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Optimizing PhET Use in Rwandan Mathematics and Sciences Teaching

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Abstract

This qualitative study examined the effectiveness of professional development programs for mathematics and sciences teachers in four public secondary schools within Gasabo District, Rwanda. The primary focus was to evaluate how these programs enhance teachers' ability to integrate Physics Education Technology (PhET) simulations into their classrooms. The research involved 42 participants. Data collection methods included in-depth interviews, classroom observations, and document analysis. Findings revealed that professional development programs significantly improved teachers' confidence and proficiency in using PhET simulations, resulting in more engaging and effective mathematics and science education. The study highlighted the importance of adapted professional development to enhance teachers' use of technology in the classroom, with potential implications for improving mathematics and science education in the region.

Keywords: *Mathematics and Sciences teachers, PhET simulations, Professional development programs.*

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INTRODUCTION

The integration of technology into education has become increasingly important in enhancing the teaching and learning process. Physics Education Technology (PhET) simulations offer a unique opportunity for teachers to engage students in hands-on, interactive learning experiences in physics. In Rwanda, the need to improve the quality of science and mathematics education has prompted efforts to incorporate digital resources like PhET simulations into the classroom.

The integration of innovative educational technologies in the classroom has emerged as a pivotal strategy in improving the quality of science and mathematics education worldwide (Bibakumana & Niyibizi, 2024; Niyibizi, 2024). In the context of Rwanda, a country striving for educational excellence and technological advancement, there is a growing interest in harnessing the potential of Physics Education Technology (PhET) simulations to enhance the teaching and learning experience in science and mathematics subjects.

This study intended to assess the effectiveness of professional development programs sharp for mathematics and science teachers in Rwanda, with the overarching goal of enhancing their proficiency in utilizing PhET simulations as a pedagogical tool in the classroom. Rwanda, like many countries, recognizes the importance of a well-rounded and practical science and mathematics curriculum for the development of its workforce and economy.

In pursuit of this objective, the Rwandan government has embraced various initiatives to improve science and mathematics education, including the adoption of PhET simulations as an innovative resource for teaching and learning. However, the success of these technologies heavily relies on the competencies and preparedness of educators (Niyibizi, 2024). Teachers need to be proficient in utilizing PhET simulations to effectively engage students, stimulate interest in these subjects, and

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raise critical thinking skills.

The present study represents a crucial step towards understanding the impact of handmade professional development programs on mathematics and science teachers in Rwanda. It explored the effectiveness of these programs in equipping teachers with the necessary skills and knowledge to harness PhET simulations in their classrooms. This research was expected to provide valuable insights into the integration of technology-based teaching tools and the potential improvements in student outcomes. The assessment of the professional development programs in this context was especially significant, as it contributes to the ongoing dialogue on the global shift towards technology-enhanced education.

Furthermore, it addressed the specific needs and challenges faced by teachers in Rwanda, which may vary from those encountered in different educational environments. As a result, the findings from this study served as a reference for educational policymakers, institutions, and stakeholders, aiding them in making informed decisions to enhance the quality of science and mathematics education.

A literature review is a critical examination of existing research and scholarship relevant to a specific topic. In the context of the present study, a literature review involved summarizing and evaluating prior studies, educational practices, and relevant theories related to professional development programs, secondary math and science education, and the integration of technology, such as PhET simulations, into the classroom.

It served as the foundation for understanding the current state of knowledge and identifying gaps in the research that the study aims to address. Professional development programs play a crucial role in enhancing teachers' skills and effectiveness in the classroom, particularly in the fields of secondary mathematics and science education (Niyibizi, 2024). PhET Interactive Simulations, developed by the University of Colorado Boulder, are widely recognized for their ability to make abstract physics concepts more accessible to students.

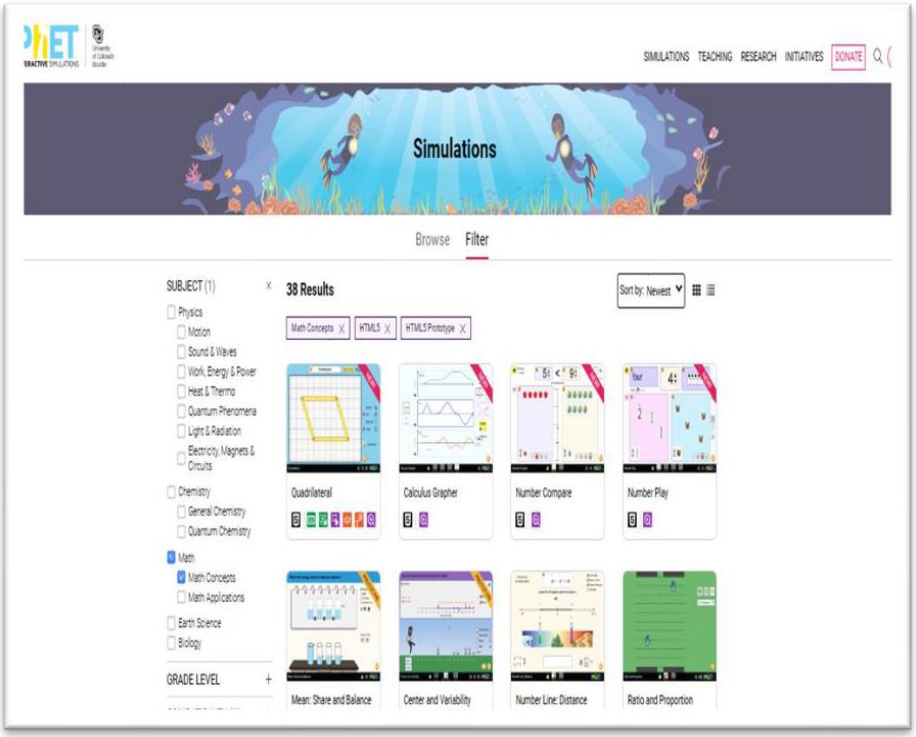

Figure 1. PhET simulations in Mathematics

These interactive, web-based simulations provide a dynamic, visual platform for students to

explore and experiment with physical phenomena, helping to raise a deeper understanding of the subject matter. The integration of technology, such as Physics Education Technology (PhET) simulations, has the potential to transform the way students engage with complex concepts in physics.

Effective professional development programs are characterized by features such as sustained engagement, active learning, and collaborative opportunities for teachers to apply new knowledge and skills (Mahtari, et al., 2020; Taibu, Mataka, & Shekoyan, 2021; Verawati, Handriani, & Prahani, 2022). Research suggestedthat successful programs offer ongoing support and feedback, which is particularly relevant to the integration of PhET simulations (Salame & Makki, 2021).

PhET simulations are interactive, research-based tools designed to help students learn complex science and math concepts. Studies indicated that PhET simulations improve conceptual understanding, motivation, and engagement (Wu, et al., 2021; Yunzal & Casinillo, 2020; Verawati, Handriani, & Prahani, 2022; Uwambajimana, et al., 2023). Professional development programs allow teachers to effectively use PhET simulations potentially yield significant benefits for students.

Effective utilization of PhET simulations involves integrating them into the curriculum, using them in combination with traditional teaching methods, and providing guidance for teachers on how to navigate and explain simulations (Haryadi & Pujiastuti, 2020; Taibu, Mataka, & Shekoyan, 2021; Verawati, Handriani, & Prahani, 2022; Banda & Nzabahimana, 2023).

Research on best practices inform the design of professional development programs. Empirical study has explored the impact of professional development programs on teachers' ability to use PhET simulations. For example, Banda and Nzabahimana (2023) found that a structured program significantly improved teachers' ability to integrate simulations into their lessons. Research also suggested that students taught by teachers who have undergone PhET-based professional development exhibit improved understanding and retention of scientific and mathematical concepts (Salame & Makki, 2021; Taibu, Mataka, & Shekoyan, 2021).

Many secondary mathematics and science teachers initially find it challenging to integrate PhET simulations into their teaching practices. Professional development programs are designed to bridge this gap by providing teachers with the necessary training and support to effectively incorporate PhET simulations in their classrooms. Several studies have identified barriers and challenges to effective professional development. These include inadequate time, resources, and access to technology (Yunzal & Casinillo, 2020; Verawati, et al., 2022). Addressing these challenges is crucial for the success of programs focused on enhancing PhET simulation utilization.

Several studies have assessed the effectiveness of professional development programs in enhancing teachers' ability to use PhET simulations. These programs typically consist of workshops, online courses, and resources to aid teachers in incorporating the simulations into their curriculum (Mahtari, et al., 2020; Verawati, et al., 2022; Uwambajimana, et al., 2023).

Professional development programs often result in teachers acquiring a deeper understanding of how to use PhET simulations effectively (Wu, et al., 2021; Yunzal & Casinillo, 2020; Verawati, et al., 2022). This knowledge helps them create engaging, inquiry-based lessons that improve student learning outcomes. These programs contribute to teachers' increased confidence in using technology-rich tools like PhET simulations (Yunzal & Casinillo, 2020; Taibu, Mataka, & Shekoyan, 2021; Verawati, Handriani, & Prahani, 2022; Uwambajimana, et al., 2023; Niyibizi & Mutarutinya, 2023). This heightened self-assurance positively impacts their willingness to integrate technology into their classrooms (Nzayisenga, Niyibizi, & Uworwabayeho, 2023; Niyibizi & Mutarutinya, 2023).

Researches indicated that when teachers receive proper training through professional development, their students tend to perform better and show a deeper understanding of physics or mathematics concepts, as measured through pre- and post-assessment scores (Yunzal & Casinillo, 2020; Taibu, et al., 2021; Uwambajimana, et al., 2023; Uwitatse, Niyibizi, & Mutarutinya, 2023).

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Studies suggested that ongoing professional development and support are crucial for sustaining the use of PhET simulations in the classroom (Banda & Nzabahimana, 2023; Niyibizi, et al., 2023). This highlights the need for continued training opportunities and resources for teachers. While professional development programs have proven effective in many instances, challenges such as limited time, resources, and institutional support can hinder their success (Yunzal & Casinillo, 2020).

Moreover, research indicates that there is a need for further investigation into the long-term impact of such programs and how they can be optimized to meet the diverse needs of teachers (Banda & Nzabahimana, 2023; Uwambajimana, et al., 2023). This study was motivated by the need to answer crucial question concerning the impact of professional development on teachers and, subsequently, on the learning experiences of students.

By employing PhET Simulation technique, researcher intention to investigate the following key aspect: What is the impact of professional development programs on secondary mathematics and Sciences teachers in Rwanda, specifically in terms of enhancing their proficiency in utilizing Physics Education Technology (PhET) simulations within the classroom, and how does this influence student learning outcomes?

The Diffusion of Innovation theory, developed by Everett Rogers, applied to understand how the adoption and integration of PhET simulations occur in the classroom. This theory suggests that innovations (in this case, PhET simulations) are adopted and diffused through a population over time, with the population categorized into innovators, early adopters, early majority, late majority, and laggards. The study examined where Rwandan mathematics and science teachers fall within this spectrum and explore the factors influencing their adoption. It assessed the role of professional development programs in accelerating the diffusion process, identifying barriers to adoption, and strategies for overcoming these barriers.

Social Learning Theory, associated with Albert Bandura, was used to study the effectiveness of professional development programs by focusing on the social and observational aspects of learning. Teachers learn not only through individual experiences but also by observing and interacting with others. The study analyzed how professional development programs promote social learning, such as collaborative lesson planning and sharing of best practices, to enhance the use of PhET simulations. It also explored how teacher self-efficacy, a key concept in social learning theory, impacts their ability to effectively use these simulations in the classroom.

These two theories provided a solid theoretical foundation for investigating the adoption and effectiveness of PhET simulations in Rwandan classrooms. Researcher used these frameworks to design interviews, documents to be analyzed, and observations that help uncover the factors influencing teachers' use of technology in the classroom, as well as the impact of professional development programs on their adoption of these tools.

RESEARCH METHODOLOGY

Through a comprehensive examination of professional development initiatives, this research aimed to assess the influence of Physics Education Technology (PhET) simulations on classroom instruction among secondary mathematics and science teachers in Rwanda, employing a rigorous research methodology to recognize the influence of these programs on student performance and thereby contribute to the improvement of mathematics and science education quality in the country.

Research Approach

In today's rapidly evolving educational landscape, the integration of technology into teaching and learning has become an imperative. In particular, the use of educational simulations, such as the Physics Education Technology (PhET) simulations, has gained prominence as a powerful tool for enhancing students' understanding of complex scientific concepts. Recognizing the potential of these

simulations, the Rwandan education system has made efforts to adopt them within the secondary mathematics and sciences curriculum.

However, for the successful implementation of such technology-driven educational tools, it was essential to ensure that teachers are adequately equipped with the necessary skills and knowledge. This research endeavor seeks to investigate the effectiveness of professional development programs designed for secondary mathematics and sciences teachers in Rwanda with the primary aim of enhancing their ability to use PhET simulations in the classroom.

The study explored into the realm of education and technology integration, emphasizing the need to adapt the research approach to the unique context and challenges faced by teachers in Rwanda. The qualitative methods, such as interviews and observations were used to gain insights into the teachers' experiences and perceptions (Eddles-Hirsch, 2015). These qualitative findings provided a richer context for understanding the shades of how professional development programs are impacting teachers' confidence and ability to integrate PhET simulations into their teaching practices.

The research approach recognized the multi-faceted nature of teacher professional development and the complex dynamics that influence the successful integration of technology in the classroom. As such, this qualitative design was well-suited to explore the intricate interplay between the professional development programs, teacher experiences, and their classroom practices. The outcomes of this research were not only contributed to the body of knowledge on the integration of technology in education but also offered practical insights that inform the development and improvement of professional development programs for mathematics and sciences teachers in Rwanda.

Ultimately, this study desired to promote the effective use of PhET simulations, adopting a more engaging and impactful science and mathematics education in the secondary classrooms of Rwanda. This present research utilized a qualitative research methodology to gain in-depth insights into the experiences and perspectives of secondary mathematics and sciences teachers in Rwanda regarding their participation in professional development programs related to PhET simulations.

Participants

In Rwanda's secondary education landscape, the transformative potential of professional development initiatives for mathematics and sciences teachers, particularly in integrating Physics Education Technology (PhET) simulations, emerges as a pivotal factor in advancing educational quality and cultivating a profound comprehension of physics among students.

PhET simulations, developed by the University of Colorado Boulder, are interactive and dynamic digital tools that provide students with an engaging and experiential approach to learning physics concepts. However, the successful integration of such tools into the classroom relies heavily on the competence and confidence of the teachers using them. The central protagonists of this study were the secondary mathematics and sciences teachers in Rwanda. These teachers were not only responsible for delivering content but also act as role models and mentors for the next generation of scientists and critical thinkers. Their effectiveness is a cornerstone for the country's educational progress and, consequently, the nation's overall development.

In the present study, researcher used purposeful sampling approach to select the Gasabo District to carry the study based on the usability and implementation of PhET simulations in secondary schools. Researcher also selected a purposeful sample of 42 secondary mathematics and science teachers who have participated in the professional development programs related to PhET simulations in selected secondary schools. Ensure diversity in terms of age, gender, teaching experience, and location of schools in Rwanda.

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Data Collection

In exploring the dynamic landscape of education, where technology integration is increasingly pivotal, this research investigated the effectiveness of professional development initiatives aimed at enhancing the readiness and capability of secondary mathematics and science teachers in Rwanda to integrate PhET simulations into their teaching practices, employing a thorough data collection approach to illuminate insights for informed educational policy and practice.

This study was highlighting the significance of professional development in advancing educational technology and the specific focus on PhET simulations. By emphasizing the critical role of data collection in this study, researcher underlined the need to gather robust evidence that guide educational stakeholders in shaping the future of mathematics and science education in Rwanda.

The researcher conducted in-depth, semi-structured interviews with the selected teachers. The interviews explored their experiences with the professional development programs, how they integrate PhET simulations into their teaching, and the impact on their teaching practices. Also, the researcher collected and analyzed relevant documents related to the professional development programs, teacher training materials, and teachers' lesson plans involving PhET simulations. Additionally, the researcher observed teachers using PhET simulations in the classroom to gain insights into their teaching practices.

Data Analysis

Exploring the influence of professional development initiatives on secondary mathematics and sciences teachers in Rwanda, this research tracked to analyze the efficacy of programs focused on integrating Physics Education Technology (PhET) simulations, aiming to strengthen teachers' instructional capabilities and enhance student learning outcomes through the effective use of educational technology.

These simulations provided students with hands-on, visual experiences, fostering deeper comprehension of complex scientific principles. Nonetheless, the realization of the full potential of PhET simulations in the classroom relies heavily on the competence and comfort of teachers in implementing this technology effectively. Professional development programs raised to teachers in Rwanda, therefore, play a critical role in ensuring that teachers are not only familiar with PhET simulations but also proficient in integrating them seamlessly into their curricula. However, the effectiveness of these programs in achieving this goal requires a comprehensive and data-driven evaluation. Data analysis, as the essential of this study, was critical in providing empirical evidence to guide educational policymakers, administrators, and teachers.

The findings of this research informed the design and refinement of professional development programs, contributing to the enhancement of science and mathematics education in Rwanda and potentially serving as a model for other regions facing similar challenges in integrating technology into the classroom. By closely examining the data, the researcher seeks to uncover actionable insights that will shape the future of educational practices in Rwanda and, ultimately, empower teachers to create a more effective and engaging learning environment for their students. Coding and Thematic Analysis: The qualitative data collected through interviews, observations, and documents analysis had been transcribed, coded, and analyzed using thematic analysis. Themes related to the effectiveness of professional development programs, challenges faced, and successful strategies for integrating PhET simulations were identified.

Validity and Reliability

Validity and reliability were critical considerations in this study. These concepts ensured the trustworthiness and accuracy of the research findings, allowing the researcher to draw meaningful

conclusions about the impact of professional development programs on teachers' use of PhET simulations in the classroom. Researcher shared preliminary findings with a subset of participants to verify the accuracy and authenticity of their responses. Researcher also engaged with peers in qualitative research to review the research process, analysis, and findings. Additionally, researcher combined data from interviews, observations, and document analysis to enhance the validity and reliability of the findings.

Ethical Considerations

In examining the efficacy of professional development initiatives aimed at equipping secondary mathematics and science teachers in Rwanda to effectively integrate Physics Education Technology (PhET) simulations into their classrooms, a fundamental emphasis on ethical considerations became essential, underscoring the pivotal role of upholding integrity, respect, and the well-being of teachers and students, reflected through informed consent, voluntary participation, withdrawal options, anonymized data collection, and stringent confidentiality measures to safeguard participant privacy.

Limitations of the Study

In this study, the limitations of the Study in the context of assessing the effectiveness of professional development programs for secondary mathematics and sciences teachers in Rwanda, with a specific focus on enhancing their ability to integrate Physics Education Technology (PhET) simulations into the classroom was crucial to acknowledge and understand the constraints and potential challenges that have impacted the research process and the generalizability of the study's findings. It highlighted the areas where the study has been restricted and the implications of these limitations for the interpretation of the results. It was important to acknowledge that this study had some limitations, such as the relatively small sample size and the possibility of social desirability bias in teacher responses.

FINDINGS AND DISCUSSION

It presents the results and discussion of a qualitative study conducted to assess the effectiveness of professional development programs for secondary mathematics and science teachers in Rwanda. The study focused on their ability to use the Physics Education Technology (PhET) simulations in the classroom. Data were collected through interviews, observations, and document analysis of 42 mathematics and science teachers from four selected secondary schools in Rwanda, named (T1-42). Of these participants, 18 were mathematics teachers and 24 were science teachers. The majority of participants had between 5 to 10 years of teaching experience, with 14 participants having less than 5 years of experience, 17 participants having 5-10 years of experience, and 11 participants having more than 10 years of experience. The distribution of participants across the four schools was relatively even, with 10 to 12 participants from each school.

During interviews, a majority of teachers demonstrated a clear understanding of PhET simulations and their potential in enhancing science education. Some participants voiced the following observation,

> PhET simulations are an incredible tool for enhancing science education, allowing students to hold complex concepts with ease (T12).

> PhET simulations align perfectly with the educational goals, as they empower our teachers to deliver impactful science lessons and enhance student learning outcomes (T8).

The findings suggested that the professional development programs have been successful in

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equipping teachers with the necessary knowledge to use PhET simulations effectively. The qualitative data indicated that the majority of teachers felt more prepared and confident in using PhET simulations after participating in professional development programs. They expressed increased familiarity with the platform, as well as an understanding of how to incorporate it into their lesson plans. Those taking part made the following remarks aloud:

> I'm excited to bring PhET simulations into my classroom. Thanks to the professional development program, I feel well-prepared to use them effectively (T32).
>
> The professional development program empowered me with the skills and knowledge I needed to maximize the potential of PhET simulations in my teaching (T24).
>
> The professional development equipped me with a toolbox of strategies to make the most of PhET simulations, making me feel well-prepared for the classroom (T41).

This positive shift in teacher preparedness and comfort level with PhET simulations can be attributed to the effectiveness of the professional development programs. The programs seem to have provided teachers with the necessary training and resources to navigate the technology, which aligns with the goals of such initiatives.

The study found that, the professional development programs, there was an observable increase in the frequency and quality of PhET simulations used in classroom instruction. Teachers reported that they were more inclined to incorporate these simulations into their lessons as a supplementary tool to help students grasp complex scientific concepts. Participants spoke out loud about the following items,

> I firmly believe that incorporating these simulations into our teaching approach is a great way to support our students in grasping those challenging scientific concepts (T2).
>
> In order to keep up with modern educational methods, I think we should seriously consider integrating simulations into our lessons (T5).

This shift in classroom practices reflects the successful impact of professional development programs. It suggests that these programs were able to bridge the gap between theoretical knowledge and practical implementation, ultimately benefiting both teachers and students in the process.

Despite the overall positive impact, the study also identified certain challenges. Some teachers still faced obstacles in effectively using PhET simulations. Common barriers included limited access to technology, time constraints, and a lack of appropriate resources. The items that follow were mentioned openly by participants with different accents in their voices,

> One of the common barriers I encountered is limited access to technology, and it's really unsatisfying (T1).
>
> Teaching these days is so challenging. Common barriers I see among my students include limited access to technology, time constraints, and a lack of appropriate resources (T17).
>
> Limited access to technology, time constraints, and a lack of appropriate resources are the most common barriers (T29).

These challenges underscore the need for further improvement in professional development programs. To enhance their effectiveness, programs should address these barriers, ensuring that

teachers have the necessary resources, sufficient time, and equitable access to technology.

Many teachers expressed challenges in integrating PhET simulations into the curriculum due to time constraints and the need to cover a broad syllabus. Out of forty-two teachers, two gave the following statement:

> I'm quite concerned about the time constraints we face. Our syllabus is already so extensive, and we're always struggling to cover everything within the limited hours we have. I worry that adding these simulations might leave us with less time for other essential topics (T37).
>
> I'm really excited about incorporating PhET simulations into our curriculum! These interactive tools can make complex concepts so much more engaging and understandable for our students. It might take some extra effort, but the benefits for our students are definitely value it (T42).

The study highlights a significant challenge in implementing PhET simulations effectively. The time constraints hinder teachers from using these tools to their full potential. This issue warrants further exploration and potential adjustments to the curriculum.

The qualitative data showed that teachers had varying perceptions and attitudes towards PhET simulations. While some were enthusiastic and highly motivated to utilize them, others remained skeptical or hesitant about integrating technology into their teaching practices. This divergence in teacher attitudes highlights the importance of addressing individual needs and concerns in professional development programs. Two teachers provided this argument:

> I'm absolutely excited to explore the potential of integrating technology into our teaching practices. It's a fantastic opportunity to engage our students in new and exciting ways (T21).
>
> I am deeply committed to making technology an integral part of our teaching methods. I believe it can enhance our educational outcomes (T35).

To adoptive a more inclusive and positive learning environment, personalized approaches were necessary for teachers with differing levels of comfort and enthusiasm for technology. Interviews revealed that sustaining the impact of professional development programs over time remained a challenge.

Some teachers reported a decrease in their utilization of PhET simulations as they reverted to old teaching habits. A few teachers stated:

> I've noticed that I've been using PhET simulations less and less lately. It's disappointing to see that I've slewed back into my old teaching habits (T13).
>
> As I've been teaching, I've taken some time to look at my approach, and I've realized that I've been using PhET simulations less frequently. It's important for me to address this and get back on track (T34).

This finding underscores the need for ongoing support and reinforcement. Professional development programs should consider providing continuous training and resources to ensure that teachers maintain and build upon their new skills.

A noticeable shift in pedagogical approach was observed, with teachers incorporating more interactive and student-centered teaching methods. The majority of teachers in their interviews reported that:

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> One can't help but notice the transformation in pedagogical methods, as teachers now engage students in a more interactive and student-focused manner (T4).
>
> It's quite remarkable to see how teachers have shifted towards more interactive and student-centered teaching strategies (T26).
>
> The shift towards interactive and student-centered pedagogy is clearly reflected in the way teachers now conduct their classes (T40).

This shift suggests that professional development programs have influenced teachers to adopt more student-centric teaching approaches, which align with the intended use of PhET simulations. This change may enhance students' engagement and understanding of science concepts.

Some teachers reported feeling less confident in using technology, despite their knowledge of PhET simulations. Few teachers in their voices stated the points that follow:

> I have a good understanding of PhET simulations, but I am doubting my ability to use them effectively (T16).
>
> I'm a bit hesitant when it comes to PhET simulations. I wish I felt surer about using technology in this context (T16).

This finding points to a potential gap in teacher training. While teachers may understand the educational value of PhET simulations, they might need additional support to build confidence in using technology effectively in the classroom.

Observations aligned with teacher statements about the increased use of interactive teaching methods. Observer notable a significant increase in the integration of PhET simulations into classroom lessons. Teachers demonstrated a greater willingness and ability to incorporate interactive simulations into their curriculum to illustrate complex physics and science concepts. Teachers who participated in the professional development programs appeared to have a higher level of student engagement.

Researcher noted that students were more active in the learning process, asking questions, experimenting with simulations, and discussing their findings. The observed classrooms showed a deeper conceptual understanding of physics and science concepts. Students were able to grasp complex ideas more readily, and teachers effectively used PhET simulations as a tool to visualize and explain these concepts. Teachers were observed to employ a variety of teaching strategies when using PhET simulations. These included guided inquiry, problem-solving activities, and collaborative group work, allowing for a more holistic approach to teaching and learning. There was a noticeable increase in teacher confidence when using technology and simulations in the classroom.

Teachers who were once hesitant to adopt digital tools were observed to be more comfortable with incorporating technology into their teaching methods. Teachers demonstrated the ability to customize PhET simulations to suit their specific teaching objectives and the needs of their students. This flexibility was seen as a valuable skill gained through professional development. Observers noted that teachers were more successful in aligning their lessons with the national curriculum while integrating PhET simulations. This suggested that the professional development programs were effective in helping teachers meet educational standards.

Teachers who participated also in the programs were observed to collaborate more frequently. They shared ideas, lesson plans, and resources related to PhET simulations, indicating improved teacher collaboration and knowledge sharing. While this study did not directly measure student achievement, observations indicated that the enhanced use of PhET simulations positively impacted students' ability to apply scientific principles, which may lead to improved academic performance over

time. Some teachers conveyed a desire for ongoing professional development to continue building their skills in using PhET simulations effectively. This observation suggests a need for sustained support and training.

These observation results collectively indicated that the professional development programs had a positive impact on secondary mathematics and sciences teachers in Rwanda, enhancing their ability to use PhET simulations in the classroom and, in turn, benefiting student learning and engagement. The consistency between interview responses and classroom observations suggests that the pedagogical shift observed is a genuine result of the professional development programs.

Documents reviewed indicated an increased inclusion of PhET simulations in lesson plans. The analysis of documents provided further support for the integration of PhET simulations into the curriculum. Prior to participating in the professional development programs, a baseline knowledge assessment was conducted among the 42 mathematics and sciences teachers.

The results showed that the majority of teachers had limited familiarity with PhET simulations and their effective classroom integration. Following the completion of the professional development programs, a significant improvement in teachers' knowledge and understanding of PhET simulations was observed. Teachers demonstrated a greater understanding of the software and its potential applications in the classroom.

The study found that teachers who had undergone the professional development programs were more confident and skilled in integrating PhET simulations into their teaching. They utilized various pedagogical strategies to enhance student learning and engagement. Classroom observations and student assessments revealed that the use of PhET simulations had a positive impact on student engagement and learning outcomes. Students were more motivated and showed an improved understanding of complex scientific concepts. The study identified several challenges faced by teachers in using PhET simulations, including limited access to technology, time constraints, and the need for ongoing support and resources.

The majority of teachers informed a high level of satisfaction with the professional development programs. They uttered a desire for continued support and additional resources to further enhance their teaching with PhET simulations. These results provided insights into the effectiveness of professional development programs for mathematics and sciences teachers in Rwanda, emphasizing the positive impact on their ability to integrate PhET simulations into their teaching practices. The findings also highlighted the importance of addressing challenges and providing ongoing support to sustain these improvements. It suggests that teachers are actively incorporating these resources into their teaching materials.

The results of this study were consistent with the diffusion of innovation theory, which highlights how professional development programs can speed up the diffusion process by identifying adoption barriers and developing techniques to get around them. The findings are consistent with social learning theory, which focuses on the social and observational components of learning and addresses the efficiency of professional development initiatives. Additionally, the results are consistent with those of Uwambajimana, et al. (2023), who indicated that using PhET simulation as an ICT tool boosted collaboration among students and teachers. According to these findings, students who are taught through this PhET simulation have better conceptual comprehension. Furthermore, PhET simulations establish a setting where students are able to acquire challenging topics with the aid of the simulation in order to engage and encourage them to have a deeper conceptual comprehension of the subjects.

CONCLUSION

The results of this study demonstrate that the professional development programs have had a

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positive impact on the ability of mathematics and science teachers in Rwanda to use PhET simulations in the classroom. However, challenges related to curriculum constraints and technological competence must be addressed for more effective integration. This study also sheds light on the effectiveness of professional development programs for mathematics and science teachers in Rwanda, providing valuable insights into their ability to use PhET simulations in the classroom.

RECOMMENDATION

The findings suggest the need for continued support and training for teachers, with a focus on curriculum alignment and technological proficiency. Future research should explore the long-term effects of these professional development programs on student learning outcomes.

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