35*(3), 292–307. https://doi.org/10.1080/02635143.2017.1295370

Tuyizere, G., & Yadav, L. L. (2023). Effect of interactive computer simulations on academic performance and learning motivation of Rwandan students in Atomic Physics. *International Journal of Evaluation and Research in Education*, *12*(1), 252–259. https://doi.org/10.11591/ijere.v12i1.23617

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*, *7*(1), 22–30. www.jriiejournal.com

Uwambajimana, S., Minani, E., Mollel, A. D., & Nyirahabimana, P. (2023a). *The impact of using PhET simulation on conceptual understanding of electrostatics within selected secondary schools of Muhanga*. *3*(2).

Uwambajimana, S., Minani, E., Mollel, A. D., & Nyirahabimana, P. (2023b). The impact of using PhET simulation on conceptual understanding of electrostatics within selected secondary schools of Muhanga District, Rwanda. *Journal of Mathematics and Science Teacher*, *3*(2), em045. https://doi.org/10.29333/mathsciteacher/13595

Uwayezu, J. C., & Uzabakiriho, V. (2024). *Assessing Learning in Mathematical Sensemaking Electromagnetism Instructions among Rwanda Polytechnic Students at Huye College I . INTRODUCTION*. *5*, 748–760.