Journal of Classroom Practices
Parabolum Publishing
Vol.4 (1), pp. 96-110, 2025
Doi: 10.58197/p221yn10

Available online at http://www.parabolumpublishing.org/

Type of article: Research Article

Training STEM Teachers in Resource-Constrained Environments: Are Computer-Based Technologies Effective?

Celine Byukusenge[1]*, Josiane Mukagihana[2], Emmanuel Shyaka[1], & Florien Nsanganwimana[2]

[1]Catholic University of Rwanda, Huye, Rwanda, P.O. Box 46 Butare
[2]University of Rwanda-College of Education (UR-CE), Kayonza, Rwanda, P. O. Box 55 Rwamagana

Abstract

This study investigates the effectiveness of computer-based technologies, such as computer animations and virtual labs, in enhancing STEM education, particularly in resource-constrained environments. The research focuses on pre-service biology teachers at the University of Rwanda-College of Education (UR-CE) and examines the impact of these technologies on their teaching and students' academic performance. Employing an Exploratory Sequential Mixed Methods design, the study first explores pre-service teachers' perceptions through qualitative focus group discussions and then tests hypotheses quantitatively with a quasi-experimental approach involving secondary school students. Results show that traditional teaching methods result in minimal improvement in student performance while using computer animations and virtual labs significantly enhances understanding and academic achievement. The study highlights the potential of technology to overcome the limitations of inadequate resources, making complex subjects like molecular biology more accessible and engaging. These findings suggest that integrating such technologies could be a viable strategy for improving STEM education in developing regions. Future research should explore the long-term effects of these tools on teaching efficacy and sustainable student performance in all STEM subjects.

Keywords: STEM education, Resource-constrained environments, Animations, Virtual labs, pre-service teachers

Article information

Received date: 13/05/2025;
Reviewed: 13/05/2025;
Revised date: 02/06/2025;
Accepted date: 02/06/2025

*** Corresponding author:** Celine Byukusenge (celinebyukusenge@gmail.com)

How to cite this article: Byukusenge, C., Mukagihana, J., Shyaka, E., Nsanganwimana, F. (2025) 'Training STEM Teachers in Resource-Constrained Environments: Are Computer-Based Technologies Effective?, *Journal of Classroom Practices*, 4(1), 96-110. Available at: https://doi.org/10.58197/p221yn10

Introduction

Training teachers, particularly pre-service teachers (PT), in STEM (Science, Technology, Engineering, and Mathematics) disciplines is crucial for preparing a skilled workforce for the future (Hoon et al., 2022). These future teachers must be well-equipped with the necessary knowledge and skills to effectively transfer their understanding to the next generation of students (Ahmad, Yakob, & Ahmad, 2018). The availability of various resources, such as well-equipped science laboratories and up-to-date educational materials, undoubtedly supports this process. However, in many resource-constrained environments, the lack of these critical resources poses a significant challenge to the effectiveness of teacher training programs (Ryu et al., 2019).

The absence of essential resources such as science laboratories limits hands-on learning opportunities for pre-service teachers, which are vital for deepening their understanding of scientific concepts and experimental procedures (Orhan & Sahin, 2018). This deficiency affects their training and their ability to deliver quality education to their future students (Ryu et al., 2019). Research has consistently shown that the availability of resources is a fundamental component of effective STEM education (Ejiwale, 2013).

According to Darling-Hammond et al. (2009), well-resourced learning environments provide students with better opportunities to engage in hands-on activities, critical thinking, and problem-solving, essential skills in STEM fields. However, in many developing regions, schools face severe shortages of such resources, hampering the overall quality of education (Orhan & Sahin, 2018). This challenge of providing quality STEM education due to a shortage of resources becomes even more pronounced in many Sub-Saharan African countries, making it difficult for pre-service teachers to gain the full experiences they need for their future careers (Osborne & Dillon, 2008). This training gap directly impacts their preparedness and confidence in teaching STEM subjects effectively.

To address these challenges in STEM education, computer-based technologies have been suggested as a viable solution (Aebersold et al., 2020). These technologies offer alternative ways to provide experiential learning opportunities without actual resources. For instance, virtual laboratories and Simulations can replicate the experience of performing scientific experiments, allowing pre-service teachers to practice and hone their skills in a virtual environment (Hamed &ljanazrah, 2020). Additionally, educational software and online resources like computer animations can provide access to vast information and interactive content that can enhance the learning experience (Smetana & Bell, 2012).

In Rwanda, many teacher training institutions lack basic STEM teaching tools and materials; pre-service teachers often resort to theoretical instruction without the opportunity to engage in practical experiments or use teaching aids (Mukagihana, 2022). Despite Rwanda's policy emphasizing promoting STEM education, there is still a shortage of resources to strengthen STEM education, and the research exploring how computer-based technologies can alleviate resource scarcity, specifically in training and preparing future STEM educators in the Rwandan context, is limited.

Mayer's Cognitive Theory of Multimedia Learning supported integrating technology into science education. This theory posits that individuals learn more effectively from a combination of words and images than from words alone, as it aligns with the way the human brain processes information through dual channels, visual and auditory. According to Mayer (2009), meaningful learning occurs when learners can actively select, organize, and integrate information presented in both verbal and visual formats. In the context of biology education, especially in complex areas like molecular biology and cell processes, multimedia tools such as animations, simulations, and interactive visualizations can reduce cognitive overload and enhance comprehension. By making abstract concepts more concrete, these tools support deeper learning and better retention, particularly for pre-service teachers who need strong content mastery to teach effectively.

Several studies have highlighted the potential benefits of integrating computer-based technologies into STEM education. Means et al. (2010) conducted a meta-analysis demonstrating how technology-enhanced learning environments can improve students' understanding of complex concepts and increase engagement. Similarly, McKnight et al. (2016) emphasized that technology can transform teaching practices and provide students with more interactive and meaningful learning experiences when used effectively. Research has also indicated that effective training for pre-service teachers improves their attitudes toward the subject matter, motivation, confidence, and eventual classroom practices (Yılmaz-Tüzün, 2008). Research has shown that when pre-service teachers develop favorable perceptions of teaching resources, they are more likely to adopt them for innovative methods in their future teaching, which can lead to higher student engagement and achievement (Teo, 2011; Ejiwale, 2013). Attitude shapes teachers' learning and teaching; thus, fostering positive attitudes during training is essential for preparing effective, enthusiastic educators. This study also explores how technological tools contribute to attitudinal shifts that support meaningful and sustainable teaching and learning in biology.

Objectives

1. To determine the effect of using computer animations and virtual labs on pre-service teachers' attitudes toward learning biology
2. To examine the effect of computer animations and virtual labs on students' academic achievement in biology

Research Questions

1. How does using computer animations and virtual labs affect pre-service teachers' attitudes toward learning biology?
2. How does computer animations and virtual labs affect students' academic achievement in biology?

Research Hypothesis

The use of computer animations and virtual labs in biology lessons significantly enhances students' academic achievement compared to traditional teaching methods.

Methodology

Research design and approach

In the present study, we employed an Exploratory Sequential Mixed Methods design complemented by a Quasi-Experimental approach. This methodological framework was chosen to develop and rigorously test our hypotheses regarding the effectiveness of these innovative STEM teaching tools. Initially, we began with the qualitative phase of the Exploratory Sequential Mixed Methods design. This phase involved year three pre-service teachers from UR-CE exploring their perceptions about learning biology as one of their major subjects and learning through technological tools, specifically Computer animations and virtual labs. This phase helped to gather the challenges they face during learning and teaching as prospective teachers. We also gathered their perceptions regarding using animations and virtual labs in teaching and learning biology.

Following the qualitative phase, we transitioned to the quantitative phase to test the hypotheses derived from our initial findings. For this purpose, we employed a quasi-experimental design, and this phase involved secondary school students who studied biology as a major subject. We divided the participants into an intervention group, which received training through computer animations and virtual labs, and a comparison group, which continued with traditional teaching methods. Due to the practical constraints of our research environment, random assignment was not feasible, making the Quasi-Experimental design a suitable choice. This design allowed us to compare the outcomes between the two groups and infer the causal impact of the computer animations and virtual labs on the teachers' training outcomes.

Study population and sample

In this study, the population comprised three distinct groups. First, we included pre-service biology teachers from the University of Rwanda - College of Education (UR-CE). These individuals are currently enrolled in teacher training programs and represent the future corps of biology teachers in secondary schools. Second, the study encompassed biology teachers who have graduated from UR-CE, bringing practical teaching experience and reflecting on the impact of their initial training. Third, the study extended to biology students currently being taught by these UR-CE graduates, thereby evaluating the trickle-down effects of the teachers' training on student learning outcomes.

A sample of Fifty-seven (57) pre-service biology teachers was taken purposively from UR-CE in the combination of Mathematics and Biology Education (MBE). The latter sample was used during the qualitative phase of the study. For the quantitative phase, 168 students from the combination of Mathematics, Biology, and Chemistry (MBC) participated in the study. In addition, four secondary school biology teachers contributed to teaching both the control and experimental groups, where two taught using traditional teaching methods while the other two contributed to teaching the experimental group using virtual labs and computer animations.

Research intervention topic

To investigate pre-service teachers' perceptions of biology learning and teaching and the impact of using technological tools, this study focused on molecular biology topics across both qualitative and quantitative phases. The choice of the topic took into consideration the teaching calendar, and especially the decision to concentrate on molecular biology was informed by prior research indicating that both students and teachers often find it to be one of the most challenging and abstract subjects within the biology curriculum (Byukusenge et al., 2022). In addition, the intervention focused on integrating computer animations and virtual labs as computer-based technologies to explore how these technological tools could potentially mitigate those difficulties by enhancing comprehension and making the learning process more engaging

Research instruments

This study utilized two research instruments. The first was a focus group discussion (FGD) given to pre-service teachers before and after being taught using virtual labs and animations. The latter instrument was used to gather qualitative data for the first research question. The FGD guide consisted of six primary questions, with additional questions arising from the students' responses; for instance, Students (Pre-service teachers) were asked, "How do you feel about learning molecular biology topics?" "Do you think you would also understand these molecular biology topics without the visual aids? Why or why not?". The focus group discussion explored pre-service teachers' perceptions, experiences, and attitudes toward learning molecular biology by integrating technological tools such as animations, simulations, and visualizations. The discussion aimed to understand how these tools influenced their comprehension, engagement, and motivation to learn complex topics like transcription, translation, cell division, and the viral life cycle. Participants reflected on the challenges they previously faced with traditional instruction methods and how the use of visual aids transformed their learning experiences.

The second instrument used was a biology achievement test (BAT) for the second research question, and the collected data was used to test the hypothesis set for this study. This instrument comprised fifteen Multiple choice questions (MCQs), reflecting the content of cell and molecular Biology. Each item had four answer options (A–D), targeting a range of cognitive levels from basic recall to application. For instance, the test covers key topics including DNA structure and replication (Questions 1–2), RNA and protein synthesis (Questions 3–5), Genetic engineering and biotechnology (Questions 6–7), Cell organelles and their functions (Questions 8–9, 13)

Data analysis

As the study commenced with the qualitative phase, the qualitative data analysis was conducted using Nvivo software. Pre-service teachers from the UR-CE were subjected to focus-group discussions before and after experiencing biology lessons with virtual labs and animations. The pre-intervention interviews captured their initial perceptions and expectations, while post-intervention focus group discussions provided insights into their experiences and any changes in perception. All recordings were transcribed verbatim and imported into Nvivo, where a detailed coding process identified key themes and patterns. A thematic analysis was then performed to organize the codes into broader themes, which were refined to accurately reflect the data. Comparing the themes from pre- and post-intervention data revealed shifts in the pre-service teachers' attitudes and experiences after using virtual labs and animations.

SPSS software was used to analyze the data collected during the quantitative phase to compare the performance of the control group (traditional teaching) and the experimental group (teaching through virtual labs and animations) through a mixed ANOVA. This allowed us to measure the impact of the teaching method on the pre-test and post-test results.

Results

This study explored how technological tools, such as computer animations and Virtual labs, could potentially mitigate the difficulties in preparing pre-service teachers for teaching biology, especially molecular biology, which seems challenging in resource-constrained environments. The study aimed ultimately to enhance comprehension and make the biology learning process more engaging for learners in secondary schools. The study examined pre-service teachers' perceptions before and after exposure to these tools to answer the first research question. By doing so, the study sought to provide insights into the effectiveness of these tools and identify any shifts in perceptions regarding the accessibility and understandability of molecular biology. The diagram below (Figure 1) was produced by Nvivo software and shows the frequently occurring words in pre-service teachers' responses involved in FDG. To better understand this diagram, we made the main themes and broke them into sub-themes supported by respondents' quotes extracted from the recorded discussions.

Figure 1: Word count from Nvivo

Theme 1: Challenges of Visual Learning in Molecular Biology

This theme was formed from discussions of pre-service teachers before being exposed to teaching intervention. It has two sub-themes, which are:

Memorization Without Understanding #1

Pre-service teachers in this study indicated that relying on pictures for teaching and learning concepts in molecular biology led to a superficial learning experience where they memorized steps in transcription and translation without gaining a deep understanding. They said that this memorization approach is mostly used for achieving high marks in tests and examinations rather than fostering genuine comprehension.

"*Learning through pictures alone didn't help; it made me memorize the steps of processes like transcription and translation without truly understanding them, just to score well on tests and exams. I had a basic grasp of molecular biology but never tried to visualize it, so I mainly memorized terms and processes." Said PST5*

Misconceptions from Difficulty in Visualization #2

In their discussions, visual students confirmed that they struggled to grasp molecular biology concepts through diagrams alone, as these visual aids were insufficient for accurately depicting complex molecular processes. This resulted in confusion and an inability to imagine the molecular-level activities, highlighting the limitations of traditional visual teaching methods for certain scientific topics. For instance, below are some quotes extracted from the recorded discussions

"Visually, I was very confused and couldn't imagine molecular-level processes. Although molecular biology was quite interesting, I found it challenging to understand as a visual learner since diagrams alone couldn't accurately depict the processes." Avowed PST2

"Molecular biology operates on a very small scale, so the depiction methods are often inaccurate or static, which hinders our understanding of the material. PowerPoint slides with various molecular images were not enough for me to fully grasp the complexity of molecular biology, resulting in many misconceptions." Stated PST 7

"Many PowerPoint slides are text-heavy, forcing me to visualize the molecules on my own, which was often difficult. This made my progress slow on topics related to molecular biology." PST 9 asserted ted

Theme 2: Enhanced Understanding and Engagement Through Visual Learning Tools

This major theme was generated from students' discussions about experiences while learning Biology via visualizations. The theme was subdivided into three sub-themes to clarify students' perceptions of biology and better learning through technological tools.

Improved concepts Clarity and students' Interest #1

Pre-service teachers' discussions after teaching intervention indicated that learning through visualizations made molecular biology concepts clear, transforming previously overwhelming and abstract ideas into understandable and significant knowledge. They asserted that the new teaching method deepened interest and made the sessions fascinating.

Engagement with Dynamic Animations #2

Using dynamic animations to illustrate processes like cell division greatly enhanced comprehension. This approach captivated students' interest, fostering curiosity and encouraging further exploration and learning about cellular biology.

Conceptual Grasp and Enjoyment #3

The innovative teaching methods helped students understand complex cellular functions and processes, such as the process of cell division, leading to a satisfying and enjoyable learning experience. Below are some of the students' quotations reflecting on the above theme:

"I enjoyed studying this lesson with visualizations because it made everything clear. Before, I found molecular biology concepts overwhelming and abstract. However, after using technological tools, I realized their significance. The session was fascinating and increased my interest." Said PST 4

"I loved how we used visualizations and dynamic animations to understand the process of cell division. This lesson captivated my interest and made me curious to keep exploring and learning more about cells." PST 5

"The visualization exercises improved our topic comprehension and made learning more engaging and enjoyable. The detailed views clarified molecular structures, and the animations were especially helpful for understanding processes step-by-step." PST 6

For instance, learning the life cycle of a virus through animations provided a clearer understanding of how virus DNA/RNA enters cells, replicates, and forms proteins. This method greatly aided in grasping complex processes like transcription and translation, which are difficult to understand without animations." PST 11

How do computer animations affect students' academic achievement in biology?

A comparative analysis of student's performance was done before and after the intervention to answer the second research question and test the research hypothesis. The data from the control group's performance in the biology pre-test and post-test reveal minimal changes. Initially, the majority of students (48 out of 83) scored between 26-50, with only one student reaching the highest range of 76-100 see Figure 2. In the post-test, while the number of students scoring in the lowest range (0-25) decreased from 9 to 2, the majority still scored between 26-50, and no students reached the highest range. This indicates that the traditional teaching methods led to only slight improvements in student performance, with most students maintaining their initial performance levels

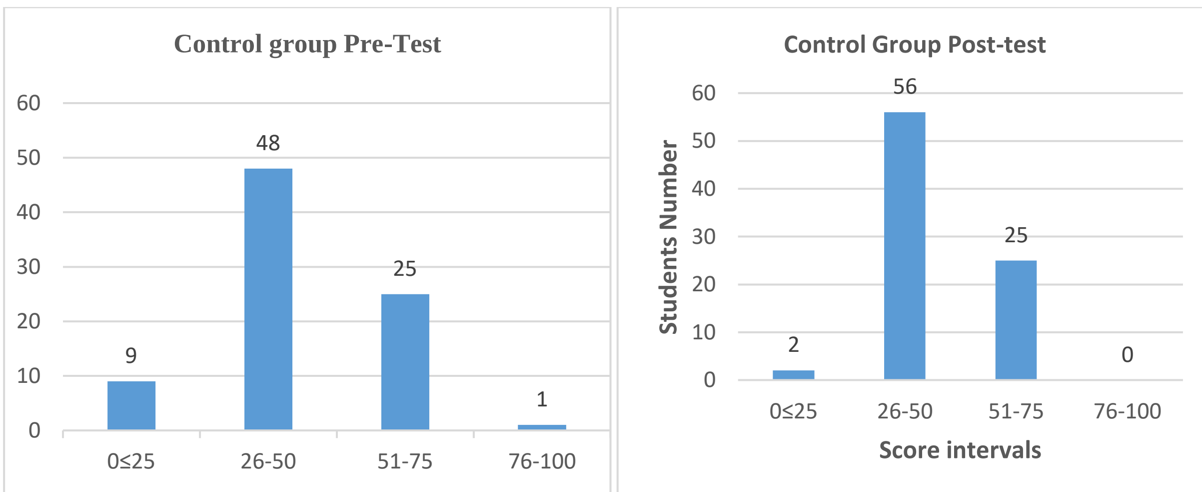

Figure 2: Performance of control group's students in biology pre and post-test

In contrast, the experimental group, which utilized Computer animation and virtual labs, showed remarkable improvement. Before the intervention, most students (55 out of 85) scored between 26-50, with a significant number (20) in the lowest range (0-25) and none in the highest range (76-100). After the intervention, no students scored in the lowest ranges, and a substantial shift occurred, with 40 students scoring between 51-75 and 45 students achieving scores in the highest range (76-100) see figure 3 below. This substantial increase in performance demonstrates the effectiveness of technology-enhanced instruction in significantly improving students' understanding and mastery of the subject matter.

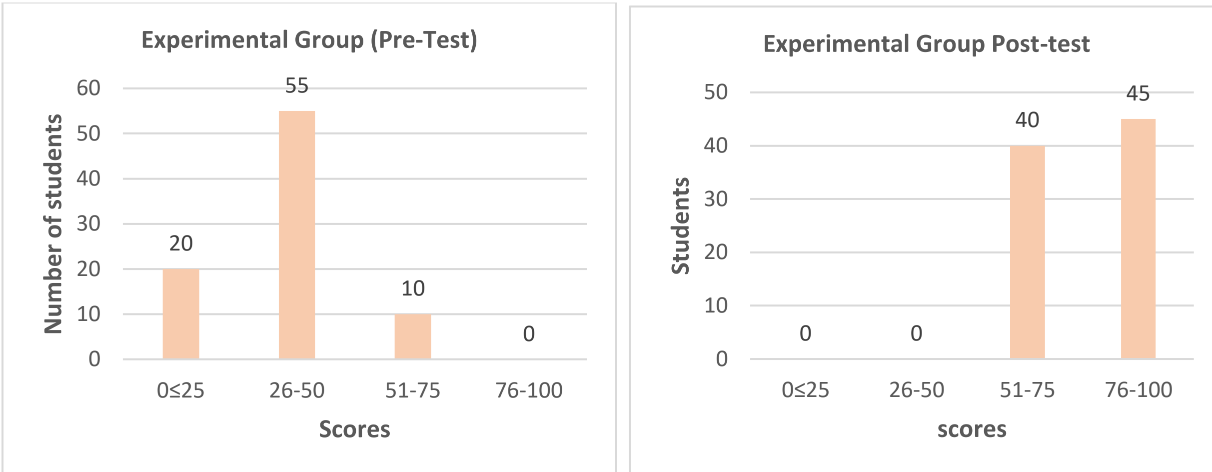

Figure 3: Performance of experimental group's students in biology pre and post-test

Testing the hypothesis

Figure 4 clearly illustrates that, at the pre-test stage, students in both the control and experimental groups were at roughly the same level, with the control group having a slightly higher mean score than the experimental group. However, following the intervention teaching, the figure shows a minimal increase in performance for the control group, whereas the experimental group exhibited a substantial gain, with a significant difference between their pre-test and post-test scores.

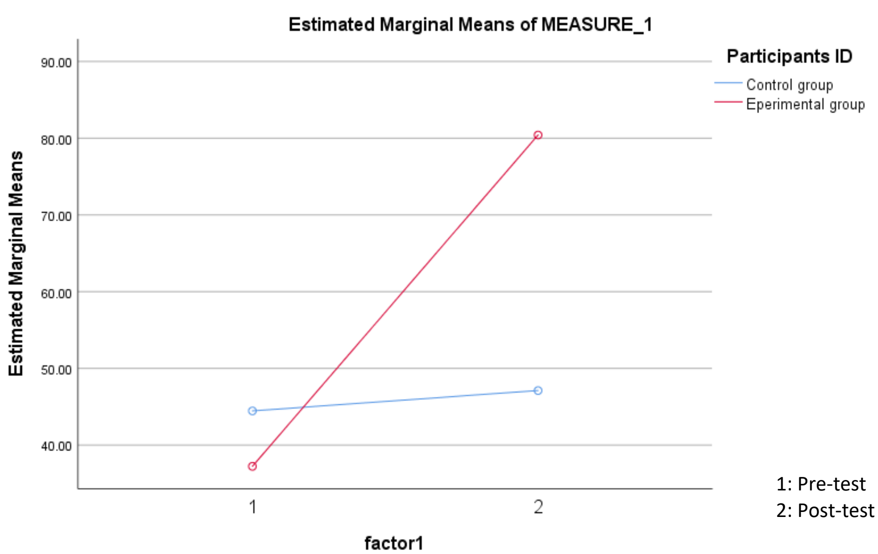

Figure 4: Estimated marginal means of performance for control and experimental in pre-and post-test

The study results showed that the experimental group, which utilized computer animation and virtual labs, had an average score of 80.41% (around 80%), while the control group had an average score of

47.11% (around 47%) With a p-value less than 0.05, this difference is statistically significant. Consequently, we retained the hypothesis, which stated that using computer animations and virtual labs in biology lessons significantly enhances students' academic achievement compared to traditional teaching methods.

Table 1: Pillai's Trace value and statistical significance

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Etha squared
factor1	Pillai's Trace	.666	330.778[b]	1.000	166.000	.000	.666
factor1 * Group	Pillai's Trace	.609	258.676[b]	1.000	166.000	.000	.609

Discussion

The findings of this study underscore the significant impact of technology-enhanced instruction, guided by Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2005), on preparing teachers, which ultimately impacts the students' academic achievement in Biology.

In this study, pre-service biology teachers highlighted the difficulties they face in biology, particularly molecular biology topics, due to the constraints on the availability of relevant teaching resources. They reported that the initial reliance on static visual aids and memorization was largely ineffective, leading to superficial learning, where concepts were memorized without deep understanding. These results follow (Nyamupangedengu, 2015), who asserted that the approach of memorization driven by the need to perform well in exams did not foster pre-service teachers' genuine comprehension of genetics concepts.

According to pre-service teachers in the present study, the difficulty in visualizing complex molecular processes through static images resulted in confusion and misconceptions, highlighting the inadequacy of traditional teaching methods for intricate biology topics. Conversely, the introduction of dynamic visualizations and animations transformed the learning experience. Pre-service teachers reported a marked improvement in clarity and interest in molecular biology concepts. "*The use of animations to illustrate processes like cell division and viral replication made abstract concepts tangible and engaging to me, leading to a deeper understanding and increased curiosity.* "*said PST 10.* These tools clarified complex processes and made learning more enjoyable, as evidenced by the students' positive feedback. These results align with Mukagihana et al. (2021), whose study' findings indicated an increased students' motivation to learn biology after being subjected to teaching intervention with computer animations. Similarly, Occa and Morgan (2022) found that learners experienced greater cognitive absorption when viewing animations than when reading brochures.

The effectiveness of technological interventions for preparing teachers has also been tested, and the performance of students taught by these teachers after their training has been tested. The students in the control group, which did not use technological tools, showed minimal improvement from pre-test to post-test scores. The control group's performance, which remained largely static, highlights the limitations of traditional teaching methods in resource-constrained environments. Despite a slight reduction in the number of students scoring in the lowest range from the pre-test to the post-test, the majority continued to perform in the mid-range (26-50), indicating that conventional methods alone are insufficient for significantly enhancing student comprehension and performance in complex subjects like biology.

In contrast, the experimental group, which utilized computer animations and virtual labs, exhibited substantial gains. In this group's shift from lower to remarkably higher score ranges, one of the most striking results was the dramatic shift in academic performance among students exposed to the intervention. The number of students scoring in the highest range (76–100) jumped from 0 to 45, underscoring the significant enhancement in understanding and mastery of molecular biology concepts facilitated by these tools. The statistical analysis confirmed that the differences in performance between the control and experimental groups were significant. The statistically significant difference between the control and experimental groups, with the experimental group's average score reaching 80.41% compared to the control group's 47.11%, further validates the hypothesis that technology-enhanced instruction substantially benefits student learning. These results are consistent with Mayer's theory, which posits that students learn more effectively when interacting with dynamic visual and auditory stimuli that help them process and integrate new information (Mayer, 2005). This study thus provides compelling evidence for adopting computer-based technologies in STEM education, particularly in environments where traditional resources are limited.

Conclusion

This study provides evidence that integrating technological tools in biology education can significantly improve pre-service teachers' comprehension and engagement and ultimately enhance students' performance in biology. These findings are particularly relevant for resource-constrained environments where traditional teaching methods fall short. The positive impact of virtual labs and animations on learning outcomes suggests that investing in such technologies could be a viable strategy to overcome educational challenges in these settings. However, it is important to acknowledge certain limitations of the study. The intervention was relatively short-term, and while the immediate effects on engagement and understanding were notable, the study does not assess the long-term retention of knowledge or the sustained impact on teaching efficacy. Additionally, the findings are based on a limited number of participants within a specific educational context, which may affect the generalizability of the results.

Future research should, therefore, aim to evaluate the long-term effects of technological integration in STEM education, including its influence on teaching practices and student outcomes over time. Longitudinal studies could provide deeper insights into how these tools affect sustained learning, instructional quality, and performance across all STEM subjects. Furthermore, exploring how to scale such interventions within national education systems would be valuable for ensuring equitable access to quality science education.

References

Ahmad, A. M., Yakob, N., & Ahmad, N. J. (2018). “Science, technology, engineering and mathematic (STEM) Education in Malaysia: Preparing the pre-service science teachers.” *Journal of Natural Science and Integration*, *1*(2), 159-165. https://doi.org/10.24014/jnsi.v1i2.6595

Aebersold, M., Rasmussen, J., & Mulrenin, T. (2020, January). “Virtual everest: Immersive virtual realitycan improve the simulation experience.” *Clinical Simulation in Nursing*, 38(C), 1-4. https://doi.org/10.1016/j.ecns.2019.09.004

Bergsten, C., Frejd, P. (2019). “Preparing pre-service mathematics teachers for STEM education: an analysis of lesson proposals.” *ZDM Mathematics Education* 51, 941–953. https://doi.org/10.1007/s11858-019-01071-7

Ejiwale, J. A. (2013). “Barriers to successful implementation of STEM education.” *Journal of Education and Learning (EduLearn)*, *7*(2), 63-74. https://doi.org/10.11591/edulearn.v7i2.220

Hamed, G.A., Ijanazrah, A. (2020). "The Effectiveness of Using Virtual Experiments on Students' Learning in the General Physics Lab." *Journal of Information Technology Education: Research*, 19 (977-996). https://doi.org/10.28945/4668

Hoon, T. S., Aris, S. R. S., Ibrahim, N., & Isa, B. (2022). "Science, technology, engineering, and mathematics (STEM) education in university: Pre-service teachers' perceptions." *Asian Journal of University Education*, *18*(3), 637-648. https://doi.org/10.24191/ajue.v18i3.18951

Galadima, U., Ismail, Z., & Ismail, N. (2019). "A new pedagogy for training the pre-service mathematics teachers readiness in teaching integrated STEM education." *International Journal of Engineering and Advanced Technology*, *8*(5), 1272-1281. https://doi.org/10.35940/ijeat.E1181.0585C19

Occa, A., & Morgan, S. E. (2022). "The role of cognitive absorption in the persuasiveness of multimedia messages." *Computers & Education*, 176. https://doi.org/10.1016/j.compedu.2021.104363

Orhan, T. Y., & Sahin, N. (2018). "The impact of innovative teaching approaches on biotechnology knowledge and laboratory experiences of science teachers." *Education Sciences*, *8*(4), 213. https://doi.org/10.3390/educsci8040213

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). "Teaching in a digital age: How educators use technology to improve student learning." *Journal of research on technology in education,* 48(3), 194-211. https://doi.org/10.1080/15391523.2016.1175856

Mayer, R. (2005). "The Cambridge handbook of multimedia learning." Cambridge, U.K. New York: Cambridge University Press.

Mukagihana, J., Nsanganwimana, F., Aurah, C. (2021). "Effect of resource-based instructions on pre-service biology teachers' motivation toward learning biology." *Lumat*, 9(1), 873-891. https://doi.org/10.31129/LUMAT.9.1.1637

Nyamupangedengu, E. (2015). "Teaching genetics to pre-service teachers: a teacher educator's approach to transformative practice through self-study" (Doctoral dissertation, University of the Witwatersrand, Faculty of Humanities, School of Education).

Ryu, M., Mentzer, N., & Knobloch, N. (2019). "Pre-service teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation." *International journal of technology and design education*, 29, 493-512. https://doi.org/10.1007/s10798-018-9440-9

Smetana, L. K., & Bell, R. L. (2012). "Computer simulations to support science instruction and learning: A critical review of the literature." *International Journal of Science Education*, 34(9), 1337-1370. https://doi.org/10.1080/09500693.2011.605182

Teo, T. (2011). "Factors influencing teachers' intention to use technology: Model development and test." *Computers & Education*, *57*(4), 2432-2440. https://doi.org/10.1016/j.compedu.2011.06.008

Yilmaz-Tuzun, O., & Topcu, M. S. (2008). "Relationships among pre-service science teachers' epistemological beliefs, epistemological world views, and self-efficacy beliefs." *International Journal of Science Education*, *30*(1), 65-85. https://doi.org/10.1007/s10972-007-9084-1