INFLUENCE OF COMPUTER SIMULATIONS ON STUDENTS' ACADEMIC PERFORMANCE IN CHEMISTRY IN SELECTED SECONDARY SCHOOLS IN KAPSERET SUB-COUNTY, KENYA

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A THESIS SUBMITTED TO THE SCHOOL OF EDUCATION, DEPARTMENT OF EDUCATION MANAGEMENT AND POLICY STUDIES IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF EDUCATION IN RESEARCH

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DECLARATION

Title: INFLUENCE OF COMPUTER SIMULATIONS ON STUDENTS' ACADEMIC PERFORMANCE IN CHEMISTRY IN SELECTED SECONDARY SCHOOLS IN KAPSERET SUB-COUNTY, KENYA

Declaration by the Candidate

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DEDICATION

I dedicate this work to my parents, Mr. Solomon Otieno Ogura and Pamela Atieno Otieno, for their unwavering love, encouragement, and support throughout my entire academic journey. Your sacrifices have not gone unnoticed; every late night spent helping me study and every moment of patience you have shown have played a crucial role in my success. Your resilience and determination have inspired me to push through challenges, and it is your belief in me that has motivated me to persevere. The achievements I celebrate today are a direct reflection of the foundation you have built for me, and I am forever thankful for all that you have done. This work is a testament to your dedication and the love that has guided me throughout my education. Thank you for being my greatest champions.

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ABSTRACT

Integrating computer simulations in education has emerged as a transformative approach to enhance the teaching and learning process, particularly in science subjects like chemistry, where abstract concepts often pose significant challenges to students. Despite increasing technology adoption in education, empirical studies reveal a gap in understanding how computer simulations influence academic performance in secondary school chemistry, especially within the Kenyan context especially in rural areas. Therefore, the purpose of this study is to examine the influence of computer simulations on students' academic performance in chemistry in selected schools in Kapseret sub-county, Kenya. The objectives of the study were to: (1) determine the differences in learners' performance in the experimental and control groups; (2) analyze gender differences in the performance of boys and girls; (3) explore students' and teachers' experiences using computer simulations in chemistry instruction; and (4) examine the support needed for successful implementation of computer simulations. Guided by Vygotsky's Constructivism Learning Theory, this Mixed methods study adopted a pragmatic paradigm and employed an embedded quasi-experimental design. The target population was 1700 Form Two students and four chemistry teachers. Purposive sampling was used to select two schools, while simple random sampling was used to select the classes in these schools, arriving at a sample size of 160 students. The chemistry teachers in the selected classes were sampled purposively, resulting in two chemistry teachers in the experimental classes. Data was collected using a chemistry achievement test, including a pretest and a posttest, questionnaires, and interviews. Quantitative data was analyzed using an independent sample t-test and Two-Way ANOVA, while qualitative data was analyzed thematically. Quantitative results showed that students taught using computer simulations significantly outperformed those in the control group, $t(158) = -9.733$, $p < .001$, indicating improved academic performance in chemistry. This difference was large and meaningful, Cohen's $d = 1.54$, suggesting a strong effect of the intervention. Gender had no significant effect, $F(1,156) = 0.065$, $p = .799$, nor did the interaction between gender and teaching method, $F(1,156) = 0.007$, $p = .932$, suggesting that the instructional benefits of computer simulations were consistent across both genders. The qualitative findings revealed that students experienced high engagement, motivation, and improved understanding of chemistry concepts. Teachers reported better student participation and found simulations helpful in explaining abstract topics. However, limited Information Communication and Technology (ICT) infrastructure, poor internet access, and lack of training were key barriers to effective implementation of the computer simulations. The study concluded that computer simulations significantly improved students' performance in chemistry, regardless of gender, enhanced learner engagement and improved understanding of chemistry concepts. Both students and teachers responded positively to the approach. However, effective implementation depends on adequate ICT infrastructure, teacher training, and institutional support. The study recommends targeted teacher training focused on simulation tools, strategic investment in ICT infrastructure particularly in rural areas, and revision of curriculum guidelines to explicitly support simulation-based teaching.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ICT – Information and Communication Technology

KCSE – Kenya Certificate of Secondary Education

KNEC – Kenya National Examinations Council

MOE – Ministry of Education

PhET – Physics Education Technology

SPSS – Statistical Package for Social Sciences

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 Introduction to the Chapter Contents

This chapter is composed of the background of the study, statement of the problem, purpose of the study, objectives of the study, research hypothesis, research questions, justification of the study, significance of the study, scope of the study, assumptions of the study, theoretical framework, conceptual framework and operational definition of terms.

1.2 Background of the Study

Computer simulation is creating models to represent an abstract system using a computer (Durán, 2018). This allows for an engaging activity on the abstract content, which would be impossible in an ordinary laboratory and classroom experience. Computer simulation is a method that employs computer programs to replicate real-world scenarios. It should mimic the system's internal processes, not just the outcomes of the modelled system (Durán, 2018). Computer simulations can represent concepts typically unseen in chemistry, such as protons, neutrons, and electrons, making it easier for learners to visualise and understand (Bennett & Boesdorfer, 2020). An example of a free simulation is Physics Education Technology (PhET) Interactive Simulations, developed at the University of Colorado Boulder. PhET simulations offer dynamic access to various representations, reveal hidden processes, support inquiry, and enable safe and quick trials, making them engaging and enjoyable for both students and teachers. These simulations are easily accessible online and are designed as flexible tools suitable for diverse teaching methods and learning environments (Moore et al., 2014).

Numerous studies suggest that students find it challenging to grasp abstract chemistry concepts such as atomic structure and bonding when taught via conventional methods (Eliphas & Shumba, 2019; Koomson et al., 2020; Dunn & Ramnarain, 2020; Tuyuzare & Yadav, 2023; Nasabayezu, 2023). This suggests that teachers should employ alternative teaching methods; otherwise, learners will struggle to comprehend these abstract concepts, resulting in poor performance in the subject.

PhET interactive simulations have been studied in various places around the globe. According to a study by Salame and Makki (2021) in the United States, PhET interactive simulations had a positive influence on students' perceptions and attitudes towards learning general chemistry. The study also found that these simulations promote the development of students' conceptual understanding of chemical content and concepts. PhET simulations motivate students and help them understand abstract concepts in chemistry that are difficult to grasp in a physical laboratory (Salame & Makki, 2021). Additionally, reports indicate that PhET simulations provide students with an enjoyable and autonomous experience, enhance positive attitudes towards chemistry, and foster the ability to visualise, thereby developing conceptual understanding.

Another study conducted in Turkey by Cayvaz et al. (2020), which compared simulation-based and textbook-based instruction on middle school students' achievement, inquiry skills, and attitudes, found that simulation-based instruction is significantly effective in enhancing students' science achievement and inquiry skills. The study also reported that simulation alone cannot be used independently but should be combined with other hands-on instructional methods, such as conducting physical experiments in the lab. Furthermore, simulation-based instruction makes learning science more engaging and accessible for students to understand complex concepts. However, the study noted that students' attitudes were not significantly affected, as attitudes are influenced by multiple factors, including the teacher's role, learning environment, motivation toward science, and student self-esteem. Furthermore, simulation can effectively teach subjects involving unobservable entities, such as the particulate nature of matter and astronomy (Cayvaz et al., 2020).

In the Philippines, Yunzal and Casinillo (2020) studied the effect of PhET simulations on students' academic performance. The study revealed a slight improvement in students' academic performance. This indicates that teaching should incorporate simulations to enhance overall academic performance in chemistry.

In Pakistan, Bibi and Nawaz (2020) examined the effect of emerging technology on students' secondary academic achievement. The study found that students' achievement after utilizing emerging technology was satisfactory. The findings also recommended that teachers employ emerging technology, such as animation and simulation, to foster students' interest in the subject for optimal teaching and learning outcomes. Similarly, Jabeen and Afzal (2020) investigated the impact of simulated chemistry practicals on students' performance at the secondary school level. This study demonstrated a significant difference between the performance of students taught through conventional laboratory demonstration and those facilitated by simulations.

Ojalade et al. (2021) investigated the impact of three-dimensional computer simulations on the academic achievement of secondary school students in chemistry. They discovered a significant difference in the achievement scores of students taught chemistry with the aid of three-dimensional computer simulations compared to their counterparts in the control group. This suggests that the use of three-dimensional simulations enhances academic achievement when integrated into classroom instruction.

In Rwanda, Byusa et al. (2022) investigated the impact of game-based learning on students' motivation and understanding of chemistry concepts. The study found that educational games enhance students' conceptual understanding of abstract concepts in chemistry while increasing their motivation to engage with the material and make sense of it. PhET simulations contribute to this motivational effect, as they include built-in games designed to help learners grasp abstract and fundamental topics in chemistry, such as atomic structure and chemical bonding.

In Kenya, Cheruiyot (2019) examined the influence of a computer-assisted teaching strategy on students' academic achievement and motivation in biology within public schools in Baringo County. The study concluded that incorporating computer-assisted teaching enhances students' achievements in biology. Furthermore, the motivation of students toward biology was positively affected by computer-aided instruction. Incorporating technology, such as computer-aided teaching and simulations, can enhance students' academic performance and increase their motivation to engage with the subject matter. Chumba et al. (2020) investigated the impact of computer simulations on students' academic achievement in physics in Ainamoi Sub-County, Kericho County, secondary schools. The study reported a statistically significant relationship between the use of computer simulations and students' attitudes towards physics lessons. Moreover, students' academic achievement improved following the use of computer simulations. The study recommended integrating computer simulations into the curriculum, as they promote positive attitudes and enhance learners' academic achievement.

Atomic structure forms a foundation for chemistry, and the knowledge gained in this topic is essential for understanding more advanced topics in the field. Consequently, a lack of comprehension of this foundational subject may hinder the student's academic success.

Technology is constantly evolving, and each new day brings innovative ideas. This trend is evident in the education sector, where information communication technology (ICT) is being integrated into schools. Performance in Chemistry is generally low in Kapseret Sub-County, with a mean score of D- (minus), as reported by the Kenya National Examination Council in 2022 (KNEC, 2023). While it may be easy to blame the students, teachers must also enhance their teaching methods to enable effective teaching and learning.

Computer simulations have a significant impact on students' academic achievement, retention, and motivation. However, none of the studies address fundamental chemistry topics such as atomic structure. Students need a strong foundation to comprehend other chemistry subjects, such as the Mole concept, which relies on knowledge of atomic structure.

According to data from the Kapseret Sub-County director of education, Chemistry has consistently recorded the lowest mean marks compared to Mathematics, Physics, and Biology. Thus, action must be taken to improve chemistry performance to match that of other sciences.

Table 1 Candidates' K.C.S.E Mean Marks in Sciences (2018-2022).

Subject	Year				
	2018	**2019**	**2020**	**2021**	**2022**
Physics	68.54	65.18	71.03	59.39	66.12
Biology	51.38	49.87	53.03	57.01	57.37
Chemistry	53.76	52.17	45.01	42.02	48.05
Mathematics	52.88	55.08	36.72	40.04	30.38

Source: ***Kenya National Examinations Council (KNEC, 2023)***

The chemistry performance of public schools in Kapseret Subcounty is dismal. The table below shows the science performance for 17 public schools in Kapseret Sub- County.

Table 2 Candidates' K.C.S.E Mean Scores in Science Subjects in Kapseret Sub-County (2018-2021).

Subject	Year			
	2018	**2019**	**2020**	**2021**
Physics	2.840	2.948	3.199	2.560
Biology	2.285	2.554	2.337	2.522
Chemistry	2.331	2.203	1.815	1.866
Mathematics	2.244	2.406	2.042	2.136

Source: Sub-County Director of Education (2023)

Several studies have demonstrated that ineffective teaching methods lead to subpar performance in chemistry (Berhe et al., 2024). Studies also show that poor pedagogical strategies are still in use in most secondary schools, despite advancements in technology and the availability of Information and communication technologies, such as computers, which can benefit teaching and learning. This may be because many teachers lack adequate skills to fully integrate ICT in teaching and learning (Ngao et al., 2022).

The integration of computer technology in Kenyan classrooms aligns with the Ministry of Education’s ICT Policy for Education and Training (Republic of Kenya, 2019), which advocates for the use of digital resources to enhance instructional delivery. Furthermore, the Kenya Institute of Curriculum Development (KICD) Chemistry Syllabus (2017) emphasizes learner-centered approaches and digital integration in science instruction. This study responds to these policy directions by examining the role of computer simulations in improving chemistry learning outcomes.

This study contributes directly to Kenya Vision 2030’s goal of improving science, technology, and innovation through quality education. It also supports Sustainable Development Goal 4, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

This study is based on the premise that computer simulations can enhance the understanding of abstract concepts in chemistry, particularly in core topics such as atomic structure. However, it depends on teachers' technological knowledge to facilitate teaching and learning.

1.3 Statement of the Problem

Integrating innovative instructional methods, such as computer simulations, effectively enhances students' understanding of fundamental chemistry concepts like atomic structure, resulting in improved academic performance and greater interest in STEM-related careers among learners in Kapseret Sub-County. As reported by the sub-county director of education, Chemistry's academic performance in KCSE examinations in Kapseret Sub-County has consistently been low, with an average mean score of 2.05, lagging behind other science and mathematics subjects. This poor performance may be attributed to the use of poor pedagogical techniques by most teachers (Chand et al., 2021). The persistent decline in performance in chemistry raises significant concern, given its critical role in enabling learners to pursue STEM-related careers such as medicine, nursing, and engineering, which are vital for societal and national development.

Research indicates that conventional teaching methods struggle to convey the abstract nature of fundamental chemistry concepts effectively (Bernardi & Pazinato, 2022). Conversely, innovative technologies, such as computer simulations, have demonstrated the potential to enhance student engagement, foster positive attitudes, and improve academic performance in chemistry (Almasri, 2022). While prior studies have examined computer simulations in science education, there is limited research on their application in chemistry instruction, particularly in teaching atomic structure. Previous research in Kenya (e.g., Cheruiyot, 2019; Chumba et al., 2020) has shown that integrating technology in science teaching improves learners' motivation and achievement. However, most of these studies focused on biology and physics, with limited attention to chemistry and the use of simulation tools for abstract topics like atomic structure. This study addresses that gap by specifically examining how computer simulations influence chemistry learning outcomes in secondary schools in Kapseret Sub-County.

To address this gap, this study investigated the influence of computer simulations on students' academic performance in chemistry, with a focus on atomic structure in Kapseret Sub-County, Kenya. By examining this innovative instructional approach, the study aimed to provide evidence-based recommendations for improving chemistry teaching and learning outcomes.

1.4 Purpose of the Study

The purpose of this study was to examine the influence of computer simulations on students' academic performance in chemistry in selected secondary schools in Kapseret Sub-County, Kenya.

1.5 Objectives of the Study

i. To determine differences in learners' performance in the experimental and control groups in selected schools in Kapseret Sub-County.
ii. To analyse the difference between the performance of boys and girls in the experimental and control groups in selected schools in Kapseret Sub-County.
iii. To assess the perceptions and experiences of students and teachers regarding the use of computer simulations in chemistry instruction in selected schools in Kapseret Sub-County.
iv. To explore the support strategies teachers need to effectively implement computer simulations in chemistry teaching in selected schools in Kapseret Sub-County.

1.6 Research Questions

i. What are the perceptions and experiences of students and teachers regarding the use of computer simulations in chemistry instruction in selected schools in Kapseret Sub-County?
ii. What support do teachers provide for the successful implementation of computer simulations in selected schools in Kapseret Sub-County?

1.7 Research Hypotheses

i. **H_{01}:** There is no significant difference in the academic performance between learners in the control group and the experimental group in selected schools in the Kapseret Sub-County.

ii. **H_{02}:** There is no significant difference in the academic performance between boys and girls in the control and experimental groups in selected Kapseret Sub-County schools.

1.8 Justification of the Study

As a foundational science, chemistry fosters analytical, innovative, and problem-solving abilities, supporting Kenya's Vision 2030 and Africa's Vision 2063. Not addressing the performance gap may lead to fewer students entering STEM fields, heightening dependency and worsening unemployment rates. It impedes progress toward Sustainable Development Goal 4, which seeks to provide inclusive and equitable quality education.

This study was warranted by the need to improve chemistry instruction and learning, especially regarding atomic structure, through innovative and effective techniques. Incorporating computer simulations into chemistry education represents a contemporary approach that aligns with global educational trends. Despite the worldwide emphasis on technology in education, there is a notable deficiency in research and application regarding using computer simulations in teaching within Kapseret Sub-County. Moreover, the results could enrich the broader discussion on the effectiveness of computer simulations in improving educational outcomes in developing areas.

1.9 Significance of the Study

This study sought to identify effective teaching strategies grounded in evidence, enabling teachers to clarify intricate concepts such as atomic structure for their students.

This study is significant in several ways, each linked to its specific objectives:

Determining differences in learners' performance between experimental and control groups provides empirical evidence on the effectiveness of computer simulations in improving academic achievement in chemistry.

Analyzing gender differences in performance helps identify whether computer simulations promote equitable learning outcomes across male and female students.

Exploring students' and teachers' perceptions and experiences offers insights into the usability, engagement level, and acceptability of computer simulations as instructional tools.

Examining teacher support needs contributes to the development of practical strategies and policy recommendations for successful implementation of computer simulations in secondary school chemistry teaching.

Collectively, these findings are expected to inform educational policy, teacher professional development, and the integration of ICT in the Kenyan secondary school curriculum.

Moreover, the findings informed educational policymakers about the advantages and challenges of using computer simulations, possibly resulting in improved curricula that utilized these technological tools. The research also aimed to illustrate how technology could boost student engagement and interest in chemistry, ultimately enhancing educational outcomes. Additionally, the study informed the design of professional development programs, equipping teachers with the skills needed to integrate technology into their teaching effectively.

1.10 Assumptions of the Study

This study was based on several key assumptions. Firstly, it was assumed that the participating teachers possessed a foundational understanding of computer simulations and their potential applications in chemistry education. Additionally, it was presumed that the selected schools had the necessary infrastructure, including computers and reliable internet access, to support the use of computer simulations. The participants were also expected to provide honest and accurate responses regarding their experiences and perceptions of integrating computer simulations into their teaching practices. Furthermore, the study assumed that the use of the analytical tools, namely, a pretest and posttest, a questionnaire, and online interviews, would effectively measure the impact of computer simulations. Specifically, it was assumed that these tools would accurately capture changes in student engagement and learning outcomes related to teaching atomic structure, thereby providing valid insights into the effectiveness of the intervention.

1.11 Scope of the Study

This study focused on examining the influence of computer simulations on students' academic performance in chemistry within selected secondary schools in Kapseret Sub-County, Uasin Gishu County, Kenya. The investigation was delimited by its specific content focus on chemistry education, its target population of Form Two students and chemistry teachers, its geographical coverage within Kapseret Sub-County. The study was conducted between January and May 2025, covering approximately five months of data collection and intervention implementation. The study specifically explored four key areas: the differences in academic performance between students taught using computer simulations (experimental group) and those taught through conventional methods (control group); the gender-based differences in performance within these groups; students' and teachers' perceptions and experiences with the use of computer simulations in chemistry instruction; and the kinds of support teachers need to effectively implement computer simulations in the classroom.

Methodologically, the study adopted a mixed-methods approach, guided by a pragmatic paradigm. An embedded quasi-experimental design was used, combining quantitative and qualitative data collection and analysis. Quantitative data were obtained using pretests and posttests of a chemistry achievement test and analyzed using independent sample t-tests and Two-Way ANOVA to measure performance differences. Qualitative data were gathered through student questionnaires and semi-structured teacher interviews and analyzed thematically to understand user experiences and contextual challenges.

The research was limited to two purposively selected public secondary schools in the sub-county that had the necessary infrastructure, like electricity, computers, and a stable internet connection. A sample of 160 Form Two students and two chemistry teachers participated in the study. The selected schools reflect typical resource and infrastructural conditions found in many rural Kenyan settings, where challenges such as limited access to digital tools and internet connectivity are common.

The study period spanned the second and third terms of the 2024 academic year, providing a structured window for intervention implementation, data collection, and analysis. This timeframe allowed for adequate exposure to the computer simulation-based instruction and meaningful assessment of its effects on students' performance and engagement.

1.12 Limitations of the Study

This study acknowledges several limitations that may have influenced the results. Efforts were made to mitigate these limitations as follows:

i. Use of Intact Classes for Group Allocation: Students were assigned to experimental and control groups based on intact class groupings, rather than through individual randomization. This was due to administrative and scheduling constraints in the participating schools. To reduce potential bias, streams were selected based on comparable academic performance records, and the same teacher taught both groups within each school to maintain consistency in instructional delivery.

ii. Gender Imbalance Among Teachers: Three of the four participating chemistry teachers were female. While this reflects the staffing reality of the selected schools, teaching responsibilities were balanced so that each teacher handled both control and experimental classes and taught students of both genders. This approach helped reduce the likelihood of teacher gender having a systematic effect on the outcomes.

iii. Reliance on Self-Reported Data: Part of the study relied on self-reported information collected through questionnaires and interviews, which could be influenced by participants' personal biases or perceptions. To mitigate this limitation, self-reported data were triangulated with objective measures such as standardized chemistry achievement tests. This combination of data sources provided a more reliable and comprehensive understanding of the effects of the intervention.

iv. Limited Generalizability of Findings: The use of purposive sampling and a relatively small sample size limits the generalizability of the findings to a broader population. The study was conducted in two mixed-day secondary schools with specific infrastructural readiness, which may not represent the diversity of schools in the region. As such, the findings should be interpreted within the context of the selected schools. However, the detailed documentation of procedures and context enhances the potential for replication in similar educational settings.

1.13 Theoretical Framework

The study was guided by Constructivist Learning Theory. The theory serves as a profound theoretical framework that emphasizes the active role of learners in constructing their understanding and knowledge of the world. Originally proposed by the eminent psychologist Jean Piaget in the early 20th century, this theory highlights that learners do not absorb information passively; rather, they engage with their environment, reflect on their experiences, and systematically build their knowledge base. Piaget's groundbreaking work focused on how children develop cognitive abilities through stages, with each stage representing a unique way of understanding the world around them. This progression underscores the iterative nature of learning, wherein experiences serve as building blocks for more advanced understanding.

Expanding upon Piaget's foundational principles, the Russian psychologist Lev Vygotsky introduced critical elements of social learning and interaction during the 1960s, which further enriched the constructivist perspective. Vygotsky emphasized that learning is inherently a social process, situating individual cognitive development within the broader context of social relations and cultural practices. He introduced the concept of the "Zone of Proximal Development" (ZPD), which identifies the difference between what learners can achieve independently and what they can achieve with guidance from more knowledgeable peers or adults. This theoretical framework champions the importance of collaborative learning and highlights the significance of language and dialogue in the learning process. Vygotsky's insights underscore that social interaction is not merely supplementary to individual learning; instead, it is a central component that enhances cognitive development.

At the heart of constructivist learning are several fundamental tenets, each contributing to a comprehensive understanding of the learning process. One of the core principles is Active Learning, which posits that learners must actively engage in the process of knowledge acquisition. This goes beyond conventional methods of education, where students receive information passively through lectures or rote memorization. Active Learning encourages hands-on experiences, experimentation, and exploration, leading to deeper comprehension and retention of knowledge. By participating in learning activities that require them to think critically and solve problems, learners develop a stronger, more integrated understanding of concepts.

Another crucial element is the recognition of Prior Knowledge. Constructivist theory asserts that new learning is profoundly influenced by what a learner already knows. Each individual comes to the learning environment with a unique set of experiences, background knowledge, and preconceived notions. As such, educators must consider these factors when designing instructional approaches. By building on existing knowledge and connecting new information to prior experiences, educators can facilitate deeper learning and understanding.

Additionally, Social Interaction plays a vital role within this learning framework. Vygotsky illustrated that through interaction with peers, learners can share perspectives, challenge each other's ideas, and collaboratively construct meaning. This social aspect of learning not only enhances cognitive skills but also fosters a sense of community among learners. Group discussions, peer teaching, and collaborative projects create environments where diverse viewpoints can be explored, enriching the learning experience for all participants.

Problem-solving is another significant component of constructivist learning. Constructivist theorists advocate for an educational approach that engages students in solving complex, real-world problems. This strategy develops both problem-solving and critical thinking skills, empowering learners to analyze situations, evaluate options, and devise solutions based on evidence. A constructivist classroom often presents students with open-ended questions and scenarios, encouraging them to draw from their experiences and knowledge while applying creative and analytical thought.

The concept of Scaffolding is integral to supporting learners in achieving higher levels of understanding. Scaffolding refers to the various supportive structures that educators can provide to assist learners in progressing through their learning journey. This could involve breaking tasks into smaller, manageable components, providing guidance or prompts, and gradually reducing support as learners gain confidence and competence. As students become more proficient, the role of the educator shifts from being a direct instructor to that of a facilitator who encourages independence and self-directed learning.

In applying Constructivist Learning Theory to contemporary education, computer simulations emerge as a powerful tool that aligns with its principles. These simulations create interactive environments where students can engage with content dynamically. For instance, in science education, computer simulations allow students to visualize atomic structures and chemical reactions in ways that conventional textbooks cannot. This hands-on, experiential learning enables students to experiment and manipulate variables, fostering a deeper understanding of complex scientific concepts.

The study conducted to investigate the impact of these interactive constructivist tools highlighted the efficacy of computer simulations in enhancing learning outcomes. By comparing the performance of an experimental group that utilized these simulations with that of a control group instructed through conventional teaching methods, the results revealed a significant improvement in the experimental group's comprehension and retention of content. This suggests that when learners are provided with opportunities to engage actively and interactively with their learning materials, they are more likely to achieve meaningful educational outcomes.

Constructivist Learning Theory provides a theoretical framework for understanding how knowledge is constructed and informs practical approaches to teaching and learning. By emphasizing active participation, recognizing the influence of prior knowledge, fostering social interaction, promoting problem-solving skills, and incorporating scaffolding techniques, educators can create enriched learning environments that cater to the diverse needs of learners. Furthermore, integrating technology, such as computer simulations, reinforces the relevance of constructivist principles in contemporary education and highlights the transformative potential of these strategies in enhancing learning outcomes across various disciplines. The implications of this theory extend beyond the classroom, encouraging lifelong learning and fostering critical thinking skills that prepare individuals to navigate an increasingly complex world.

1.13 Conceptual Framework

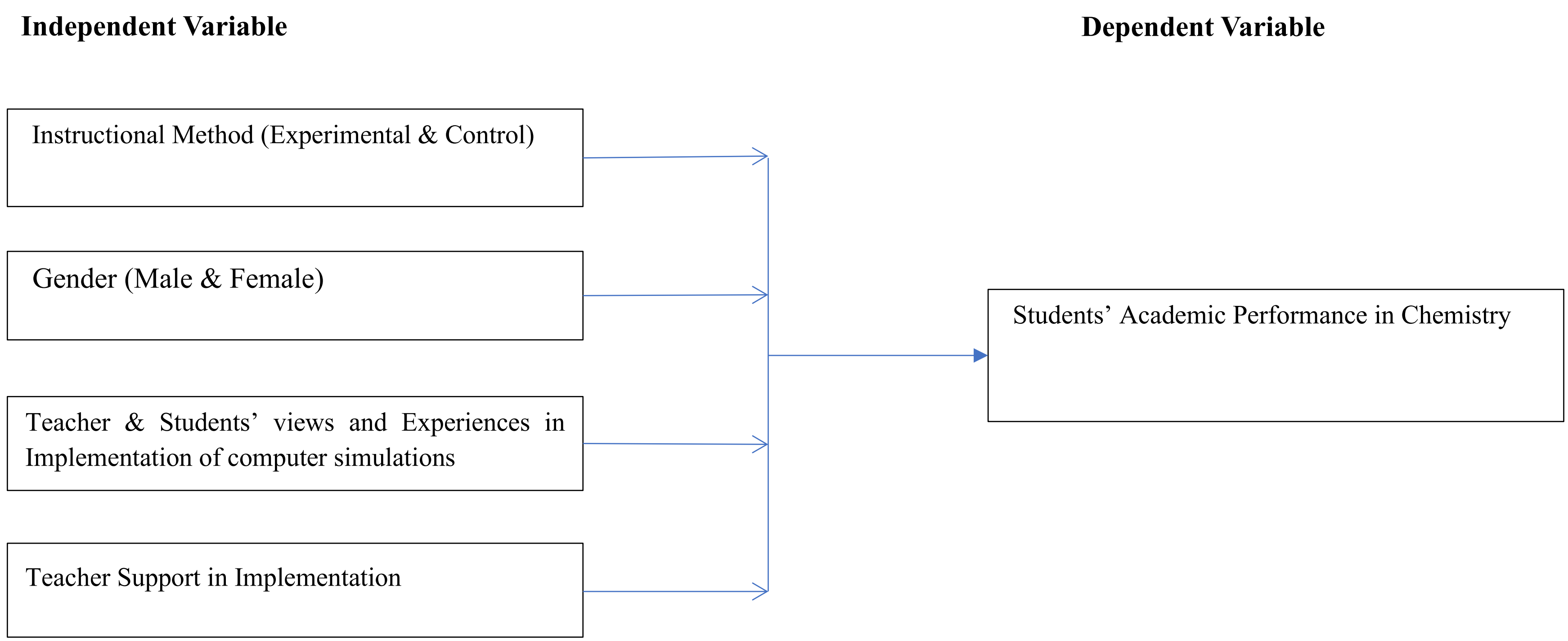

Figure 1 Conceptual framework (Researcher, 2024)

The conceptual framework shown in Figure 1 illustrates the relationship between the independent and dependent variables that guided the investigation into the influence of computer simulations on students' academic performance in chemistry. The dependent variable in this study is students' academic performance in chemistry, which was measured using mean scores derived from a pretest and posttest Chemistry Achievement Test administered to both experimental and control groups. In addition, teacher-related factors such as gender, teaching experience, and qualification were controlled to minimise potential bias in student outcomes.

The independent variables include the instructional method, gender, teacher and student experiences with computer simulations, and teacher support in implementation. Instructional method refers to whether students were taught using computer simulations (experimental group) or conventional teaching methods (control group). This variable was central to the study's aim of determining the effectiveness of simulations in enhancing conceptual understanding and learning outcomes in chemistry.

Gender was included to examine whether the use of computer simulations affects boys and girls differently in terms of academic performance. The study specifically assessed whether simulations support gender-equitable learning in science. The views and experiences of teachers and students in the implementation of computer simulations were also considered as an independent variable. This encompassed students' engagement, motivation, and perceived ease of use, as well as teachers' observations of student participation and their own instructional practices. These perceptions provided context to the quantitative results and helped explain the effectiveness of simulations in real classroom settings.

Lastly, teacher support in implementation refers to the availability of professional development, digital infrastructure, and institutional backing necessary for the effective integration of simulations in instruction. This includes access to functioning equipment, technical assistance, and curriculum alignment.

Together, these variables interact to influence students' academic outcomes. The framework helped shape the study's objectives, informed the design of data collection tools, and provided a structure for analyzing how different instructional and contextual factors contribute to learning performance in chemistry.

1.14 Operational Definition of Key Terms

Academic Performance: How well students do in their chemistry studies, measured by the change in their test scores before and after the new teaching method. Academic performance can be assessed by examining the improvement in students' test scores from the pre-test to the post-test, providing a clear picture of their learning progress. It was measured through pretest and posttest mean scores, generating quantitative data analysed using t-tests and ANOVA.

Computer Simulations: Interactive software tools (PhET simulations) used to teach chemistry concepts; measured by presence/absence of treatment (categorical variable).

Perceptions and Experiences: Participants' views and feelings toward using computer simulations, captured through questionnaire and interview responses (qualitative data).

Teacher Support: The institutional, technical, and professional assistance provided to facilitate computer simulation use, captured qualitatively through interviews.

Control Group: This group of students will continue with their usual chemistry lessons without the new computer simulations. The control group sticks with conventional teaching methods, helping us see if any changes in the experimental group are due to the computer simulations and not other factors.

Experimental Group: Students will use computer simulations to learn chemistry. They will test the new computer simulations to see if they help improve their chemistry learning compared to conventional teaching methods.

Gender: Information about whether a student is male or female. Gender information will be used to check for differences in learning improvements between boys and girls, helping us understand if the new method works equally well for everyone.

Post-test: A quiz given to students after they have experienced the new teaching method to see what they have learned. The post-test allows us to see the effectiveness of the new teaching method by comparing the scores with the pre-test results, showing how much the students' chemistry knowledge improved.

Pre-test: A quiz given to students before starting the new teaching method to see what they already know about chemistry. The pre-test helps to understand each student's starting point in chemistry, showing us their initial knowledge and skills before introducing the new computer simulations.

Support: Support refers to the resources, assistance, encouragement, or facilitation provided by stakeholders (e.g., school administration, government, parents, or peers) to enable or improve the implementation of a particular intervention or practice.

Influence: The measurable effect that computer simulations have on students' academic performance in chemistry as determined through statistical analysis of pretest and posttest scores.

Chemistry: A science subject in the secondary school curriculum dealing with matter, its composition, properties, and changes.

Perceptions: Learners' and teachers' attitudes, beliefs, and opinions toward the use of computer simulations in teaching and learning chemistry.

Experiences: The actual interactions, challenges, and observations encountered by learners and teachers while using computer simulations during instruction.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents the computer simulations and students' performance, gender and academic performance in the treatment group, students' experiences with computer simulations, teachers' experiences with computer simulations and a critical review of the literature and the gaps therein.

2.2 The Secondary School Chemistry Curriculum in Kenya

The secondary school chemistry curriculum in Kenya is designed and regulated by the Kenya Institute of Curriculum Development (KICD). The syllabus emphasises the acquisition of scientific knowledge, practical skills, and positive attitudes that enable learners to apply chemistry concepts to real-life situations (KICD, 2017).

The general objectives of teaching chemistry are to:

1. Promote understanding of fundamental chemical principles and their applications in daily life;
2. Develop problem-solving, analytical, and practical skills through experimentation;
3. Stimulate interest in science-related careers and technological innovation; and
4. Encourage responsible attitudes toward the environment and safety in handling chemicals.

Recommended teaching methods include inquiry-based learning, demonstrations, problem-solving, and the use of information and communication technology (ICT) resources such as virtual laboratories and simulations. The curriculum recognizes ICT as a catalyst for improving learner engagement and conceptual understanding, aligning with the Ministry of Education's ICT Policy (Republic of Kenya, 2019).

In practice, however, integration of ICT in chemistry lessons remains limited by inadequate infrastructure, teacher preparedness, and access to digital content. The current study, therefore, investigates how computer simulations, an emerging ICT-based strategy, can enhance academic performance and motivation in secondary school chemistry.

Globally and nationally, there is a growing emphasis on ICT integration in STEM education. In Kenya, initiatives such as the Digital Literacy Programme and the National ICT Master Plan (2022) aim to promote digital pedagogy across subjects. In chemistry, computer simulations provide opportunities for learners to visualize microscopic phenomena and conduct virtual experiments that may be unsafe or costly in physical laboratories.

2.3 Computer Simulations and Students' Performance

In the evolving landscape of education, integrating new technologies has emerged as a pivotal factor in enhancing teaching and learning experiences across various disciplines. Computer simulations, particularly, have gained traction as effective pedagogical tools, particularly in science education. This review critically examines the efficacy of computer simulations in teaching chemistry, drawing on a wealth of recent research that underscores their potential to revolutionise the educational process.

The integration of computer simulations in science education, particularly chemistry, has garnered considerable attention due to its potential to enhance students' academic performance. As global education systems shift toward more technology-enhanced learning environments, computer simulations have emerged as transformative tools that can improve conceptual understanding, engagement, and learner outcomes.

Computer simulations are digital representations of real-world or hypothetical phenomena that allow students to manipulate variables and observe outcomes in a controlled, repeatable, and often visual environment. Rooted in constructivist learning theory, simulations promote active learning by enabling students to construct knowledge through exploration and experimentation (Piaget, 1950; Vygotsky, 1978). According to Mayer (2009), multimedia learning tools such as simulations facilitate the dual coding of information, visually and verbally, thereby improving retention and understanding. In chemistry, where abstract concepts and microscopic processes often pose a challenge to learners, simulations offer a concrete and visual alternative that enhances comprehension (Wu & Shah, 2004).

Empirical studies consistently report positive outcomes associated with the use of computer simulations in science education. For example, Rutten, van Joolingen, and van der Veen (2012) conducted a meta-analysis of 51 studies and found that simulations had a moderate to large positive effect on student achievement, particularly when combined with conventional instructional methods. Similarly, Smetana and Bell (2012) reviewed research from 1997 to 2010 and concluded that simulations improve student learning when integrated thoughtfully into curriculum and pedagogy. Their analysis emphasized that simulations are most effective when accompanied by teacher guidance, scaffolding, and opportunities for reflection.

In the context of chemistry education, simulations have been shown to significantly improve learners' conceptual understanding of complex topics such as chemical bonding, reaction kinetics, and molecular structure. A study by Tatli and Ayas (2013) in Turkey demonstrated that students who learned through simulation-based instruction scored significantly higher in post-tests than those who received conventional instruction. The authors attributed this improvement to the interactive nature of simulations, which allowed learners to visualise and manipulate atomic and molecular processes that are otherwise difficult to represent through static images or verbal explanations.

Supporting this finding, Adesoji and Babatunde (2008) investigated the effects of computer-assisted instruction on Nigerian secondary school students' achievement in chemistry. Their quasi-experimental study showed that students exposed to simulations performed better in both theoretical and practical assessments compared to their counterparts taught through conventional methods. The researchers noted that simulations provided an engaging platform that reduced cognitive overload and increased learner motivation.

The positive impact of simulations on student performance extends beyond conceptual understanding to influence attitudes and engagement. According to Bell and Trundle (2008), simulations can foster positive attitudes toward science by making learning enjoyable and accessible. In their study on lunar phases, students using simulations expressed greater interest and confidence in science than those taught through lectures alone. Similarly, Zacharia and Olympiou (2011) found that students perceived simulations as enjoyable and beneficial for exploring and understanding abstract scientific phenomena, which in turn enhanced their academic performance.

Moreover, simulations provide opportunities for individualized and differentiated learning. Research by Jaakkola and Nurmi (2008) suggests that simulations cater to different learning styles and paces, thereby allowing students to learn at their own speed and revisit difficult concepts as needed. This flexibility is particularly beneficial in classrooms with diverse learners and limited laboratory resources, as is common in many schools in sub-Saharan Africa.

In Kenya, studies exploring the impact of computer simulations on student performance are growing in number, though still limited. Keter and Wachanga (2013) conducted a study in Kericho County and found that students who used simulations in learning electrochemistry demonstrated improved achievement and higher retention rates compared to those who learned through conventional approaches. The study also highlighted the importance of teacher training and access to digital infrastructure in realizing the full potential of simulation-based learning.

Despite the overwhelming evidence in support of simulations, challenges remain in their adoption and effectiveness. A study by Chandra and Watters (2012) indicated that without proper instructional design, simulations may not lead to significant learning gains. They argued that simulations should not replace laboratory experiments but rather complement them by providing preparatory or supplementary experiences. Furthermore, teachers' digital literacy and beliefs about technology significantly influence the success of simulation-based instruction (Ertmer & Ottenbreit-Leftwich, 2010). In many developing countries, lack of ICT infrastructure, inadequate teacher training, and inconsistent internet access hinder the widespread implementation of simulations (Mugo et al., 2021).

In addition, students' prior experience with technology can influence how they interact with simulations. A study by Tüysüz (2010) found that learners with strong computer skills benefited more from simulations than those with limited digital experience. This suggests the need for a scaffolded introduction to simulations, particularly in under-resourced schools where exposure to digital tools may be limited.

Gender differences in the effectiveness of simulations have also been explored, though findings are inconclusive. While some studies, such as that by Omosewo and Babajide (2011), found that both male and female students benefited equally from simulation use, others reported that male students tended to engage more with the technological aspects of simulations, leading to slightly better performance. These findings underscore the importance of designing inclusive simulation experiences that appeal to all learners.

Overall, the literature affirms that computer simulations positively influence students' academic performance in chemistry and other science subjects. They enhance conceptual understanding, foster engagement, and support differentiated learning. However, their effectiveness depends on several mediating factors, including instructional design, teacher competence, infrastructure availability, and student familiarity with technology. To maximize the benefits of simulations, it is essential to provide adequate teacher professional development, improve access to ICT infrastructure, and adopt policies that integrate simulations into the broader science curriculum.

Numerous studies have attested to the advantages of employing computer simulations in the teaching of abstract and complex concepts in chemistry, which can often be challenging to convey through conventional methods such as conventional lecturing. For instance, Kabigting (2021) and Lasisi et al. (2021) emphasize that computer simulations facilitate a deeper understanding of intricate scientific principles by allowing students to visualize three-dimensional structures and interactions that are often inadequately represented on a two-dimensional chalkboard. Indeed, when students engage with computer simulations, they can better grasp the elusive dynamics of subatomic particles like protons and electrons, leading to enhanced comprehension that may elude them in a conventional classroom setup.

Moreover, the use of computer simulations in education fosters the development of a variety of essential skills. As highlighted by Sari et al. (2020) and Siahaan et al. (2017), learners not only improve their graphic interpretation skills and drawing abilities but also enhance their overall understanding of complex concepts. The acquisition of these science process skills is critical, as it prepares students to operate in scientific contexts like natural scientists. Such foundational skills are invaluable not just in school settings, but also in nurturing future scientists and informed citizens capable of engaging with scientific issues.

The empirical evidence supporting the positive impact of computer simulations on student performance is compelling. Alake & Olojo (2020), Cayvaz et al. (2020), and others have shown that students who learn through computer simulations generally outperform their peers in conventional learning environments. This discrepancy in outcomes indicates that simulations not only aid in knowledge retention but also enhance students' capabilities to apply their knowledge in practical contexts. The consistent findings across various studies underscore the transformative potential of computer simulations as educational tools that significantly bolster student learning outcomes.

In particular, the effectiveness of computer simulations in chemistry has been further substantiated by recent research. For example, a notable study conducted by Mukama et al. (2023) emphasizes the role of simulations in fostering multisensory connections and promoting active engagement in students. By relating abstract chemical concepts to tangible applications, simulations substantially improve students' comprehension of the subject matter. Furthermore, the study found no significant influence of gender on students' preferences or performances regarding computer simulations, suggesting that these tools provide equitable benefits across diverse demographic groups and may help to bridge gaps in education.

Another significant contribution to this field was made by Ibitomi et al. (2022), who explored the effects of computer simulations on high school students' grasp of chemical equations. Utilizing a quasi-experimental design, the study revealed marked improvements in students' performance when taught using simulations, in contrast to the more conventional instructional approaches. The research shed light on the potential of simulations not only to enhance academic performance but also to bolster cognitive engagement with complex chemical principles that are otherwise difficult to comprehend.

The work of Udo and Etiubon (2023) reinforces these findings, illustrating that secondary school students taught through computer-based science simulations achieved significantly better performance outcomes compared to peers engaged through conventional methods. Their study advocates for the institutional incorporation of computer simulations as a legitimate and effective pedagogical alternative that can markedly enhance students' academic performance, particularly in chemistry.

Importantly, Adebusuyi (2023) conducted an investigation comparing the efficacy of computer simulations with conventional hands-on activities. This research discovered that while conventional methods led to higher average performance improvements, the integration of computer simulations provided critical enhancement to students' science process skills. This dual benefit reflects a promising avenue for future educational strategies where both methodologies can be harmonized to optimize learning outcomes for students in scientific disciplines.

Moreover, Tuyizere and Yadav (2023) explored the application of interactive computer simulations in teaching atomic physics in Rwanda. Their findings revealed substantial gains in student motivation and academic performance among those engaging with computer simulations, suggesting broader implications for these tools across various scientific fields that present inherent teaching challenges. These simulations are especially beneficial in contexts where practical experimentation is either limited or poses safety risks, as articulated by Nkemakolam et al. (2018). Their advocacy for computer simulations as instructional methods highlights the safety, practicality, and flexibility of utilizing technology to convey potentially hazardous chemistry concepts in a controlled and secure manner.

Overall, the cumulative findings across these various studies collectively indicate a profound enhancement in both academic performance and conceptual understanding in chemistry through the strategic implementation of computer simulations. This approach not only enriches the conventional curriculum but also fosters an inclusive, engaging, and secure environment for students to immerse themselves in complex scientific ideas. The integration of computer simulations represents a substantial innovation in chemistry education and holds the potential to drastically elevate student learning outcomes. Consequently, it is imperative that educational institutions adopt and incorporate these advanced technologies widely within their teaching strategies to cultivate a generation of learners who are equipped with the necessary skills and knowledge to thrive in an increasingly complex and technological world.

In conclusion, computer simulations represent a powerful pedagogical tool that aligns well with modern educational goals emphasizing learner-centered, inquiry-based instruction. As digital technologies become increasingly accessible, especially with the advent of affordable educational software and mobile devices, simulations are poised to become integral to science teaching worldwide. Nonetheless, their successful adoption requires systemic support, targeted investment, and continuous evaluation to ensure they enhance, not merely replace, effective teaching practices.

2.4 Gender and Academic Performance in the Treatment Group

The relationship between gender and academic performance in science subjects has been extensively studied over the past decades. With the increasing integration of educational technology, including computer simulations, into science instruction, there is a renewed interest in exploring how gender differences manifest within such digital learning environments. Specifically, in treatment groups where learners are exposed to computer simulations, researchers have sought to determine whether boys and girls benefit equally, or whether technology-enhanced instruction exacerbates or reduces existing gender gaps in academic performance.

Gender differences in academic performance have long been a subject of concern in education, particularly in the science, technology, engineering, and mathematics (STEM) disciplines. Conventionally, studies have shown that boys tend to perform better in physical sciences and mathematics, while girls excel in biological sciences and languages (Hyde & Linn, 2006). However, these trends are context-dependent and often influenced by sociocultural, psychological, and instructional factors (Else-Quest et al., 2010). In many African contexts, including Kenya, societal gender norms and stereotypes continue to influence participation, confidence, and achievement in science subjects (Njuguna & Wambugu, 2019).

The advent of computer simulations in science education has brought about new dimensions to the study of gender and performance. Simulations are interactive, often game-like visual learning tools that can offer equal access to scientific experimentation and conceptual learning. As such, they have the potential to mitigate conventional gender disparities rooted in access to hands-on laboratory resources and confidence in manipulating physical equipment (Jimoyiannis & Komis, 2001). However, the question remains whether boys and girls derive equal academic benefit from these tools.

A number of empirical studies suggest that computer simulations positively impact both male and female students' academic performance, with varying degrees of effectiveness. For instance, Papastergiou (2009) examined the use of computer-based simulations and games in high school physics education in Greece and found that both male and female students showed significant improvement in learning outcomes. Notably, girls performed as well as boys, and in some cases outperformed them in post-tests, especially when simulations were designed with user-friendly interfaces and relevant contextual examples.

In the Kenyan context, Mwaluko and Ndung'u (2022) investigated the impact of computer simulations on students' achievement in secondary school physics and found no statistically significant gender difference in performance in the treatment group. Their study emphasized that simulations provided an equalizing platform by shifting the learning experience from conventional teacher-centered instruction to learner-centered engagement.

This approach appeared to benefit girls, who often report lower self-confidence in science due to longstanding gendered classroom dynamics (Chege & Sifuna, 2006).

Similarly, Yusuf and Afolabi (2010) conducted a study in Nigeria comparing the academic performance of boys and girls in chemistry when taught using computer-assisted instruction, including simulations. Their findings showed that both genders benefited from the technology-enhanced approach, with girls slightly outperforming boys. The authors suggested that the interactive and non-threatening nature of simulations allowed girls to engage more actively with abstract concepts, which may not occur as effectively in conventional laboratory settings dominated by boys.

On the contrary, some studies have found marginal differences favoring boys in simulation-based learning environments. For instance, Tüysüz (2010) examined the effects of virtual laboratories on Turkish high school students and found that while simulations improved learning outcomes for both genders, boys demonstrated slightly higher achievement scores. This was attributed to boys' generally higher familiarity with computer interfaces and gaming environments, which may make them more comfortable navigating digital simulations. However, the differences were not statistically significant, and the overall impact of simulations was positive for both genders.

Cai et al. (2017) further explored this dynamic in their cross-cultural study on digital game-based learning in science education. They found that while boys initially engaged more with the technological aspects of simulations, girls caught up quickly in terms of academic performance once they became familiar with the tools. The study emphasized the importance of scaffolding and gender-inclusive design features in educational technology, such as narratives, feedback, and collaborative features, to support equitable learning outcomes.

Another important factor influencing gender performance in simulation-based learning is learners' affective characteristics, such as motivation, interest, and self-efficacy. According to Bandura's (1997) social cognitive theory, self-efficacy significantly influences learning and performance. Research has shown that computer simulations can enhance self-efficacy among girls, particularly when learning environments are structured to promote agency and mastery (Zacharia & Olympiou, 2011). This is particularly relevant in chemistry, where many girls may enter the classroom with low confidence in their ability to understand complex or quantitative topics.

In addition, teacher attitudes and classroom practices play a significant role in mediating gender performance. A study by Ertmer and Ottenbreit-Leftwich (2010) highlighted that when teachers adopt inclusive strategies and encourage both boys and girls to actively engage with simulations, performance differences tend to narrow. Conversely, when technology is introduced without adequate gender-sensitive training for teachers, existing disparities may persist or even widen due to differential encouragement and expectations.

While studies generally support the notion that simulations contribute to gender equity in academic performance, they also highlight contextual challenges, particularly in low-resource settings. In rural and under-resourced schools, girls may face additional barriers, such as limited access to computers, social norms that discourage female participation in science, and insufficient teacher training (Wambugu et al., 2020). These factors underscore the need for targeted interventions to ensure that both male and female learners benefit equally from simulation-based learning.

From a methodological perspective, several studies recommend disaggregating performance data by gender in experimental groups to determine the nuanced effects of simulations. For example, Kebede and Tadesse (2018) analyzed gender differences in Ethiopian secondary schools and found that although overall performance improved with simulations, girls made greater relative gains compared to boys, narrowing the performance gap. This finding supports the idea that simulations may serve as compensatory tools, benefiting underrepresented or disadvantaged learners more significantly.

The relationship between gender and academic performance has been a pivotal aspect in educational research, particularly when examining the interplay between various instructional methods and learning outcomes. Previous studies indicate that gender can significantly influence academic performance, especially when specific interventions, such as computer simulations, are implemented in science education. In a comparative study, it was found that when computer simulations were used to enhance learning in scientific disciplines, a noteworthy correlation emerged between gender and the students' academic results. The experimental group that utilized computer simulations showcased distinct variations in performance attributed to gender, contrasting sharply with the control group, which was taught through conventional lecture methods. The latter group, devoid of any significant performance differences between male and female students, suggested that when instruction followed the lecture format, gender did not play a significant role in shaping academic outcomes. This raises an important inference: both male and female participants encountered no evident challenges in comprehending the scientific concepts presented through computer simulations. However, this assertion is not universally accepted, as a body of literature counters that gender does not exert a significant influence on learners' academic achievement, highlighting the complexity and contentious nature of this topic.

Research exploring the impact of computer simulations on students' performance in science subjects has yielded varying conclusions. A considerable number of studies underscore the notion that incorporating computer simulations within the instructional framework does not create a significant disparity in performance between male and female students in the experimental groups. Such findings indicate that the introduction of computer simulations tends to nullify the conventional gender biases often observed in educational settings, thereby suggesting that the technology-based instructional methods foster a more equitable learning environment. This view is backed up by prominent studies with key contributions from researchers such as Alake and Olojo (2020), Lasisi et al. (2021), Nkemakolam et al. (2018), and Oladejo et al. (2023), all of which contend that gender has little to no bearing on the performance outcomes when computer simulations are employed.

In recent scholarly discourse, the analysis of gender disparities in academic achievement, particularly in the context of chemistry education utilizing computer simulations, has attracted notable attention. This refined focus aims to unravel how computer-based instructional methodologies can influence learning outcomes across genders. Comprehensive studies have revealed that the application of computer simulations within the framework of chemistry education does not preferentially benefit one gender over the other. For example, Uzezi and Deya (2020) conducted an examination on the effects of computer simulations focused on Acid-Base Reactions, revealing no statistically significant variations in academic performance between male and female participants. This outcome supports the argument that computer simulations can function as impartial educational resources, promoting fairness in learning results across various student demographics.

Moreover, recent research by Bazie et al. (2024), which delved into the ramifications of virtual laboratories on undergraduate chemistry students, further extended these findings by asserting that gender does not have a substantial impact on student performance in virtual settings. The observations from this research underscored that the absence of significant performance discrepancies between males and females hails the potential of computer simulations and virtual laboratories to foster an equitable educational environment. This may play a crucial role in mitigating gender gaps historically observed in science education.

Delving into secondary education, the research conducted by Nkemakolam et al. (2018) pursued to uncover the effects of computer simulations on the academic performance of students in chemistry, stressing the importance of assessing gender differences among treatment groups. The investigation concluded with strong evidence that computer simulations are effectively advantageous for students across genders, further endorsing the assertion that these innovative methods provide an unbiased educational experience.

Collectively, the results corroborate the broader understanding that when utilized as educational tools, computer simulations facilitate equitable learning environments by diminishing conventional gender biases that have pervaded science education for decades. The consistency in academic achievements across different gender groups underscores the inherent capability of these technological tools to standardize educational outcomes in chemistry, prioritizing the engagement and comprehension of every learner over entrenched gender-related expectations and stereotypes.

The existing body of literature overwhelmingly supports the perspective that the integration of computer simulations within the chemistry educational landscape promotes gender inclusivity, thereby empowering both male and female students to achieve academic success. This integration lays a foundational role in advancing innovative educational methods while fostering an equitable climate in science education, ultimately enhancing the opportunities available to all learners and challenging the persisting norms associated with gender bias in academic performance.

In conclusion, the literature reviewed suggests that computer simulations have the potential to minimize gender disparities in academic performance, particularly in the treatment group where all learners are exposed to the same interactive and exploratory learning conditions. While boys may initially display greater confidence in using digital tools, girls often demonstrate equal or superior academic gains once familiarity and support structures are in place. The effectiveness of simulations in promoting gender equity, however, depends on several factors, including design, teacher facilitation, access to infrastructure, and cultural attitudes toward gender and technology. As such, efforts to implement computer simulations in science education must be accompanied by gender-sensitive policies and practices that promote equal opportunity and engagement for all learners.

2.5 Teachers and Students Experiences Using Computer Simulations

Computer simulations have increasingly been adopted as instructional tools in science education, particularly in subjects such as chemistry where abstract and complex concepts often present cognitive challenges to learners. As their use becomes more prevalent, it is crucial to understand the lived experiences of both teachers and students engaging with these technologies. Exploring these experiences provides insight into how simulations affect pedagogical practice, student engagement, and learning outcomes, and sheds light on the practical enablers and barriers to their effective implementation.

Chemistry, as a subject, often requires students to visualize microscopic phenomena, such as molecular interactions, atomic structures, and chemical reactions. Conventional teaching methods sometimes fall short in conveying these abstract concepts, leading to low comprehension and disengagement (Taber, 2002). Computer simulations provide dynamic visualizations and interactive environments that can bridge this gap, offering students opportunities to explore, experiment, and manipulate variables in a virtual laboratory. According to de Jong and van Joolingen (1998), simulations support discovery learning and conceptual change by allowing learners to test hypotheses, receive immediate feedback, and refine their understanding through experimentation.

From the students' perspective, the use of simulations is generally associated with increased motivation, enjoyment, and perceived understanding. Research by Smetana and Bell (2012) found that students often describe simulations as engaging and helpful in making abstract ideas more concrete. Similarly, Tatli and Ayas (2013), in a quasi-experimental study in Turkey, reported that students found simulations enjoyable and easy to use, leading to improved performance and more positive attitudes towards chemistry. The interactive nature of simulations, combined with visual feedback, enhances learners' involvement and sense of autonomy, which are crucial components of self-regulated learning (Zimmerman, 2000).

Qualitative investigations further illustrate students' positive experiences with simulations. In a study by Adegoke (2011), Nigerian secondary school students reported that simulations allowed them to learn at their own pace and revisit difficult topics, features not always available in physical laboratory settings. Students appreciated the opportunity to explore experiments that were either dangerous or resource-intensive, such as reactions involving corrosive acids or expensive reagents. These experiences increased their confidence and curiosity, particularly among learners who previously struggled with chemistry.

Students also highlighted the value of simulations in enhancing retention and recall. A study by Akinsola and Ifamuyiwa (2008) in Nigeria revealed that learners perceived simulations as more memorable than textbook instruction because they could visually and kinesthetically interact with content. Visual animations helped them understand processes such as titration, chemical bonding, and equilibrium,topics typically taught theoretically in resource-constrained schools. The experiential nature of simulation learning aligns with Kolb's experiential learning theory (1984), which posits that meaningful learning occurs when students actively engage in concrete experiences followed by reflection and conceptualization.

However, student experiences are not universally positive. Some learners express difficulties in navigating complex simulation interfaces or understanding the simulated processes without adequate guidance (Rutten et al., 2012). This suggests the need for teacher facilitation and structured lesson design to support learners in maximizing the benefits of simulation tools. Furthermore, students from low-technology backgrounds may require additional orientation to use simulation platforms effectively, especially in rural or under-resourced settings where digital literacy is limited (Mugo et al., 2021).

From the teachers' perspective, computer simulations offer a promising but sometimes challenging innovation in instructional practice. Teachers generally acknowledge the pedagogical value of simulations in enhancing student engagement, visualizing abstract concepts, and facilitating inquiry-based learning. According to a study by Jimoyiannis and Komis (2001), teachers perceived simulations as tools that enriched their instructional repertoire and promoted deeper understanding among students. In addition, simulations helped overcome logistical constraints such as the lack of laboratory chemicals, equipment, or physical lab space,a common issue in many developing countries.

Many educators appreciate the flexibility simulations offer in lesson planning and delivery. For instance, teachers interviewed by Zacharia and Olympiou (2011) noted that simulations enabled them to demonstrate multiple phenomena in a short time, something that would be impractical or time-consuming in a conventional lab. Moreover, simulations provide safe environments for students to explore hazardous reactions or high-risk scenarios without physical danger, thereby supporting both learning and safety.

Nevertheless, teachers' experiences with simulations are also shaped by several practical challenges. A major barrier is the lack of adequate training and professional development. Several studies report that teachers often feel underprepared to integrate simulations effectively into their teaching (Ertmer & Ottenbreit-Leftwich, 2010). A study by Wambugu and Changeiywo (2008) in Kenya found that while teachers were enthusiastic about ICT integration, many lacked the pedagogical skills to align simulations with curriculum objectives or to scaffold students' inquiry processes. Without proper training, teachers may underutilize or misuse simulations, reducing their pedagogical impact.

Technical issues also affect teachers' experiences. In a study by Tüysüz (2010), teachers cited problems such as unreliable electricity, lack of computers, slow internet speeds, and outdated software as significant constraints. In Kenyan public schools, particularly those in rural areas, these infrastructural limitations are widespread and inhibit consistent use of simulations (Keter & Wachanga, 2013). Additionally, teachers report challenges in managing large class sizes when using simulations, especially in cases where there are insufficient devices to accommodate all learners.

Furthermore, some teachers express concerns about simulations replacing conventional hands-on experiments. While most agree that simulations are valuable supplements, they emphasize that physical lab work fosters important psychomotor and procedural skills that simulations cannot fully replicate (Chiu et al., 2015). Therefore, teachers prefer a blended approach where simulations are used to introduce or reinforce concepts, followed by practical experiments where feasible.

Teachers also navigate complex attitudes from students and school administrators regarding educational technology. According to Almekhlafi and Almeqdadi (2010), teachers sometimes encounter resistance from students who are either unfamiliar with digital tools or distracted by other online applications. Moreover, school leaders may be reluctant to invest in simulation software or hardware due to budget constraints or limited awareness of their educational value.

Despite these challenges, there is a growing body of literature advocating for the integration of simulations into teacher training programs. Pre-service and in-service teacher development that includes exposure to simulation tools, lesson planning, and pedagogical strategies can enhance teacher confidence and effectiveness in using simulations (Richardson et al., 2017). Professional learning communities and peer support networks are also vital in helping teachers share resources and experiences, thereby strengthening the collective capacity to implement simulation-based learning.

The role of computer simulations in education has gained increasing attention, particularly in disciplines like chemistry where abstract concepts can be challenging for students to grasp. A recent study investigated the effects of PhET simulations on students' attitudes towards learning general chemistry in the United States. The results indicated a positive correlation between the use of these simulations and student understanding of the concepts taught in lessons. Specifically, learners reported that the simulations not only aided their comprehension but also contributed to a more logical and structured understanding of the material. The implementation of computer simulations rendered topics clearer and more sensible, thus enhancing the students' overall learning experience.

In addition to improving comprehension, other research highlights a marked increase in student interest in chemistry following the integration of computer simulations as an educational intervention. As students engage with simulations, many have developed not only favorable attitudes towards science but also a deeper appreciation for the subject matter. The interactive nature of such tools allows abstract concepts to be simplified, making challenging theories more approachable and easier to understand. This has been corroborated by multiple studies, including those by Ayasrah et al. (2024) and Cayvaz et al. (2020), which underline the effectiveness of computer simulations in transforming students' perceptions of the subject matter.

Moreover, the engagement level of learners using simulations often surpasses that of conventional lecture-based approaches. Students tend to find these lessons more enjoyable, as they are actively involved in their learning rather than remaining passive recipients of information. The Phet interactive computer simulations, among others, encourage learners to interact with different tasks and gamified elements, facilitating mastery of the content at the end of each unit. Teachers have observed that students become more engaged during lessons, participating actively by answering questions and showing increased concentration compared to conventional methods. This contrast highlights a significant pedagogical shift, where abstract concepts are communicated through engaging visual representations, particularly in intricate topics such as stoichiometry. For instance, students can visualize atomic interactions in chemical reactions and comprehend the balancing of chemical equations in a way that is fundamentally more accessible than conventional board explanations, as noted by Rehman et al. (2021).

Despite the many advantages presented by simulations, challenges still exist. Many educators report that a substantial number of students tend to memorize chemical equations primarily for examination purposes, often lacking a fundamental understanding of the underlying principles behind these equations. This points to an educational gap that computer simulations can bridge, emphasizing the need for deeper conceptual understanding rather than mere rote memorization.

The integration of computer simulations has significantly transformed the educational landscape, particularly in subjects requiring nuanced visualizations and comprehensive conceptual frameworks, such as chemistry. Notably, Mukama's (2023) study illustrates how simulations can notably enhance student engagement in chemistry learning. Through interviews and surveys conducted with secondary school students, it was revealed that the use of simulations promotes an interactive and self-directed learning environment. The findings suggest that students equate simulations with an enhanced ability to quickly engage with critical chemistry concepts, thereby improving their retention and comprehension of the subject matter.

Crucially, the involvement of educators is paramount in this transformative learning approach. Teachers play a vital role in directing the application of simulations to meet diverse learning needs and preferences effectively. For instance, an investigation by Beichumila et al. (2022) into the use of computer simulations in Tanzanian schools underscores the essential role educators play in enhancing the learning experience. Their findings suggest that simulations serve as instrumental educational tools, enabling both educators and learners to grasp complex chemistry concepts through animated and interactive methods. Educators noted that simulations effectively support the development of hypotheses, experiments, and critical analysis, thus providing a holistic educational experience that far exceeds conventional teaching methodologies.

Furthermore, research conducted by Sarabando et al. (2016) emphasizes the critical balance between teacher intervention and student autonomy in the use of computer simulations. The study reveals that the successful execution of simulations hinges not solely on the technological resources available but also on the teacher's proficiency in tailoring the learning experience to align with the dynamics of the classroom. This fosters an environment conducive to exploratory learning, where students are encouraged to investigate and understand the subject matter in-depth.

Integrating educators' insights and strategic methodologies into the development and application of simulations is vital for maximizing their educational potential. Gong et al. (2022) explored the pedagogical decision-making processes educators undergo when incorporating PhET simulations into their curriculum. Their analysis reveals that educators who successfully marry their instructional expertise with the capabilities of simulations can facilitate enhanced learning environments that significantly boost student involvement and achievement.

The cumulative findings from these important studies underscore the profound impact that computer simulations can exert on enhancing educational outcomes in chemistry. These insights also reinforce the significance of customized teacher engagement and the intentional use of simulations to cater to diverse educational needs. Incorporating computer simulations into the educational framework allows instructors to foster dynamic and inclusive learning environments that prepare students for profound scientific inquiry and deeper comprehension of chemistry concepts. As the educational landscape continues to evolve, the advantages of integrating technology such as computer simulations into conventional curricula will undoubtedly lead to improved academic engagement and learning efficacy among students.

In summary, both teachers and students report generally positive experiences with computer simulations in chemistry education, citing improved understanding, engagement, and instructional flexibility. However, these benefits are moderated by contextual factors including teacher preparedness, access to technology, and institutional support. To fully harness the potential of simulations, targeted interventions such as professional development, infrastructure investment, and curriculum alignment are essential. Understanding these lived experiences is critical to developing equitable, effective, and sustainable technology-enhanced learning environments.

2.6 Support Provided by Teachers for the Successful Implementation of Computer Simulations

The integration of computer simulations in science education, particularly in chemistry, presents promising opportunities to enhance conceptual understanding, increase student engagement, and improve academic performance. However, the success of these innovations largely depends on the nature and quality of support that teachers receive. Teachers are the primary agents of instructional delivery, and their capacity, confidence, and motivation to implement technology effectively are shaped by a wide range of contextual and institutional support mechanisms. This literature review examines the forms of support required by teachers,including professional development, administrative backing, access to technological resources, peer collaboration, and curriculum alignment,for the successful implementation of computer simulations in chemistry education.

Effective implementation of educational technologies such as computer simulations begins with teacher training and professional development. Numerous studies identify teacher competence and confidence as key determinants in the adoption and sustained use of simulations in classroom practice (Ertmer & Ottenbreit-Leftwich, 2010). Teachers need not only technical skills to operate simulation software but also pedagogical knowledge to align simulations with curriculum goals, structure lessons, and scaffold student learning. According to Tondeur et al. (2012), teachers are more likely to adopt technology when professional development is continuous, collaborative, and context-sensitive. This includes workshops, mentorship programs, online modules, and follow-up support that go beyond one-time training sessions.

Research conducted by Smetana and Bell (2012) underscores the importance of pedagogical content knowledge in simulation use. Their review shows that teachers require training not just on how to use the tools, but also on how to integrate them meaningfully into their instruction. This view is supported by Hew and Brush (2007), who emphasize that without proper training in how to structure simulation-based inquiry, teachers may resort to passive, superficial usage that undermines the potential of the technology.

In the Kenyan context, studies reveal significant gaps in teacher preparedness for ICT integration in science teaching. Wambugu and Changeiywo (2008) observed that many science teachers lacked adequate exposure to simulation tools, and were often unsure about how to link simulations with practical laboratory work or curriculum outcomes. Similarly, Ndungu, Githua, and Mboroki (2015) found that while teachers expressed positive attitudes towards simulations, they felt underprepared to use them effectively due to a lack of structured training programs.

Beyond teacher training, institutional and administrative support is vital for fostering an environment conducive to simulation-based instruction. School leadership plays a crucial role in prioritizing technology integration, allocating resources, and establishing a supportive culture for innovation (Afshari et al., 2009). Supportive principals and heads of departments can advocate for budgetary provisions for simulation software and hardware, organize professional learning communities, and create policies that recognize and reward innovative teaching practices.

Administrative support is particularly crucial in low-resource settings, where teachers often operate under significant constraints. In many public schools in sub-Saharan Africa, including Kenya, limited access to computers, unreliable electricity, and lack of internet connectivity are common barriers to the use of simulations (Mugo et al., 2021). Teachers in such environments require logistical and infrastructural support, such as access to computer labs, portable devices, offline simulation packages, and dedicated ICT support personnel. A study by Koehler et al. (2007) emphasizes the importance of technical support in reducing teacher anxiety and minimizing disruptions during lesson delivery. Teachers who receive prompt assistance when encountering technical issues are more likely to persist in using technology.

Another form of critical support for teachers is peer collaboration and professional learning communities. According to Vescio, Ross, and Adams (2008), collaborative teacher networks foster the sharing of ideas, resources, and strategies, and provide emotional support that can ease the adoption of new instructional practices. Teachers who work in isolation are less likely to take risks or innovate. In contrast, when teachers regularly engage in reflective dialogue with colleagues,through departmental meetings, teacher WhatsApp groups, or communities of practice,they are more likely to adopt and sustain the use of simulations.

Studies in simulation-rich environments further highlight the benefits of peer coaching and co-teaching models. For instance, the TPACK framework (Technological Pedagogical Content Knowledge) proposed by Mishra and Koehler (2006) encourages interdisciplinary collaboration between ICT specialists and subject teachers to ensure that technology is not only used correctly but also effectively integrated into teaching. Teachers need support to design simulation activities that align with learning outcomes and cater to students' diverse needs.

Curriculum and policy alignment is another factor that influences teacher implementation of simulations. When national or school curricula include clear guidelines, expectations, and assessment frameworks for technology use, teachers are more likely to adopt and embed simulations into their teaching practices. Conversely, in systems where examination syllabi do not explicitly reward technology-enhanced instruction, teachers may prioritize rote learning strategies that are perceived to produce better exam results (Onguko et al., 2008). As such, curriculum developers and policy makers must ensure that simulations are recognized within the curriculum and supported by instructional materials, such as schemes of work, textbooks, and digital repositories.

Moreover, teachers require time and autonomy to plan, test, and refine their use of simulations. The implementation of new pedagogies often demands significant planning time, especially when adapting simulation tools to local contexts or aligning them with lesson objectives. In high-pressure teaching environments where teachers are overburdened with administrative duties and examination preparation, lack of time becomes a major impediment (Zhao et al., 2002). Supportive school structures should provide flexible timetables, co-planning opportunities, and reduced non-teaching responsibilities to enable teachers to experiment and grow professionally.

In addition, teachers need support in addressing students' digital readiness. For simulations to be effective, students themselves must possess a basic level of digital literacy. Teachers, therefore, need resources and strategies to orient students, troubleshoot challenges, and scaffold learning. As suggested by Tüysüz (2010), some students may become frustrated or disengaged if they lack the confidence or skills to navigate simulations. Hence, teacher support should include strategies for inclusive and equitable technology use.

Finally, motivation and recognition are crucial elements of teacher support. Teachers are more likely to adopt innovations when they feel valued, recognized, and intrinsically motivated. Intrinsic motivation may stem from witnessing improvements in student engagement and learning, while extrinsic motivation can be fostered through recognition, awards, or incentives (Deci & Ryan, 2000). Educational systems and school leadership can nurture a culture of innovation by celebrating teacher successes in using simulations, publishing best practices, and integrating technology-related competencies into teacher appraisal systems.

The successful integration of computer simulations within educational settings fundamentally hinges on robust and continuous support from teachers. Teachers play a multifaceted role as facilitators in this environment, guiding learners through various simulation experiences to elucidate complex concepts while providing essential contextual frameworks that enhance the learning process. Their involvement is not merely supplementary; rather, it is critical in ensuring that these computer simulations are effectively navigated by students, while also aligning them with established learning objectives.

Teachers bolster the implementation of computer simulations through a diverse set of strategies, including explaining core concepts, mediating interactions, coaching students through challenging scenarios, and facilitating meaningful discussions. This active engagement bears significant implications for student success, as teachers wield their critical thinking skills and innate creativity to elevate student engagement levels dramatically. Enhanced levels of engagement invariably lead to improved learning outcomes, which are essential markers of academic success.

Specifically within the realm of forces operation planning, teacher-led support in computer simulations enables students to develop vital competencies related to coordinating defense means and verifying troop deployment processes. Such simulations, which are grounded in realistic technological frameworks, empower students to engage deeply with the subject matter, thereby fostering their analytical and strategic thinking abilities. Teachers are also instrumental in enhancing student engagement within chemistry education through computer simulations by promoting various approaches, such as self-reliance, encouraging peer collaboration, providing teacher guidance, incorporating strategic variations in teaching methods, and creating multisensory connections that cater to different learning styles.

Moreover, the establishment of a safe learning environment, combined with a strong focus on student-centered learning principles and reflective practices, are pivotal support mechanisms employed by nurse educators in the effective implementation of simulation exercises during nursing education. These strategies not only enhance the security of the educational environment but also ensure that students are actively involved in their learning processes, which is crucial for the development of professional competencies in nursing.

In the context of teacher education, computer simulations serve as a valuable resource for enhancing pre-service teachers' skills related to classroom management and instructional techniques. The positive repercussions on self-efficacy among pre-service teachers are noteworthy, although the presence of technical barriers necessitates the design of user-friendly interfaces to maximize the effectiveness of these technological tools.

The successful incorporation of computer simulations into chemistry education is heavily reliant on the support and guidance extended by educators. Teachers function as pivotal agents in the integration of technology into the educational experience, guiding students along their learning journeys and fostering an interactive atmosphere that promotes the utilisation of innovative tools. The insights provided by Mukama (2023) highlight the importance of educator-led frameworks designed to enhance students' active participation in chemistry education through the use of computer simulations. The emphasis on effective pedagogical strategies reflects a broader understanding of educators' roles in both managing the technical aspects of simulations and elucidating the connections between abstract scientific concepts and their practical applications in real-world contexts. This holistic approach guarantees that simulations are leveraged not merely as adjunct tools but are incorporated into a multifaceted learning paradigm that enriches educational experiences.

Further, Traube (2023) underscores the critical need for comprehensive professional development courses aimed at equipping educators with the requisite skills and knowledge essential for the seamless integration of computer simulations into contemporary teaching methodologies. Such courses provide educators with up-to-date insights on state-of-the-art computational chemistry tools, enhancing their ability to embed this technology into their pedagogical practices effectively. The evidence presented indicates that well-structured workshops for teachers, accompanied by hands-on training, are indispensable for fostering educators’ confidence and competence in leveraging simulations to elevate the quality of chemistry education.

In the research conducted by Gong et al. (2022), the intricacies of critical reasoning and decision-making processes necessary for successfully integrating simulations into classroom instruction are examined. Their findings suggest that a solid understanding of pedagogical content knowledge (PCK) is a prerequisite for educators seeking to effectively select and apply simulations that align with instructional goals, especially within the TPACK (Technological Pedagogical Content Knowledge) framework. This necessitates that educators tailor available resources to meet specific classroom needs, ensuring that all tools utilized correspond adequately with curriculum standards and expected student achievement outcomes.

Rodríguez-Becerra et al. (2020) contribute to this discourse by focusing on the significance of embedding computational approaches into pre-service teacher education. This integration plays a vital role in cultivating a formidable pedagogical framework for aspiring educators, merging conventional teaching methodologies with advanced simulation-based learning experiences. Such a blend creates conducive environments for professional growth among educators, simultaneously nurturing students' learning experiences within technology-enhanced educational frameworks.

An extensive review of contemporary literature reveals a common thread: the necessity for ongoing institutional support, access to critical resources, and the establishment of collaborative communities among teachers are fundamental to fostering the effective application of simulations in educational settings. Such supportive architectures not only bolster teacher development but also facilitate the successful incorporation of computer simulations within teaching practices.

In conclusion, existing scholarship highlights an urgent need for a comprehensive strategy aimed at aiding educators in the seamless integration of computer simulations into their instructional practices. This strategy requires meticulous planning that encompasses organized professional development, intentional educational design, and considerable institutional backing. Collectively, these elements are imperative for maximizing the potential of technology to enhance chemistry education and to foster elevated academic outcomes for students engaged in these learning modalities. Such a thorough approach will ensure that educators are well-prepared to not only teach using technology but to innovate their instruction continuously, thereby enriching the educational landscape for all stakeholders involved.

In conclusion, the successful implementation of computer simulations in chemistry classrooms requires a multidimensional support system for teachers. Professional development must be ongoing and focused on both technical and pedagogical dimensions. Administrative and infrastructural support should ensure that teachers have access to the necessary tools and conducive environments for simulation-based learning. Peer collaboration and professional networks provide platforms for knowledge sharing and collective problem-solving. Curriculum alignment, time for planning, and recognition of effort further enhance teacher readiness and motivation. Without these support mechanisms, the adoption of simulations may remain superficial or unsustainable, regardless of the proven benefits to student learning. Policymakers, school leaders, and education stakeholders must therefore invest in comprehensive teacher support systems to harness the full potential of computer simulations in science education.

2.7 Summary of the Review

The reviewed literature highlights significant insights into the impact of computer simulations on student performance, focusing on various aspects such as overall academic performance, gender differences, and the experiences of both students and teachers. In the context of student performance, several studies (Kabigting, 2021; Lasisi et al., 2021; Sari et al., 2020; Siahaan et al., 2017) support the notion that computer simulations enhance students' understanding of complex and abstract concepts in science, particularly in chemistry. These studies consistently report that students in the experimental group, who utilised computer simulations, outperformed those in the control group taught by conventional lecture methods (Alake & Olojo, 2020; Cayvaz et al., 2020; Rehman et al., 2021). Despite these findings, there is a limited exploration of the long-term retention of knowledge gained through simulations compared to conventional methods, which presents a significant gap in the current literature.

Regarding gender and academic performance, the research presents mixed findings. Some studies (Kabigting, 2021) indicate a significant relationship between gender and performance in the experimental group, suggesting that either males or females had differing experiences with grasping concepts through simulations. In contrast, other studies (Alake & Olojo, 2020; Lasisi et al., 2021; Nkemakolam et al., 2018; Oladejo et al., 2023) suggest no significant gender differences in performance when computer simulations are introduced. These conflicting results highlight the need for more nuanced studies considering additional variables, such as socio-cultural factors and pre-existing attitudes towards science and technology among male and female students.

The literature also sheds light on student experiences with computer simulations. Studies (Ayasrah et al., 2024; Cayvaz et al., 2020) report that students perceive computer simulations positively, noting increased understanding, interest, and enjoyment in science subjects. However, there is limited literature examining the potential challenges students might face when using computer simulations. These challenges may include accessibility issues, varying levels of digital literacy, and the adequacy of available technological resources in schools.

Similarly, teacher experiences with computer simulations reveal increased student engagement and comprehension (Rehman et al., 2021). Teachers also report challenges, such as students' tendency to memorise rather than understand concepts. There is a notable gap in the literature regarding professional development and support for teachers to integrate computer simulations into their teaching practices effectively. Moreover, the impact of such interventions on teaching efficacy and job satisfaction remains underexplored. Despite the growing body of literature demonstrating the potential of computer simulations to enhance learning, several contextual and methodological gaps remain, as discussed below.

2.8 Research Gap

Numerous studies have explored the use of computer simulations in science education globally (e.g., Tatli & Ayas, 2013; Rutten et al., 2012; Cayvaz et al., 2020), with most reporting improved academic performance and engagement. However, many of these investigations have focused on physics and biology, while limited attention has been given to chemistry, particularly in the African and Kenyan contexts.

In Kenya, existing studies (e.g., Chumba et al., 2020; Cheruiyot, 2019) examined technology-enhanced learning generally but did not isolate the role of computer simulations in teaching abstract chemistry topics such as atomic structure. Furthermore, few studies have explored teachers' and students' experiences and the institutional support needed for successful simulation-based instruction in resource-constrained secondary schools.

Another notable gap is that most research has emphasised overall performance without disaggregating data by gender or assessing how teacher characteristics (such as experience and ICT proficiency) might influence outcomes.

Therefore, this study fills these gaps by:

Focusing specifically on chemistry instruction within secondary schools in Kapseret Sub-County, comparing experimental and control groups to determine the measurable effect of computer simulations on academic performance, exploring gender-based differences in learning outcomes, examining students' and teachers' experiences with simulation use; and identifying the support mechanisms required for sustainable implementation of computer simulations in chemistry education.

The literature reviewed in this chapter is anchored on the theories guiding the study—Constructivist Learning Theory and Cognitive Load Theory. Constructivism emphasizes that learners build knowledge actively through interaction and experience (Piaget, 1972; Vygotsky, 1978). The reviewed studies on computer simulations demonstrate that technology can provide interactive environments that facilitate such active knowledge construction.

By addressing these dimensions, the study contributes context-specific empirical evidence to inform both policy and pedagogical practice in Kenya and other similar developing contexts.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter outlines the methodology employed in this study to explore the influence of computer simulations on students' academic performance on atomic structure in Kapseret Sub-County, Kenya. This chapter encompasses the research design, philosophy, target population, sample design, data collection methods, data analysis techniques, and ethical considerations. Each component is discussed in detail to comprehensively understand the approach taken to investigate the research questions.

3.2 Research Philosophy

The study was grounded in the philosophical framework of pragmatism, which advocated using multiple methods and perspectives to address research questions. Pragmatism was particularly well-suited to educational research as it emphasized the practical application of research findings to improve educational practices. The study incorporated quantitative and qualitative methods, facilitating a balanced exploration of numerical data and personal experiences. Pragmatism allowed the researcher to focus on the outcomes of using computer simulations to teach atomic structure, evaluating the measurable impact on academic performance and the participants' subjective experiences.

3.3 Research Approach

This study adopted a quantitative-dominant mixed-method approach. Quantitative data were collected through pretest and posttest Chemistry Achievement Tests to measure changes in students' academic performance, while qualitative data were obtained from questionnaires and interviews to explore perceptions and experiences of students and teachers. The combination of quantitative and qualitative approaches provided comprehensive insights into the influence of computer simulations on teaching and learning outcomes (Creswell & Plano Clark, 2018).

3.4 Research Design

This study adopted an embedded quasi-experimental design to investigate the influence of computer simulations on students' academic performance in chemistry. The mixed method quasi-experimental research design involved a pre-test and post-test control group design with no randomness on participants; instead, it utilized intact classes of learners and their chemistry teachers. Quasi-experimental designs were particularly suitable when random assignment of participants was not feasible. Combining mixed methods, as advocated by Creswell and Plano Clark (2011), strengthened the design by integrating quantitative and qualitative approaches, thereby providing a more comprehensive understanding of the phenomenon. This design was appropriate for evaluating the effects of an intervention while exploring contextual and experiential factors in real-world settings.

The quantitative component of the research utilized a pretest-posttest control group approach. An experimental group, which was exposed to computer simulations in their chemistry lessons, was compared with a control group that was taught using conventional instructional methods. Both groups completed a pretest to establish baseline performance and a posttest to measure changes after the intervention. The qualitative component collected data through interviews with teachers to explore their experiences using computer simulations and the support structures for their implementation.

This design was justified for several reasons. Firstly, it aligned with the study's objectives, which included assessing the impact of computer simulations on academic performance, examining gender-based performance differences, and understanding the experiences of teachers and students. Secondly, it accommodated the practical constraints of the educational context in Kapseret Sub-County, where random assignment was not feasible while enabling a robust evaluation of the intervention.

3.5 Study location

This study was conducted among Form Two students and their chemistry teachers in selected secondary schools within Kapseret Sub-County, in Uasin Gishu County, Kenya. According to the 2019 Kenya National Bureau of Statistics (KNBS) report, Kapseret Sub-County had a population of 196,883. It encompassed five administrative wards: Nigeria, Megun, Langas, Simat, and Kipkenyo. Geographically, Kapseret Sub-County lies southwest of Eldoret town, bordered by Kesses Sub-County to the east and Turbo Sub-County to the west.

Kapseret Sub-County hosts 19 public secondary schools, comprising two extra-county schools, two county schools, and 15 sub-county schools. Despite having both physical and human resources in place, the sub-county has consistently recorded lower performance in chemistry compared to neighbouring sub-counties, as reported by the County Director of Education. This persistent underperformance in chemistry made Kapseret a suitable setting for investigating alternative instructional methods aimed at improving learning outcomes in the subject.

The study focused on evaluating the influence of computer simulations on students' academic performance in chemistry, specifically targeting the topic of atomic structure. By exploring this instructional approach within a context of ongoing academic challenges, the research aimed to provide practical insights that could contribute to improving chemistry education in the sub-county and similar settings.

Kapseret Sub-County was purposively selected because successive KCSE analyses (2018–2022) showed consistently low mean scores in chemistry compared with other sciences, indicating a need for pedagogical intervention. Form Two students were chosen because they have acquired foundational knowledge in chemistry but have not yet begun KCSE examination preparation, which reduces external exam-pressure influences on performance. This level also allows adequate exposure time to the experimental treatment before national examination demands intensify.

3.6 Target Population

The target population for this study comprised Form Two students and chemistry teachers in secondary schools within Kapseret Sub-County. According to records from the sub-county education office, the region has 19 secondary schools, with an estimated 40 chemistry teachers and approximately 1,700 Form Two students. Form Two students were selected because they had already acquired foundational knowledge in science and were at a stage where they were beginning to engage with more complex chemistry concepts. This made them an appropriate group for evaluating the impact of computer simulations on academic performance.

Table 3 Summary of target population

Category	Population (N)	Description
Students	1700	Form Two students from 19 public secondary schools in Kapseret Sub-County
Teachers	4	Chemistry teachers handling Form Two classes
Total	1704	Combined target population

3.7 Sample Design

3.7.1 Determining the Sample Size

The sample size was determined purposively by selecting two mixed-day secondary schools that had the necessary infrastructure to support the use of computer simulations. This included reliable electricity, internet connectivity, and adequate computer resources. Most schools in the sub-county lacked one or more of these requirements, which narrowed the number of schools eligible for selection.

Mixed-day secondary schools were selected because they are representative of the broader public secondary school population in the sub-county. Additionally, these schools commonly organise students into single-gender classes, particularly for science subjects, which provided a natural framework for examining gender-related differences in performance, one of the study's objectives.

In the selected schools, four Form Two classes, two for boys and two for girls, were selected and randomly assigned to either the experimental or control group. This ensured a balanced representation of both genders in each study condition.

The final student sample included 160 Form Two students, with approximately 40 students in each class. In addition to the students, four chemistry teachers (two from each school) participated in the study. Two chemistry teachers were involved with the experimental group and two with the control group. These teachers were selected based on their availability and willingness to take part in the study. Their involvement provided insight into instructional methods and supported analysis of the intervention's impact.

3.7.2 Sampling Procedure

Purposive sampling was used to select the two mixed-day secondary schools based on their readiness to support the intervention, particularly in terms of infrastructure. Within each school, simple random sampling was used to select two Form Two classes, one for boys and one for girls. These four classes were then randomly assigned to the experimental or control group, resulting in one boys' and one girls' class in each condition.

Each class had an equal chance of being included in either control or experimental group, which helped reduce selection bias while preserving the existing classroom structure. The final sample consisted of 160 students across the four classes, with a balanced distribution of boys and girls in both the experimental and control groups. Two chemistry teachers were assigned to each group (experimental and control) to reflect typical instructional arrangements in the schools. Their participation supported the delivery of lessons and contributed data on their experience with the instructional methods used.

Two schools were purposively selected from the nineteen because they met essential inclusion criteria: availability of functional computer laboratories, access to reliable electricity, and willingness of chemistry teachers to participate. Selecting schools with similar resource levels ensured control of extraneous variables that could confound the influence of computer simulations. Although the number of schools was limited, the study adopted a quasi-experimental design emphasizing internal validity rather than generalization; hence, findings provide indicative trends that can inform larger-scale studies.

3.7.3 Group Allocation and Control of Extraneous Variables

With the classes selected and assigned to study conditions, steps were taken to allocate students to groups and control for potential extraneous variables that might affect the validity of the results. Students were assigned to the experimental and control groups based on intact class assignment. Random allocation was not feasible due to school timetables and administrative structures. Each participating school had at least two streams of Form Two students. One stream was assigned to the experimental group, and the other to the control group. This approach maintained logistical feasibility while preserving academic comparability between groups. To reduce selection bias, streams were selected based on similar academic performance histories, as recorded by each school.

To ensure that any observed differences in student performance were attributable to the instructional method rather than other factors, several measures were implemented. Both groups studied the same chemistry topics including; stoichiometry, atomic structure, and chemical reactions, over a four-week period. A common scheme of work and a standardized lesson plan were used across all classes.

Furthermore, the same teacher taught both the experimental and control classes within each school, minimizing differences in teaching style and delivery. Instructional time was also held constant, with all lessons conducted during regular school hours. The only difference between the two groups was the mode of instruction: students in the experimental group were taught using computer simulations, while those in the control group received instruction through conventional methods such as lecture and chalkboard. These controls were implemented to isolate the effect of the intervention and strengthen the internal validity of the study.

3.8 Piloting of Instruments

Before the main data collection, the research instruments were piloted in one secondary school outside Kapseret Sub-County that possessed comparable characteristics to the study schools. A sample of 20 students and 2 chemistry teachers participated. The purpose of piloting was to assess the clarity, validity, and reliability of the items. Feedback from the pilot informed refinement of ambiguous questions and adjustment of the time allocated for tests and questionnaires.

The reliability of the Chemistry Achievement Test was established using the test–retest method, where the same test was administered twice within a two-week interval. The reliability coefficient ($r = 0.82$) indicated acceptable stability. This method may be influenced by memory effects or changes in respondent motivation between tests; however, the two-week gap was deemed sufficient to minimise such bias.

3.9 Data Collection Instruments

This study employed both quantitative and qualitative data collection instruments. A standardised chemistry achievement test was used to assess students' academic performance before and after the intervention. The test focused on the topic of atomic structure and was designed to measure conceptual understanding and knowledge retention.

To supplement the test, questionnaires and semi-structured interviews were used to collect data on students' and teachers' experiences and perceptions of using computer simulations in instruction. The questionnaires were structured to capture information related to ease of use, engagement, and perceived effectiveness. Semi-structured interviews allowed for more detailed responses, offering context-rich insights into participants' experiences that could not be fully captured through closed-ended questions.

3.9.1 Chemistry Achievement Test (CAT)

The CAT comprised 20 multiple-choice and 5 structured items based on the KICD secondary school chemistry syllabus. It assessed learners' understanding of topics such as atomic structure and chemical bonding. The instrument's strength lies in its objectivity and quantifiability, allowing reliable measurement of academic performance before and after exposure to computer simulations.

3.9.2 Student Questionnaire

The questionnaire collected information on students' attitudes, motivation, and perceptions toward the use of computer simulations. It contained both closed and open-ended items. Its strength is in capturing students' subjective experiences and attitudes that cannot be assessed through achievement tests alone.

3.9.3 Teacher Interview Schedule

This semi-structured instrument captured teachers' experiences with computer simulations and their views on the support required for effective implementation. Its flexibility allowed for follow-up questions and deeper exploration of teachers' perspectives.

3.10 Validity and Reliability of the Instruments

3.10.1 Validity of the Instruments

Face and content validity of the chemistry achievement test were established through expert review. Subject matter specialists in chemistry education evaluated the test items to ensure alignment with the Form Two chemistry curriculum and relevance to the topic of atomic structure. Based on their feedback, revisions were made to improve coverage, clarity, and appropriateness of the items. A pilot study was also conducted in a school with similar characteristics to the main study sites. This helped identify and address ambiguous or unclear questions, further enhancing the instrument's validity.

Similarly, the questionnaires and interview guides were reviewed by experts in education and instructional technology. The review focused on the clarity, relevance, and alignment of each item with the study's objectives. Pilot testing was carried out with a small group of students and teachers, and their feedback informed the final revisions. Items that were confusing, redundant, or poorly sequenced were modified or removed to improve the overall validity of the instruments.

3.10.2 Reliability of the Instruments

The reliability of the chemistry achievement test was determined using the test-retest method during the pilot phase. The same group of students completed the test twice, with a two-week interval and no instructional intervention between the two administrations.

Pearson's correlation coefficient was used to evaluate the stability of the scores over time. The test yielded reliability coefficients of .83 for the pretest and .84 for the posttest, indicating strong test-retest reliability.

The internal consistency of the questionnaire was assessed using Cronbach's alpha, which produced a coefficient of .90. This value indicated high internal reliability among the questionnaire items (Hair et al., 2019). While the interview guide was not subject to statistical reliability analysis due to its qualitative nature, it was pilot-tested for clarity, flow, and consistency in how the questions were interpreted by different respondents. Revisions were made based on pilot feedback to enhance its effectiveness and ensure consistent administration during data collection.

3.11 Instrument Administration

The achievement test had been administered to the experimental and control groups at the beginning (pre-test) and end (post-test) of the intervention period. This pre-test/post-test design allowed for the measurement of changes in academic performance attributable to the use of computer simulations. Questionnaires had been distributed to students and teachers at the end of the intervention period. A subset of participants, selected based on their responses and availability, was invited for semi-structured interviews. The data collection had been carefully supervised to maintain consistency and minimise bias. All participants received instructions and guidance to ensure accurate and honest responses.

3.12 Data Collection Procedures

Before data collection, the researcher obtained the necessary permissions to conduct the study. This included approval from the National Commission for Science, Technology, and Innovation (NACOSTI). Additionally, the researcher sought authorization from the County

Commissioner and the County Director of Education in Uasin Gishu County. Permission was also sought from the principals of the sampled secondary schools within Kapseret Sub-County to allow research activities in their respective institutions.

Prior to the main data collection process, the data collection instruments were validated, piloted, and tested for reliability to ensure their effectiveness. The study utilized questionnaires, interview schedules, chemistry achievement tests, and observation checklists as data collection tools.

The researcher booked appointments with the relevant respondents, including Form Two chemistry teachers and students. Face-to-face, semi-structured interviews were conducted with teachers to explore their perceptions and experiences regarding the use of computer simulations in teaching chemistry, particularly on the topic of atomic structure. Open-ended questions guided these interviews, allowing for flexibility in probing deeper into specific responses. Structured instruments were used to ensure consistency and comparability across groups (Mugenda & Mugenda, 2003)

Data collection involved the administration of questionnaires and chemistry achievement tests to students, while interviews were conducted with teachers. Before initiating the data collection, a reconnaissance visit to the selected schools was undertaken. During this visit, the researcher sought permission from the school principals and established rapport with the chemistry teachers who participated in the study. This familiarization process also helped finalize logistical arrangements for the data collection activities.

3.13 Data Analysis

Quantitative data from the chemistry achievement tests were analyzed using both descriptive and inferential statistical methods. Descriptive statistics were used to summarize performance patterns within each group, including means and standard deviations. To determine whether observed differences in academic performance between the experimental and control groups were statistically significant, independent samples *t*-tests and analysis of variance (ANOVA) were employed.

Qualitative data from questionnaires and interviews were analyzed using thematic analysis. This involved systematic coding of responses to identify recurring patterns, themes, and insights related to students' and teachers' experiences with computer simulations. Thematic findings provided context for interpreting the quantitative results and offered deeper understanding of how the intervention was perceived and implemented in classroom settings. Data were analyzed using both descriptive and inferential statistics as recommended for experimental studies involving comparison groups (Kothari, 2014)

In summary:

Objective 1: Differences in learners' performance between experimental and control groups were analysed using *independent-sample t-tests* to compare pretest and posttest mean scores.

Objective 2: Gender differences in performance were analysed using *Two-Way ANOVA* to test the main and interaction effects of teaching method and gender.

Objective 3: Students' and teachers' perceptions and experiences were analysed qualitatively through *thematic analysis* of questionnaire and interview responses.

Objective 4: Support strategies required for implementing simulations were identified through *thematic coding* and interpretation of teacher interview data.

3.14 Ethical Considerations

Ethical approval for this study was obtained from the relevant educational and research authorities prior to data collection. The researcher first sought clearance from the School of Education at Moi University. Following this, a national research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI), in compliance with both national and international research regulations. With these approvals in place, additional clearance was secured from the Uasin Gishu County and Kapseret Sub-County education offices to allow access to the study sites.

The researcher initiated the data collection process by familiarization with the research sites through visiting the selected schools and meeting with gatekeepers and school administrators. Permission was obtained before engaging with any participants. Informed consent was obtained from participating teachers and students. All participants were fully briefed on the study's purpose, procedures, potential risks, and anticipated benefits. They were assured that participation was voluntary and that they could withdraw from the study at any time without any negative consequences.

Confidentiality and anonymity were strictly maintained throughout the research process. All data were de-identified and stored securely. Findings were reported in aggregate form to ensure that individual participants could not be identified. Additionally, care was taken to ensure that the study did not interfere with normal school activities or place any undue burden on students or teachers. The subsequent entails data presentation, analysis, interpretation and discussion of the findings.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS, INTERPRETATION, AND DISCUSSION OF FINDINGS

4.1 Introduction

This section outlines the research objectives, questions, hypotheses, findings, interpretations, and discussions. Quantitative data analysis commenced with descriptive analysis, followed by inferential statistics, including independent samples t-tests to evaluate the null hypotheses established to direct the study. Additionally, this section details the qualitative data analysis collected via the open-ended questionnaire and interview guide. Notably, the study's outcomes were analysed in the context of the reviewed literature. The current study aimed to achieve the following research objectives:

i. To determine differences in learners' performance in the experimental and control groups in selected schools in Kapseret Sub-County.

ii. To analyse the difference between the performance of boys and girls in the experimental and control groups in selected schools in Kapseret Sub-County.

iii. To assess the perceptions and experiences of students and teachers regarding the use of computer simulations in chemistry instruction in selected schools in Kapseret Sub-County.

iv. To explore the support strategies needed by teachers need to effectively implement computer simulations in chemistry teaching in selected schools in Kapseret Sub-County.

Additionally, the study explored the following research question

i. What are the perceptions and experiences of students and teachers regarding the use of computer simulations in chemistry instruction in selected schools in Kapseret Sub-County?
ii. What support do teachers need to successfully implement computer simulations in selected schools in Kapseret Sub-County?

Furthermore, this study evaluated the subsequent null hypotheses established to meet the research objectives:

i. **H_{01}:** There is no significant difference in the academic performance between learners in the control group and the experimental group in selected schools in the Kapseret Sub-County.
ii. **H_{02}:** There is no significant difference in the academic performance between boys and girls in the control and experimental groups in selected Kapseret Sub-County schools.

4.2 General and Demographic Information

This section presents general information concerning the questionnaire return rate. Further, it presents the demographic data of the sampling units, such as the sample's gender. This investigation first presents the questionnaire return rate, followed by the demographic data described below.

4.2.1 Instruments Return Rate

The questionnaire served as one of the research instruments to collect information about the learners' experiences after being taught with the intervention of computer simulations. The researcher gave the students in the experimental group the questionnaires, a total of 80 questionnaires, and the response rate was 100%. All the test scores for the pretest and the posttest were also returned.

4.2.2 Demographic Gender Representation of the Respondents

Table 4 Gender Distribution of Teacher and Student Samples.

	Female		Male	
Sample	n	%	n	%
Teachers	3	75	1	25
Students	80	50	80	50

This study involved Form Two students from two selected mixed secondary schools in Kapseret Sub-County, chosen for their computer infrastructure and access to simulation software for chemistry teaching. A total of 160 students participated, with each school providing an experimental group (using computer simulations) and a control group (utilising conventional teaching methods), ensuring gender representation. Additionally, the study gathered teachers' perspectives on the implementation challenges and benefits of using computer simulations in chemistry instruction. This data lays the groundwork for analysing student performance and experiences in later sections.

4.3 Differences in Learners' Performance in the Experimental and Control Groups in Selected Schools in Kapseret Sub-County

To determine the influence of computer simulations on students' academic performance in chemistry, the study compared the pretest and posttest scores of the experimental and control groups. An independent samples t-test was used to assess whether the observed differences in mean scores were statistically significant.

Table 5 Group Statistics for Pretest and Posttest Scores.

Score Type	**Group**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Pretest Score	Control	80	15.15	4.30	0.48
	Experimental	80	15.58	3.57	0.40
Posttest Score	Control	80	16.75	2.89	0.32
	Experimental	80	22.43	4.34	0.49

Before the intervention, the pretest scores showed that the control group (M = 15.15, SD = 4.30) and the experimental group (M = 15.58, SD = 3.57) were roughly equivalent in performance. An independent samples t-test confirmed that this difference was not statistically significant, t (158) = -0.681, p = .497, with a mean difference of -0.425. Although an ANCOVA could be used to control for pretest scores, the lack of significant baseline difference (p = .497) justified the use of posttest comparisons via independent samples t-test.

Table 6 Independent Samples t-test for Pretest and Posttest Scores.

		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
Pretest Score	Equal variances assumed	1.507	0.221	-0.681	158	0.497	-0.425	0.624	-1.658	0.808
	Equal variances not assumed			-0.681	152.841	0.497	-0.425	0.624	-1.659	0.809
Posttest Score	Equal variances assumed	11.198	0.001	-9.733	158	0	-5.675	0.583	-6.827	-4.523
	Equal variances not assumed			-9.733	137.631	0	-5.675	0.583	-6.828	-4.522

After the intervention, the posttest scores revealed a substantial difference. The experimental group (M = 22.43, SD = 4.34) outperformed the control group (M = 16.75, SD = 2.89). This difference was statistically significant, t (158) = -9.733, p < .001, with a mean difference of 5.675 and a 95% confidence interval ranging from 4.523 to 6.827. To assess the magnitude of this difference, Cohen's d was calculated using the pooled standard deviation (SD = 3.687). The resulting effect size was Cohen's d = 1.54, indicating a very large effect. This suggests that the intervention had a strong and meaningful impact on learners' academic performance in chemistry.

These results support the idea that computer simulations significantly enhance student understanding and performance, likely by making abstract scientific concepts more tangible and interactive. These findings align with earlier research. Kabigting (2021) highlighted that simulations help students visualize molecular interactions more clearly than conventional instruction. Lasisi et al. (2021) and Sari et al. (2020) also found that simulations promote deeper conceptual understanding and develop science process skills. Similarly, Siahaan et al. (2017) reported improved performance among students taught using virtual simulations.

The results are also consistent with constructivist learning theory, which emphasizes active, hands-on engagement. Simulations allow students to manipulate variables, test hypotheses, and receive immediate feedback, experiences that help learners build and retain conceptual knowledge. Mukama et al. (2023) noted that simulations support multisensory learning, which enhances comprehension and memory. Udo and Etiubon (2023), as well as Ibitomi et al. (2022), observed increased motivation and confidence among students using simulation tools.

These findings emphasize that computer simulations are not merely complementary tools, but central mechanisms in enhancing student achievement in chemistry. The large effect size (Cohen's $d = 1.54$) suggests that the intervention did not just improve performance, it fundamentally shifted how students engaged with and understood chemistry concepts. This calls into question the adequacy of conventional instruction in fostering deep scientific understanding, particularly in content areas that rely heavily on visualization and conceptual abstraction.

The implication is that teaching strategies should no longer treat simulations as supplemental. Instead, they should be embedded as core components of instruction. To make this shift viable, teachers must be equipped with both the technical skills and pedagogical frameworks needed to integrate simulations effectively. Professional development should focus on inquiry-based lesson design, where simulations guide students through conceptual exploration rather than rote completion.

At the policy level, curriculum developers and education authorities must recognize simulation-based instruction as a necessary feature of 21st-century science education. Its integration should be reflected in teaching standards, resource allocation, and assessment frameworks. Failing to incorporate this mode of instruction risks limiting student access to high-impact learning experiences, particularly in under-resourced schools.

Theoretically, these findings further validate constructivist learning models, which prioritize interaction, experimentation, and feedback. Conventional content delivery models may underestimate the value of engagement and exploration, especially for complex scientific ideas. The intervention's success underscores that what drives improved outcomes is not just content exposure, but the structure of learner engagement.

The study findings support a broader shift toward technology-mediated, learner-centered instruction in science education. They demonstrate that meaningful gains in performance and understanding are achievable when students are actively involved in constructing knowledge. Without such pedagogical innovation, attempts to improve learning outcomes may fail to address the root causes of underachievement in chemistry subject.

4.4 Difference Between the Performance of Boys and Girls in the Experimental and Control Groups in Selected Schools in Kapseret Sub-County

To examine the effects of gender and instructional method on students’ academic performance in chemistry, a two-way Analysis of Variance (ANOVA) was conducted using the post-test scores. The independent variables were gender (male, female) and instructional method (control, experimental), while the dependent variable was the chemistry post-test score. Group allocation was based on intact classes. Although random assignment wasn't feasible, classes with similar academic performance histories were selected, and the same teacher taught both groups within each school to reduce bias. The results are presented in Table 4.4.

Table 7 Two-Way ANOVA Results for Post-Test Chemistry Scores by Gender and Teaching Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1289.225	3	429.742	31.217	.000
Intercept	61387.225	1	61387.225	4459.224	.000
Gender	0.900	1	0.900	0.065	.799
Group	1288.225	1	1288.225	93.578	.000
Gender * Group	0.100	1	0.100	0.007	.932
Error	2147.550	156	13.766		
Total	64824.000	160			
Corrected Total	3436.775	159			

R Squared = .375 (Adjusted R Squared = .363)

The results from the ANOVA, as presented in Table 4.5, revealed a statistically significant main effect of group, $F(1, 156) = 93.578$, $p < .001$. This robust statistical finding indicates conclusively that the method of instruction, specifically, the comparison between computer simulations and conventional teaching techniques, had a pronounced and significant impact on students' performance in the post-test assessments. Notably, students in the experimental group, who engaged with the curriculum through the innovative medium of computer simulations, exhibited markedly higher performance metrics when compared to their counterparts in the control group. This outcome suggests a clear correlation, demonstrating that the use of computer simulations not only engages students but also effectively enhances their academic achievement in the challenging subject of chemistry.

Conversely, the analysis of variance regarding the main effect of gender did not yield statistically significant results, with $F(1, 156) = 0.065$, $p = .799$. This finding indicates a lack of overall significant differences in the academic performance between male and female students participating in the study. Furthermore, the interaction effect between gender and group was also statistically non-significant, $F(1, 156) = 0.007$, $p = .932$. These results imply that the positive efficacy of computer simulations on academic achievement is consistent across both genders, thereby demonstrating that the benefits of the teaching method were not influenced by the gender of the students. This universality is particularly important as it highlights the potential of computer simulations as a gender-neutral instructional resource in educational settings.

The results of this study, therefore, provide compelling evidence that computer simulations represent an effective instructional strategy for both male and female learners alike. This finding supports the notion of integrating technology into the chemistry curriculum as a tool that promotes inclusivity and equity among students. Furthermore, the findings of this study align well with previous research, such as those conducted by Ayasrah et al. (2024) and Cayvaz et al. (2020), which have similarly observed that students perceive computer simulations as a means to make abstract scientific content considerably more comprehensible, irrespective of their gender identity or background. In this current study, students who were instructed using simulations demonstrated a notably greater understanding of complex chemistry topics, including stoichiometry, atomic structure, and chemical reactions, as evidenced by their significantly higher mean scores on the post-test assessments.

Additionally, the research conducted by Rehman et al. (2021) emphasized that simulations play a critical role in promoting learner engagement and mastery of content, effectively replacing conventional rote memorisation practices with opportunities for meaningful understanding. This is especially crucial in the field of chemistry, where abstract reasoning skills are essential for success. In the context of this study, such engagement was consistently evident across both gender groups within the experimental condition, reaffirming the inclusive and effective nature of simulation-based instruction for a diverse student population.

Moreover, the insights provided by Mukama (2023) further bolster these findings, highlighting the fact that computer simulations not only enhance collaborative learning experiences but also foster self-directed learning and deep cognitive engagement in both male and female students alike. Furthermore, the study conducted by Beichumila et al. (2022) underscores the simulations' capacity to support hypothesis testing, experimentation, and analytical reasoning skills that are beneficial for all learners, regardless of their gender identity. Such findings are especially relevant in developing a comprehensive and equitable approach to teaching in STEM fields.

The results of this study also reflect and build upon the insights from Sarabando et al. (2016) and Gong et al. (2022), who emphasized that the success of simulation-based learning is not solely dependent on the technological tools employed, but significantly influenced by the ways in which educators integrate these tools into their classroom practices. This research indicates that teachers were able to deliver the simulation experiences equitably across both gender groups, thereby supporting various learning styles and promoting notable academic achievement for all students involved in the study.

In conclusion, the lack of significant gender differences observed in the post-test scores suggests a strong implication that computer simulations serve as an inclusive educational tool, capable of fostering improved learning outcomes for both male and female students alike. These findings hold significant implications for educators and curriculum developers, as they advocate for the integration of simulations into chemistry instruction as a strategy to bridge performance gaps and promote equity in science education. Therefore, it is crucial for policymakers to consider supporting teacher training initiatives in simulation technologies while also ensuring equitable access to digital resources in schools, particularly in regions such as Kapseret Sub-County and beyond, to foster a more inclusive educational landscape.

4.5 Students and Teachers' Views on the Use of Computer Simulations in Chemistry Instruction

4.5.1 Students' Views and Experiences with Computer Simulations in Chemistry Instruction

To explore students' experiences, descriptive statistics were computed from their responses on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). The responses reflect various aspects such as ease of use, conceptual understanding, engagement, motivation, and preference over conventional teaching. The findings are presented in table 4.5.

Table 8 Descriptive Statistics on Students' Views and Experiences.

Item no	Statement	Mean	SD
SV1	I found the computer simulations easy to use.	3.63	1.036
SV2	The computer simulations captured my attention and kept me engaged.	3.64	0.984
SV3	The simulations helped me understand the concepts better.	3.83	1.003
SV4	I feel more confident about the topic after using the simulations.	3.62	0.986
SV5	Using the computer simulations motivated me to explore the topic further.	3.86	1.028
SV6	I understand the concepts better through simulations than through conventional teaching methods.	3.58	1.016
SV7	The computer simulations were more engaging than conventional classroom instruction.	3.7	1.048
SV8	I feel more motivated to learn when using simulations than conventional teaching approaches.	3.77	1.018
SV9	The simulations provided clearer explanations of the material than conventional methods.	3.8	1.036
SV10	Using simulations improved my ability to apply concepts in practice more effectively than conventional teaching.	3.79	1.099
	Grand Mean	**3.722**	**1.0254**

The results in table 4.5 indicate that students generally found that computer simulations were easy to use (*M* = 3.63, *SD* = 1.04). They also agreed that the simulations captured their attention and kept them engaged (*M* = 3.64, *SD* = 0.98). In terms of conceptual understanding, students responded positively to the statement "The simulations helped me understand the concepts better," which received a relatively high mean (*M* = 3.83, *SD* = 1.00). When asked whether they felt more confident about the topic after using simulations, students also responded favorably (*M* = 3.62, *SD* = 0.99).

Motivational responses were among the most positive. The highest mean score was recorded for the item "Using the computer simulations motivated me to explore the topic further" (*M* = 3.86, *SD* = 1.03). Students also agreed that they understood concepts better through simulations than through conventional methods (*M* = 3.58, *SD* = 1.02), and that simulations were more engaging than conventional classroom instruction (*M* = 3.70, *SD* =

1.05). Additionally, the statement "I feel more motivated to learn when using simulations than conventional teaching approaches" received strong agreement (*M* = 3.77, *SD* = 1.02).

Students perceived simulations to offer instructional advantages as well. They agreed that simulations provided clearer explanations of material than conventional teaching methods (*M* = 3.80, *SD* = 1.04) and helped them apply concepts more effectively in practice (*M* = 3.79, *SD* = 1.10). The overall grand mean across all ten items was *M* = 3.72 (*SD* = 1.03), indicating that students generally viewed the use of computer simulations positively across multiple learning dimensions.

These results suggest that students found the simulations accessible, engaging, and pedagogically useful. The moderate-to-high mean scores indicate that students did not just enjoy using the simulations but also believed that the approach improved their understanding, motivation, and practical application of chemistry concepts. For example, their strong agreement with statements related to attention (*M* = 3.64), understanding (*M* = 3.83), and confidence (*M* = 3.62) indicates that the simulations contributed meaningfully to both cognitive and affective aspects of learning. The relatively low standard deviations (ranging from 0.98 to 1.10) suggest consistent responses across the sample, reinforcing the conclusion that the intervention was broadly well-received.

These findings are consistent with earlier studies that emphasize the educational value of simulation-based learning. For instance, Ayasrah et al. (2024) and Cayvaz et al. (2020) found that computer simulations enhanced clarity by simplifying complex content, making abstract topics more accessible. The observed engagement levels mirror findings by Sarabando et al. (2016), who noted that simulations promote active learning and sustained attention. Rehman et al. (2021) similarly reported that students using simulations exhibited a shift from rote memorization to deeper conceptual processing, particularly in topics like balancing equations and visualizing molecular interactions. The motivational effects found here are in line with Mukama (2023) and Beichumila et al. (2022), who reported that simulations increase student curiosity, involvement, and willingness to participate. Furthermore, Gong et al. (2022) emphasized the role of simulations in enhancing students' ability to apply theoretical knowledge, a benefit echoed in the present findings ($M = 3.79$).

The implications of these findings are significant for classroom practice and instructional design. The findings suggest that computer simulations can be a valuable pedagogical tool not only for improving understanding but also for fostering student motivation and engagement, both of which are critical for sustained academic success. Moreover, the perception that simulations provide clearer explanations and support better application indicates their suitability for topics that are conventionally challenging, abstract, or resource-intensive. Furthermore, the consistent student preference for simulations over conventional teaching highlights the need for curriculum developers and policymakers to support the integration of digital tools in science education. This includes investing in teacher training and ensuring schools are equipped with the necessary technological infrastructure. Therefore, when implemented thoughtfully, computer simulations have the potential to enrich learning environments, promote equity in access to complex content, and enhance overall student outcomes in chemistry.

4.5.2 Teachers' Views and Experiences with Computer Simulations in Chemistry Instruction

This section presents the findings from teacher interviews regarding their experiences and perceptions of using computer simulations in the teaching of chemistry. Two key themes emerged: (1) Enhanced Conceptual Understanding and Student Engagement, and (2) Constraints and Challenges in Simulation Use. Each theme includes two categories that help clarify teachers' perspectives as presented in table 4.6.

Table 9 Summary of Emerging Themes and Categories

Theme	Categories
1. Enhanced Conceptual Understanding and Student Engagement	• Simulations as Tools for Visualization and Active Learning • Improved Student Motivation and Attitudes Toward Chemistry
2. Constraints and Challenges in Simulation Use	• Infrastructure and Access Barriers • Digital Literacy and Student Confidence

4.5.2.1 Theme 1: Enhanced Conceptual Understanding and Student Engagement

One of the strongest themes that emerged was that simulations significantly improved student understanding, particularly with abstract or challenging chemistry topics. Teachers commonly used simulations after initial theoretical instruction to reinforce or visualize concepts that are otherwise difficult to grasp.

> *"Some of these topics, like atomic structure, are very abstract. But once I show them the simulation, you can literally see the lightbulb moments."* (Teacher 2)
>
> *"Without simulations, students are just listening… they are passive. But when we bring in the simulations, they become excited and active."* (Teacher 1)

These accounts support previous studies, such as those by Mukama (2023) and Ayasrah et al. (2024), who found that simulations helped create interactive and student-centered learning environments that support conceptual mastery.

The second category under this theme was improved student motivation. Teachers consistently described positive emotional responses and increased engagement when simulations were incorporated into lessons. Students who previously struggled or showed little interest in chemistry became more enthusiastic.

> *"Some students who didn't like chemistry before are now asking questions and even trying out the simulations on their own."* (Teacher 1)
>
> *"I noticed that even the quieter students became more confident. They weren't afraid to try because they could see and test things themselves."* (Teacher 2)

These experiences are in consonance with Cayvaz et al. (2020) and Rehman et al. (2021), who reported that computer simulations not only improved student understanding but also fostered more positive attitudes toward science.

4.5.2.2 Theme 2: Constraints and Challenges in Simulation Use

While the benefits of using simulations were clear, teachers also identified key challenges. The first category was infrastructure and access barriers. Many schools lacked adequate computer resources, and unreliable internet access frequently interrupted lessons.

> *"Sometimes we have to squeeze students around one computer, and it's hard for everyone to see and interact with the simulation properly."* (Teacher 2)
>
> *"The network goes down often. You want to load a simulation, and you waste 15 minutes waiting. The students get bored or distracted."* (Teacher 1)

These challenges are consistent with the work of Gong et al. (2022), who found that limited ICT infrastructure and poor connectivity hinder the effective use of digital tools in schools.

The second category was digital literacy and student confidence. Teachers noted that some students were initially unfamiliar with how to operate the simulations, especially at the beginning of the school year. However, with guidance, most adapted quickly.

> *"Some students were really unsure how to get started. They had never used simulations or done any online science tasks before."* (Teacher 2)
>
> *"At first, a few students hesitated, but once we gave a short orientation, they were all on board, regardless of whether they had prior experience or not."* (Teacher 1)

Teachers emphasized that differences in engagement were not linked to gender, but rather to individual familiarity with technology and the quality of support provided. This aligns with Sarabando et al. (2016), who stressed the need for balanced teacher guidance and technological scaffolding to support diverse learners.

The findings highlight that teachers viewed simulations as valuable tools for enhancing student understanding and engagement, particularly for difficult or abstract chemistry topics. When integrated thoughtfully, simulations supported active learning and fostered greater student interest. However, the effectiveness of these tools was moderated by contextual challenges, especially infrastructure limitations and the need for initial digital support.

These findings resonate with prior literature that emphasizes the pedagogical value of simulations when paired with effective instructional strategies (Mukama, 2023; Beichumila et al., 2022). At the same time, the data underscores that systemic issues, such as access to resources and teacher capacity, must be addressed for simulations to achieve their full potential in Kenyan classrooms.

These results suggest a need for increased investment in ICT infrastructure, especially in under-resourced schools. Additionally, teachers may benefit from targeted training on how to integrate simulations effectively, including strategies for supporting students who are unfamiliar with digital tools. If these barriers are addressed, simulations have the potential to transform how chemistry is taught and learned at the secondary level.

In summary, the perspectives of both students and teachers highlight the strong educational value of computer simulations in secondary chemistry classrooms. Students reported that simulations were not only easy to use but also improved their understanding, motivation, and ability to apply concepts. They consistently found simulations more engaging and effective than conventional teaching methods. Teachers echoed these sentiments, describing how simulations helped demystify abstract topics, increased student participation, and fostered a more active learning environment. At the same time, both groups acknowledged practical barriers such as limited access to computers, unreliable internet, and initial digital unfamiliarity among some students. Importantly, these challenges did not undermine the perceived benefits but rather pointed to the need for better infrastructure, sustained teacher support, and thoughtful implementation. When these conditions are met, simulations can meaningfully enhance the quality of science education by making chemistry more accessible, interactive, and relevant to learners.

4.6 Teachers' Perspectives on the Support Needed for Successful Implementation of Computer Simulations

This section presents the qualitative findings related to the fourth objective of the study: to identify the support teachers need to effectively implement computer simulations in selected schools in Kapseret Sub-County. Data was collected through semi-structured interviews with teachers and analyzed thematically. Thematic analysis enabled the researcher to inductively identify patterns that reflect teachers' practical needs and perspectives. Responses were organized into four major themes and related sub-themes, as summarized in Table 4.7.

Table 10 Themes and Sub-Themes on Teacher Support for Computer Simulation.

Theme	Categories
1. Technical and Infrastructure Support	• Need for Reliable Computers • Internet vs Offline Options • Technical Assistance in Schools • Teacher Digital Readiness
2. Administrative and Policy Support	• School Investment in ICT Infrastructure • Equitable Student Access • Inclusion in Curriculum and Budgeting
3. Teacher Professional Development	• Continuous Training on New Technologies • Skills for Developing Local Simulations • Motivation and Incentives
4. Contextual Recommendations	• Locally Developed Simulations • Well-Equipped Computer Labs

4.6.1 Theme 1: Technical and Infrastructure Support

The most immediate and frequently cited concern among teachers was the lack of dependable digital infrastructure in schools. This challenge affected nearly every stage of implementing computer simulations in chemistry classes, from lesson preparation to classroom delivery and student engagement. Four key areas emerged under this theme: (1) Need for Reliable Computers, (2) Internet vs Offline Options, (3) Technical Assistance in Schools, and (4) Teacher Digital Readiness.

4.6.1.1 Need for Reliable Computers

Teachers emphasized that the number of computers in schools was too low to support whole-class activities involving simulations. In many cases, schools had only one functioning computer lab, often with outdated or non-functioning machines. This severely limited opportunities for students to interact directly with simulations, especially in large classes.

> *"The number of computers are not enough."* (Teacher 1)

This brief but telling statement reflects a structural problem. The few available computers were often shared among many students, making hands-on learning difficult.

> *"Computers should also be issued to the students so that each one, or at least every two, can access one and work on an activity comfortably."* (Teacher 2)

This suggestion points to the ideal learning conditions where simulations can be most effective: minimal device sharing, allowing for meaningful engagement. In practice, however, teachers reported situations where 6 to 10 students had to gather around one screen, reducing both visibility and participation. This constraint undermines one of the core advantages of simulations, personalized, active learning.

4.6.1.1 Internet vs Offline Options

Another technical constraint was the issue of internet connectivity. Many schools in the study area relied on unstable or limited internet service, which directly affected the usability of web-based simulations. Teachers described how lessons were frequently interrupted or had to be canceled due to poor connectivity.

> *"The internet should also be more reliable. Sometimes, we plan to use the simulations, but the network fails just as the lesson begins."* (Teacher 1)

The timing of such disruptions not only wastes valuable lesson time but can discourage teachers from attempting to use simulations altogether. Recognizing this, teachers proposed solutions that balance ambition with practicality:

> *"We need offline versions… in case of connectivity issues, so we're not forced to cancel or postpone a lesson."* (Teacher 1)

This sentiment suggests a strong preference for hybrid tools, resources that can be downloaded and used offline when internet access is not guaranteed. It reflects a grounded understanding of their own working conditions and a desire for flexibility in digital tools.

4.6.1.3 Technical Assistance in Schools

Teachers noted that even when computers and internet were available, technical glitches were common. What made these issues especially frustrating was the absence of dedicated IT support staff in most schools. Without someone to troubleshoot software or hardware problems, teachers often found themselves stranded mid-lesson.

> *"We also need technical support to troubleshoot software issues, because not all teachers know how to fix them, and it wastes lesson time."* (Teacher 2)

In many cases, teachers had to pause the lesson, seek help from a colleague, or simply abandon the digital activity. This lack of support made simulation-based instruction feel risky and unpredictable. The teachers' request is not just for equipment, but for reliable systems and personnel that can support digital integration on a day-to-day basis.

4.6.1.4 Teacher Digital Readiness

A recurring, and often unspoken, barrier to simulation use was teacher comfort with technology. While some teachers had strong ICT skills, others lacked the confidence or training to use computers effectively in a lesson. This uneven digital literacy was seen as a major implementation gap.

> *"Some teachers are computer-shy. They avoid using the lab unless it's absolutely necessary."* (Teacher 1)

This comment underscores the human side of the infrastructure challenge. Even in schools with functioning labs and internet, underuse can occur if teachers feel intimidated by the tools or fear failure in front of students. Teachers who are not confident in navigating basic applications may find the idea of using simulations overwhelming, especially under time pressure.

Improving digital readiness among teachers requires more than access to devices. It involves sustained support, mentorship, and hands-on opportunities to build familiarity and confidence. Without this, efforts to introduce simulations may be limited to a few tech-savvy teachers, leaving others behind.

These findings suggest that while infrastructure challenges such as insufficient computers and unreliable internet remain significant, they are part of a broader system of technical and human constraints. Even when digital tools are available, their use depends heavily on whether teachers feel equipped to use them, and whether support systems are in place to manage problems when they arise. These findings are consistent with Mukama (2023), who emphasized that technical barriers, both hardware-related and human, must be addressed simultaneously if digital tools are to be effectively used in classrooms.

4.6.2 Theme 2: Administrative and Policy Support

Teachers made it clear that the integration of computer simulations in chemistry lessons cannot rest solely on individual effort. Without administrative backing and policy-level inclusion, their use remains ad hoc and unsustainable. This theme is organized around three key areas: (1) School Investment in ICT Infrastructure, (2) Equitable Student Access, and (3) Inclusion in Curriculum and Budgeting.

4.6.2.1 School Investment in ICT Infrastructure

Several teachers pointed out that while they understood the value of simulations, their ability to use them meaningfully was limited by what their school leadership prioritized. In particular, they called for direct investment in the physical infrastructure needed to support digital learning.

> *"Administrators should invest in more ICT infrastructure."* (Teacher 2)

This was more than just a plea for more computers; it reflected the belief that school leaders play a critical role in whether or not digital tools are used in classrooms. Teachers noted that some school heads showed limited interest in ICT-related initiatives, which led to outdated labs, under-maintained equipment, and no structured plan for technology use in teaching science.

There was also a strong preference for subject-specific infrastructure. Instead of relying on shared labs that were often scheduled across departments, teachers called for dedicated spaces where science simulations could be regularly integrated into lessons.

> *"We need computer labs specifically for science, so chemistry and biology teachers can plan around it, not fight for space."* (Teacher 1)

This would allow science departments to take ownership of digital resources and incorporate them consistently, rather than sporadically.

4.6.2.2 Equitable Student Access

Teachers also raised the issue of student access, not just in terms of the number of devices, but how these were allocated during lessons. In overcrowded settings, multiple students had to cluster around a single computer, making it difficult for everyone to engage meaningfully.

> *"Instead of a whole group of 5 to 10, let it be per 2 or 3 students."* (Teacher 1)

This quote highlights a key concern: when group sizes are too large, students either lose interest or passively observe rather than interact. Teachers believe that smaller groupings, ideally pairs or triads, would enhance student participation and learning outcomes. However, this goal requires policy and administrative changes, not just pedagogical intention. Without sufficient hardware and structured timetabling, equitable access remains out of reach.

Some teachers added that this imbalance reinforces existing inequalities: students who are more assertive tend to dominate device use, while others, particularly girls or quieter students, are left out.

4.6.2.3 Inclusion in Curriculum and Budgeting

Another recurring issue was the perceived disconnect between what teachers know can enhance learning, such as simulations, and what the formal curriculum prioritizes. Several teachers noted that unless simulations are explicitly included in the national curriculum, they will remain optional and underused.

> *"Policymakers should consider including computer simulations in the official curriculum and allocate funds."* (Teacher 1)

Teachers expressed frustration that despite evidence of their benefits, simulations were often treated as enrichment activities rather than core components of instruction. This marginal status means that schools are under no obligation to support their use, and teachers often lack the time, resources, or motivation to incorporate them consistently.

In addition to curriculum inclusion, teachers called for financial planning at the national and school levels to support simulation use. This includes budget lines for equipment upgrades, software licenses, and teacher training. Without this backing, simulation use remains dependent on the personal initiative of individual teachers, which is neither scalable nor fair.

Taken together, these findings show that successful implementation of computer simulations depends on both school-level leadership and broader policy reform. Teachers are willing to integrate these tools, but they need supportive systems to do so sustainably. These insights echo the work of Gong et al. (2022), who emphasized that innovations like simulations are most effective when embedded in educational policy, curriculum, and budgeting processes, ideally under the guidance of the TPACK framework, which aligns technology use with pedagogy and content knowledge.

4.6.3 Theme 3: Teacher Professional Development

While infrastructure and policy support were seen as foundational, many teachers emphasized that these alone are not enough. The ability to effectively use computer simulations depends heavily on teachers' skills, confidence, and motivation. This theme breaks down into three main areas: (1) Continuous Training on New Technologies, (2) Skills for Developing Local Simulations, and (3) Motivation and Incentives.

4.6.3.1 Continuous Training on New Technologies

A recurring point across interviews was the need for sustained, up-to-date training. While some teachers had attended introductory workshops on educational technologies, they felt that one-off sessions weren't enough to keep up with the evolving nature of digital tools.

> *"Teachers should receive continuous training on new technologies."* (*Teacher 2*)

This need was especially pressing in science subjects like chemistry, where simulations can be complex and require familiarity with subject-specific software. Teachers wanted structured, long-term professional development—not just informal peer sharing or ad hoc workshops. Many felt that training programs should be embedded into their regular teaching schedules, with dedicated time and follow-up sessions.

4.6.3.2 Skills for Developing Local Simulations

In addition to learning how to use existing simulations, several teachers expressed interest in creating their own. They believed that locally developed simulations would be more relevant to their curriculum and student needs. However, most felt they lacked the technical expertise to do this.

> *"The government should train teachers on how to make more of these simulations."* (Teacher 1)

This points to a desire not just for technical competence but for creative autonomy. Teachers want to move from passive users to active contributors. Being able to customize or create simulations tailored to the local syllabus, cultural context, and available resources would make these tools more meaningful and usable in practice.

Some teachers also noted that simulations imported from foreign curricula often didn't align with local teaching goals or exam content. Training that includes basic coding skills, open-source tools, or collaborative development environments could empower teachers to design and adapt simulations themselves.

4.6.3.3 Motivation and Incentives

Beyond technical skills, teachers raised the issue of motivation. While some were genuinely enthusiastic about using simulations, others struggled to see their value or felt too overburdened to try something new. Several mentioned that without tangible support or recognition, teachers may not be willing to invest the extra time needed to learn and integrate these tools.

> *"Maybe… have a reward for teachers who use these simulations because it is beneficial."* (Teacher 1)

This quote reflects a broader concern: when new teaching approaches are introduced without supportive structures, uptake tends to be uneven. Teachers suggested that rewards—such as professional recognition, certificates, advancement opportunities, or even financial bonuses, could incentivize broader use. Some also mentioned non-monetary motivation, such as showcasing good practices or creating peer mentorship networks.

There was also an underlying sense that those who took initiative often did so in isolation. Formalizing incentives and building supportive communities of practice could address both burnout and reluctance.

Overall, the data reveals that teacher development in the context of simulations is not just a matter of digital literacy. It requires sustained engagement, opportunities for skillbuilding in content creation, and a system that values and rewards effort. These findings are in line with Traube (2023) and Rodríguez-Becerra et al. (2020), who argue that both ongoing training and meaningful incentives, intrinsic and extrinsic, are necessary for embedding digital tools into daily classroom practice.

4.6.4 Theme 4: Contextual Recommendations

In addition to identifying challenges and structural needs, teachers offered specific recommendations that reflect their daily teaching realities. These suggestions were grounded in the local context, particularly with respect to curriculum alignment and the practical learning environment. Two key areas emerged: (1) Locally Developed Simulations and (2) Well-Equipped Computer Labs.

4.6.4.1 Locally Developed Simulations

Many teachers noted that while computer simulations have great potential, imported ones often fall short in relevance. Some covered topics not included in the Kenyan syllabus, used unfamiliar examples, or assumed access to resources not available in local schools.

> *"We should have locally developed simulations that are aligned with the Kenyan syllabus."* (Teacher 1)

This comment reflects a broader concern about cultural and curricular mismatch. Teachers want simulations that use examples, terminologies, and instructional sequences familiar to Kenyan learners. For instance, simulations based on Western curricula might include chemistry experiments that rely on chemicals or apparatus not commonly available in Kenyan labs, making it hard for students to relate what they see on screen to what they experience in class.

Several teachers also mentioned that locally developed tools could support better assessment preparation, as the content would more closely reflect what students are tested on in national exams. This alignment could make simulations not just more engaging, but more practical and impactful for both teaching and learning.

4.6.4.2 Well-Equipped Computer Labs

The second major recommendation was infrastructural: the call for computer labs designed and equipped with science education in mind. Teachers emphasized that general-purpose computer labs, if they existed at all, were often insufficiently equipped, overcrowded, or unavailable when needed.

> *"Every school should have a well-equipped computer lab with enough devices."*
> (Teacher 1)

This statement points to more than just having hardware. Teachers envisioned labs that had a reliable power supply, good ventilation, fast internet where needed, and enough machines to allow all students to participate meaningfully. Such a space would support simulations as well as a broader set of ICT-based learning activities, including data analysis, virtual experiments, and research.

Teachers also suggested that these labs be designated primarily for STEM subjects to reduce competition for access and to ensure that science teachers could plan simulations into their lessons more reliably. Together, these recommendations reflect a desire for educational tools and infrastructure that are not only functional but also responsive to the Kenyan teaching environment. Teachers are not calling for generic solutions, they are asking for digital tools that speak directly to their curriculum and conditions. These findings align closely with Rehman et al. (2021) and Beichumila et al. (2022), who argue for the localization of educational technologies and support systems to increase their usability and effectiveness.

The qualitative findings from this study point to a range of interrelated conditions that shape how computer simulations can be integrated into Kenyan secondary school chemistry instruction. Teachers identified several areas where support is either lacking or inconsistent, affecting their ability to use digital tools effectively in their classrooms.

A major concern was the state of technical and infrastructure support. Teachers repeatedly noted the shortage of reliable computers, which often forced students to crowd around single devices, limiting participation and hands-on engagement. Internet connectivity was another significant issue. Simulations that depend on a stable connection were frequently interrupted by slow or unreliable networks, frustrating both students and teachers. In response, some called for offline versions of simulation tools that could function without internet access. Additionally, the absence of onsite technical assistance meant that minor issues with software or hardware could disrupt an entire lesson. This created a need for dedicated IT support within schools. However, infrastructure alone was not seen as a complete solution. Teachers emphasized that digital readiness among their peers varied considerably. Some lacked confidence or familiarity with computers, making it difficult to integrate simulations into their teaching. As one teacher put it, "Some teachers are computer-shy," pointing to the need for capacity building alongside technical investment.

Beyond the classroom, teachers also spoke about the importance of administrative and policy support. Several respondents felt that school leadership should prioritize investment in ICT infrastructure, particularly by setting up dedicated computer labs for science subjects. Equitable access was a key concern, with teachers recommending smaller student-to-computer ratios to improve the quality of interaction during simulations. At the policy level, many felt that simulations should not be treated as optional supplements. Instead, they should be formally included in the curriculum and supported through targeted budgeting. Without such top-down support, teachers feared that simulation use would remain inconsistent and heavily dependent on individual initiative.

Professional development emerged as another central theme. Teachers expressed a need for ongoing training that goes beyond basic digital literacy. They wanted support in staying up to date with new technologies and, more importantly, in learning how to design or adapt simulations to their local teaching context. Some also raised the issue of motivation, noting that without recognition or incentives, even well-trained teachers might not consistently use simulations. This highlighted a broader concern about workload and professional expectations, suggesting that teacher development efforts must be backed by structural support and acknowledgment of the additional effort involved.

Lastly, teachers offered contextual recommendations that reflected a strong desire for locally relevant solutions. Many noted that simulations developed abroad often failed to align with the Kenyan curriculum or available resources. There was clear support for locally developed simulations that speak to the specific needs of Kenyan learners and are better suited to the teaching environment. This was closely linked to calls for better-equipped and subject-specific computer labs, which teachers saw as crucial to creating a reliable and focused setting for using digital tools.

These findings suggest that the successful integration of computer simulations in chemistry education requires a coordinated, multi-level approach. Infrastructure, policy, professional development, and local context all play important roles. Teachers are open to adopting simulations and see their value, but they need an environment that enables, not hinders, that adoption. These insights echo previous studies that have emphasized the need to view digital education in resource-constrained settings not just in terms of technology, but as part of a broader educational ecosystem that supports meaningful use.

4.7 Connection of the Findings to the Theory

This study was grounded in Constructivist Learning Theory, which holds that learners actively build knowledge through experience, reflection, and interaction with their environment. Originally developed by Jean Piaget and later expanded by Lev Vygotsky, the theory emphasizes hands-on learning, social interaction, and guided support as key to cognitive development. The findings from this study strongly align with these principles, showing that computer simulations in chemistry foster deeper understanding by providing interactive and exploratory learning experiences.

The results support the idea that students learn more effectively when they are active participants in the learning process. Those who used simulations demonstrated stronger grasp of chemistry concepts compared to those taught through conventional methods. The simulations allowed learners to explore, manipulate variables, and see the effects of chemical processes in real time, something conventional instruction doesn't typically offer. This kind of experiential learning reflects Piaget's emphasis on the importance of doing and discovery in building conceptual understanding.

The study also found that students of different genders benefited equally from simulation-based instruction. This supports Vygotsky's view of learning as a social process, where learners are supported through interaction with tools, teachers, and peers. The simulations created inclusive learning environments that allowed all students to engage with the content meaningfully, regardless of background or learning preference. In this way, they functioned as learning supports, helping students achieve more than they might on their own.

Student feedback further reinforced these findings. Learners expressed that simulations helped them understand topics more clearly, kept them motivated, and made it easier to apply what they had learned. These responses point to key constructivist ideas; that learning should be active, personally meaningful, and connected to real-world contexts. Teachers' experiences echoed this. Many reported that simulations helped make abstract ideas more accessible, sparked interest among students, and led to more active participation. This reflects the constructivist view that learners benefit from guided discovery and that teachers play a critical role in scaffolding the learning process.

The study also revealed practical challenges, such as limited infrastructure, gaps in digital skills, and insufficient support. These issues underscore a key point in Vygotsky's theory: learning tools are only effective when supported by a conducive environment. For simulations to reach their full potential, schools need proper resources, teacher training, and administrative backing. Without these, even the best tools fall short.

Beyond theory, the study's findings are especially relevant in the context of science education reform in Kenya. As the education system shifts toward competency-based learning, tools like simulations offer a concrete way to promote critical thinking, problem-solving, and active engagement. However, implementation must go hand in hand with investment in capacity building and support structures to make these changes sustainable. The subsequent chapter entails the summary of findings, conclusion and recommendations.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter presents the final part of the study and focuses on summarizing the key findings, drawing conclusions based on the research objectives, and offering recommendations for practice, policy, and future research. The chapter is structured into five main sections. Section 5.1 provides a summary of the entire study, highlighting the purpose, methodology, and major findings. Section 5.2 outlines the key findings as per each research objective. Section 5.3 presents the overall conclusions derived from the study's results. Section 5.4 offers practical, policy, and research-based recommendations for stakeholders. Finally, Section 5.5 provides a reflective overview of the study, discussing its significance and potential implications for the future of chemistry education in Kenya.

5.1 Summary of the Study

This study examined the influence of computer simulations on students' academic performance in chemistry in selected secondary schools in Kapseret Sub-County, Kenya. The findings of this study addressed the identified gaps in Chapter Two by providing local evidence from Kenyan secondary schools on the role of computer simulations in improving performance and engagement in chemistry.

Specifically, it aimed to determine whether the use of simulations led to differences in performance between experimental and control groups; to analyze performance differences by gender; to assess the perceptions and experiences of both teachers and students in using simulations; and to explore the support teachers require for effective implementation of computer simulations in chemistry instruction.

The study was grounded in the constructivist learning theory, which posits that learners construct new knowledge by actively engaging with learning materials and experiences. A pragmatic research paradigm was adopted to integrate both qualitative and quantitative approaches, allowing for a comprehensive exploration of the research problem. The embedded quasi-experimental design was employed, involving pre-test and post-test assessments of experimental and control groups. The experimental group was exposed to chemistry instruction using computer simulations, while the control group received instruction using conventional methods. Quantitative data were analyzed using independent samples t-tests and one-way ANOVA, while qualitative data obtained from interviews were analyzed thematically. The findings are summarized below in line with the research objectives.

5.2 Summary of Key Findings

5.2.1 Differences in Learners' Performance Between Experimental and Control Groups

The independent-sample t-test revealed a significant difference in mean post-test scores between experimental ($M = 68.5$) and control groups ($M = 52.3$; $p < 0.05$), indicating that computer simulations improved academic performance in chemistry. The study found that students taught using computer simulations performed significantly better than those taught using conventional methods. The experimental group showed greater improvement in post-test scores compared to the control group, demonstrating that simulations enhance conceptual understanding and retention of chemistry content. The interactive and visual nature of computer simulations helped demystify abstract concepts, making them more accessible to students.

5.2.2 Gender Differences in Performance Within Experimental and Control Groups

Two-way ANOVA showed no significant gender effect ($p > 0.05$), implying that both male and female students benefited equally. The results showed no statistically significant difference in post-test performance between boys and girls in the experimental group. This indicates that computer simulations positively impacted both genders equally. In the control group, however, boys performed slightly better than girls, though not to a statistically significant extent. This finding suggests that computer simulations can help bridge the gender gap often observed in science subjects, providing equitable learning opportunities for all learners.

5.2.3 Students and Teachers Perceptions and Experiences with the Use of Computer Simulations in Chemistry Instruction

Qualitative analysis indicated that most students found simulations engaging and easier for understanding abstract concepts, while teachers appreciated their visual and interactive nature. Students reported positive experiences with computer simulations in chemistry instruction. They found the simulations engaging, easy to use, and helpful for understanding complex topics. Many noted that simulations improved their confidence, motivation, and ability to apply concepts in practical contexts. Compared to conventional teaching methods, simulations were seen as more effective in keeping their attention and making content clearer. Overall, students viewed simulations as a valuable tool that enhanced both their interest and learning outcomes in chemistry.

Interview data from teachers further highlighted the educational benefits of simulations, particularly in supporting conceptual understanding and active learning. Simulations were described as especially useful for abstract topics like atomic structure, where visualization is critical. Teachers observed increased participation, confidence, and enthusiasm among students when simulations were used. However, challenges such as limited digital infrastructure, unreliable internet, and students' initial unfamiliarity with technology were noted. Despite these barriers, teachers saw clear potential in simulations and emphasized the importance of addressing contextual constraints to maximize their impact.

5.2.4 Teachers’ Perspectives on the Support Needed for Implementing Computer Simulations

Teachers highlighted the need for technical support, ICT training, and adequate computer access as prerequisites for effective implementation. Teachers highlighted several key areas of support needed to successfully implement computer simulations in chemistry instruction. A major concern was the lack of reliable infrastructure. Many schools had too few functioning computers, forcing students to share devices in large groups, which limited engagement. Unstable internet connections further disrupted lessons, prompting teachers to call for offline versions of simulations. The absence of technical support staff meant that even minor glitches could derail a class, and teachers without strong ICT skills found it challenging to troubleshoot issues on their own. There was also a clear need for targeted capacity building, as some teachers lacked the confidence or digital readiness to integrate simulations effectively into their lessons. This suggested that infrastructure alone isn’t enough, teachers also need consistent, hands-on training and support.

Beyond technical issues, teachers pointed to the need for administrative and policy-level backing. They felt that simulation use should be formally included in the curriculum and supported through school budgets. Without this, digital tools remained optional and underused. Teachers recommended dedicated computer labs for science subjects, smaller student-to-computer ratios, and investment in simulations aligned with the Kenyan syllabus. They also expressed interest in learning how to develop or adapt local simulations, which would be more relevant and accessible. Motivation was another factor, teachers suggested that professional recognition or incentives could encourage wider adoption of simulation-based instruction. Overall, the findings show that for simulations to be used meaningfully, teachers require both structural support and the professional autonomy to adapt tools to their specific context.

The Chemistry Achievement Test used in this study was developed in consultation with experienced chemistry educators and aligned with the secondary school chemistry syllabus approved by the Kenya Institute of Curriculum Development (KICD). Content validity was ensured through expert review by two subject specialists, while reliability was confirmed through a pilot test with a Cronbach's alpha coefficient of 0.82, indicating high internal consistency.

5.3 Conclusion

1. The study concludes that computer simulations have a significant positive impact on students' academic performance in chemistry. Computer simulations significantly enhance students' academic performance in chemistry compared to conventional teaching methods. When students are taught using interactive, visual tools, they demonstrate improved

conceptual understanding, retention, and application of knowledge. The findings show that simulations support deeper learning, particularly in abstract topics, and offer a more effective approach to science instruction than conventional teaching methods. Strengthening the integration of computer simulations into the chemistry curriculum can further improve student outcomes and engagement, ensuring more meaningful learning experiences.

2. Computer simulations provide an inclusive learning environment that benefits both male and female students equally. The absence of significant gender differences in the experimental group indicates that simulations help bridge gender gaps commonly observed in science performance. In contrast, slight disparities persisted in the control group, suggesting that conventional methods may not equally support all learners. Adopting simulation-based instruction can therefore contribute to gender equity in science education, fostering equal opportunities for academic achievement across student populations.

3. Computer simulations are widely perceived by both students and teachers as effective instructional tools in chemistry education. Students find simulations engaging, easy to use, and helpful for understanding complex content, while teachers observe increased motivation, participation, and confidence in learners. These tools also support more active, student-centered classrooms. Despite initial challenges related to technology access and infrastructure, simulations were seen as valuable in making abstract content more accessible. Enhancing digital readiness and providing supportive environments for both teachers and learners can strengthen the impact of simulations on science instruction.

4. Finally, the study concludes that chemistry teachers require comprehensive support systems to effectively implement computer simulations in the classroom. Reliable

infrastructure, access to devices, offline simulation options, and targeted capacity building are essential to overcome the practical barriers that currently limit simulation use. In addition, administrative and policy-level support, such as curriculum alignment, formal integration of simulations into teaching plans, and sustained funding, is crucial. Teachers also need autonomy to adapt digital tools to local contexts and content. Strengthening institutional support, investing in professional development, and addressing structural challenges can enable broader adoption and meaningful use of computer simulations, ultimately transforming chemistry instruction in Kenyan secondary schools.

5.4 Recommendations

The study makes the following recommendations:

i. **Integrating Computer Simulations into the Chemistry Curriculum:** The Ministry of Education, Kenya Institute of Curriculum Development (KICD), and secondary school curriculum panels should formally integrate computer simulations into the national chemistry syllabus. This includes identifying key topics that benefit from visual and interactive learning, such as atomic structure and chemical bonding, and ensuring simulations are included in instructional guides, teacher training materials, and lesson plans. Schools should also prioritize the inclusion of simulation-based assessments in both classroom and national evaluations to reinforce their instructional value and encourage widespread use among teachers.

ii. **Sustaining Gender-Equitable Learning through Simulation Use:** Given that computer simulations demonstrated no significant gender differences in performance, Ministry of Education stakeholders should prioritize their continued use to maintain and reinforce equitable learning outcomes in science. Schools should ensure that both boys and girls have equal access to simulations and that classroom practices support balanced participation. Teacher training programs should highlight the role of simulations in reducing gender disparities and encourage teachers to sustain these gains by using simulations consistently across all topics.

iii. **Expanding Infrastructure and Capacity for Effective Simulation Use:** The Ministry of Education, in collaboration with county governments and school boards, should invest in expanding digital infrastructure, including reliable internet, functioning computers, and dedicated computer labs in secondary schools. Schools should implement policies to reduce student-to-computer ratios, such as through rotational lab access or mobile computer carts. Teachers should receive hands-on, continuous professional development on simulation use, troubleshooting, and integration into teaching. Technical support staff should also be deployed to schools or regions to help resolve ICT-related challenges promptly.

iv. **Strengthening Institutional and Policy Support for Simulation-Based Teaching:** The Teachers Service Commission (TSC) and the Ministry of Education should include simulation-based instruction in teacher appraisal and development frameworks. Simulation use should be promoted through national science education programs and recognized as an innovative pedagogy. Furthermore, schools should be encouraged to localize or co-create simulations aligned with the Kenyan syllabus to improve relevance, accessibility, and learner engagement.

Incentives such as professional recognition or awards for innovation in digital instruction could motivate wider adoption among teachers.

By implementing these recommendations, education stakeholders can enhance the impact of computer simulations on student learning, address access and equity issues, and create supportive environments that enable effective and sustainable use of digital tools in science instruction across Kenyan secondary schools.

5.5 Suggested Areas for Further Research

Based on the findings of this study, several areas warrant further investigation to build on the current understanding of computer simulation-based instruction in chemistry and its broader educational implications:

i. A longitudinal study on the long-term effects of computer simulations on students' academic performance and knowledge retention.
ii. A study on the impact of teacher training models on the effective integration of computer simulations in classroom instruction.
iii. A study on strategies for equitable implementation of computer simulations in under-resourced school settings.
iv. A comparative study could examine the challenges and opportunities of using computer simulations in rural versus urban school settings.

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APPENDICES

Appendix I: Chemistry Achievement Test

Post-test

1. This test is divided into three sections: Multiple Choice, Short Answer, and Diagram Interpretation.

Section A: Multiple Choice Questions (20 marks)

1. **Which subatomic particles are found in the nucleus of an atom?**
   - A) Electrons and neutrons
   - B) Protons and electrons
   - C) Protons and neutrons
   - D) Electrons only
2. **What is the chemical symbol for the element with atomic number 10?**
   - A) Na
   - B) N
   - C) Ne
   - D) Ni
3. **Which of the following statements best describes isotopes?**
   - A) Atoms of the same element with different numbers of protons
   - B) Atoms of different elements with the same number of neutrons
   - C) Atoms of the same element with different numbers of neutrons
   - D) Atoms of different elements with the same number of protons
4. **The relative atomic mass of an element is based on the following:**
   - A) Mass of an atom compared to a hydrogen atom
   - B) Mass of an atom compared to a carbon-12 atom
   - C) Number of neutrons in the atom
   - D) Number of electrons in the atom
5. **What is the maximum number of electrons that can occupy an atom's first energy level (shell)?**
   - A) 1
   - B) 2
   - C) 8
   - D) 18

6. **Which element has the electronic configuration 2, 8, 7?**
   - A) Fluorine
   - B) Chlorine
   - C) Sulfur
   - D) Nitrogen
7. **An atom with 12 protons, 12 neutrons, and 10 electrons is:**
   - A) A cation with a charge of +2
   - B) A neutral atom
   - C) An anion with a charge of -2
   - D) An isotope of magnesium
8. **The atomic number of an element represents:**
   - A) The total number of protons and neutrons
   - B) The number of protons in the nucleus
   - C) The number of neutrons in the nucleus
   - D) The number of electrons in the atom
9. **What is the name of the element with the symbol 'K'?**
   - A) Calcium
   - B) Potassium
   - C) Krypton
   - D) Nitrogen
10. **Which of the following elements has the smallest atomic radius?**
    - A) Lithium (Li)
    - B) Sodium (Na)
    - C) Potassium (K)
    - D) Rubidium (Rb)
11. **What is the mass number of an oxygen atom with 8 protons and 10 neutrons?**
    - A) 8
    - B) 10
    - C) 16
    - D) 18

12. **The number of protons in an atom's nucleus determines its:**
    - A) Chemical properties
    - B) Atomic mass
    - C) Atomic number
    - D) Number of isotopes
13. **Which of the following elements is a noble gas?**
    - A) Hydrogen
    - B) Helium
    - C) Lithium
    - D) Boron
14. **Which of the following pairs correctly matches the element with its symbol?**
    - A) Sodium - So
    - B) Magnesium - Mg
    - C) Iron - Ir
    - D) Carbon - Ca
15. **The element with atomic number 15 is:**
    - A) Nitrogen
    - B) Oxygen
    - C) Phosphorus
    - D) Sulfur
16. **An element has two isotopes: one with a mass of 10 amu and an abundance of 90%, and another with a mass of 11 amu and an abundance of 10%. What is the relative atomic mass?**
    - A) 10.1 amu
    - B) 10.5 amu
    - C) 10.9 amu
    - D) 11.0 amu
17. **What is the charge of an ion with 17 protons and 18 electrons?**
    - A) +1
    - B) -1

- C) +2
- D) -2

18. **Which elements are in Group 1 of the periodic table?**
    - A) Beryllium
    - B) Magnesium
    - C) Sodium
    - D) Calcium
19. **In which part of the atom are the electrons located?**
    - A) Nucleus
    - B) Electron cloud
    - C) Proton shell
    - D) Neutron shell
20. **Who is known for discovering the electron?**
    - A) Niels Bohr
    - B) Ernest Rutherford
    - C) J.J. Thomson
    - D) Dmitri Mendeleev

Section B: Short Answer Questions (20 marks)

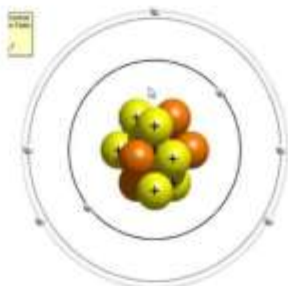
21. **Define the term 'atomic number' and explain its significance.**
    [3 marks]
22. **Calculate the number of neutrons in an isotope of carbon-14.**
    [3 marks]
23. **Describe what an isotope is and give two examples of elements with isotopes.**
    [4 marks]
24. **What are the electronic configurations of the following elements:**
    - a) Carbon (Atomic number 6)
    - b) Oxygen (Atomic number 8)
      [4 marks]
25. **An element has three naturally occurring isotopes with the following masses and relative abundances:**
    - Isotope 1: Mass = 20 amu, Abundance = 75%

- Isotope 2: Mass = 21 amu, Abundance = 20%
- Isotope 3: Mass = 22 amu, Abundance = 5%

Calculate the relative atomic mass of the element.
[6 marks]

Section C: Diagram Interpretation (10 marks)

26. **Label the following parts on the simplified diagram of an atom: nucleus, protons, neutrons, and electrons.**



[5 marks]

27. **Given the electronic configuration 2, 8, 6, draw the Bohr model for this atom and identify the element.**
[5 marks]

Answer Key and Scoring Guide

Section A: Multiple Choice Questions

1. C
2. C
3. C
4. B
5. B
6. B
7. A
8. B
9. B
10. A
11. D
12. C
13. B
14. B
15. C
16. A
17. B
18. C
19. B
20. C

One mark per correct answer, a total: of 20 marks

Section B: Short Answer Questions

21. **Atomic number**: The number of protons in the nucleus of an atom. It determines the element's identity and its position on the periodic table. *[3 marks]*
22. **Carbon-14**: Number of neutrons = Mass number - Atomic number = 14 - 6 = 8 neutrons. *[3 marks]*
23. **Isotope**: Atoms of the same element with different numbers of neutrons. Examples: Carbon-12 and Carbon-14; Hydrogen-1 (Protium) and Hydrogen-2 (Deuterium). *[4 marks]*
24. **Electronic configurations**:

- a) Carbon: 2, 4
- b) Oxygen: 2, 6 *[4 marks]*

25. **Relative atomic mass calculation**: Relative Atomic Mass=(20×0.75)+(21×0.20)+(22×0.05)\text{Relative Atomic Mass} = (20 \times 0.75) + (21 \times 0.20) + (22 \times 0.05)Relative Atomic Mass=(20×0.75)+(21×0.20)+(22×0.05) =15+4.2+1.1=20.3 amu= 15 + 4.2 + 1.1 = 20.3 \text{ amu}=15+4.2+1.1=20.3 amu *[6 marks]*

Section C: Diagram Interpretation

26. **Labeling should accurately identify the nucleus, protons, neutrons, and electrons.** *[5 marks]*
27. **The Bohr model should depict the placement of electrons: 2 in the first shell, 8 in the second shell, and 6 in the third shell. The element is sulfur (S).** *[5 marks]*

Chemistry Pretest (30 Marks)

Answer all questions.

- For multiple-choice, circle the correct letter.
- Write short-answer responses clearly in the spaces provided.
- Total marks: **30** (20 MCQs + 5 Short Answer Questions)

Section A: Multiple Choice Questions (20 marks)

Circle the correct option. Each question is worth 1 mark.

1. Which of the following is the most abundant gas in air?
   A) Oxygen
   B) Carbon dioxide
   C) Hydrogen
   D) Nitrogen
2. Which property of hydrogen makes it dangerous when mixed with air?
   A) It is colourless
   B) It is insoluble in water
   C) It forms an explosive mixture
   D) It supports combustion
3. What does oxygen do to a glowing splint?
   A) Puts it out
   B) Burns it
   C) Relights it
   D) Turns it red
4. Which of the following gases turns limewater milky?
   A) Hydrogen
   B) Oxygen
   C) Carbon dioxide
   D) Nitrogen
5. The correct word equation for preparing hydrogen in the lab is:
   A) Hydrochloric acid + Copper → Copper chloride + Hydrogen
   B) Zinc + Hydrochloric acid → Zinc chloride + Hydrogen
   C) Magnesium oxide + Water → Magnesium hydroxide
   D) Sodium + Water → Sodium hydroxide + Carbon dioxide
6. An acidic solution has a pH:
   A) Below 7
   B) Equal to 7
   C) Above 7
   D) Of exactly 14
7. Which of the following is a use of oxygen gas?
   A) Filling balloons
   B) Preserving food
   C) Cutting and welding metals
   D) Making fertilizers
8. What is the role of manganese (IV) oxide in preparing oxygen gas from hydrogen peroxide?
   A) Acid
   B) Base
   C) Catalyst
   D) Solvent
9. What happens to red litmus paper in an alkaline solution?
   A) Remains red
   B) Turns blue
   C) Becomes white
   D) Dissolves
10. Which method is used to collect a gas **insoluble in water** and **less dense than air**?
    A) Upward delivery
    B) Downward delivery
    C) Over water
    D) In a gas syringe
11. Which substance is commonly used to test for the presence of water?
    A) Litmus
    B) Limewater
    C) Anhydrous copper (II) sulfate
    D) Manganese dioxide
12. In the lab, which two substances react to produce oxygen?
    A) Zinc + Hydrochloric acid
    B) Copper + Nitric acid
    C) Hydrogen peroxide + Manganese (IV) oxide
    D) Sodium + Water
13. Which gas is **less dense than air and does not support combustion**?
    A) Oxygen
    B) Carbon dioxide
    C) Hydrogen
    D) Nitrogen
14. Which of the following is a basic oxide?
    A) Sulfur dioxide
    B) Calcium oxide
    C) Nitrogen dioxide
    D) Carbon dioxide
15. The pop sound when hydrogen burns is due to:
    A) Formation of carbon dioxide
    B) Explosion caused by oxygen

C) Sudden release of energy as water forms
D) The gas being flammable

16. Neutralization is a reaction between:
A) Acid and metal
B) Base and oxide
C) Acid and base
D) Base and salt

17. The pH of pure water is:
A) 0
B) 7
C) 14
D) 1

18. Which gas is used to inflate weather balloons because it is light?
A) Oxygen
B) Hydrogen
C) Carbon dioxide
D) Argon

19. What happens to cobalt chloride paper in the presence of water?
A) Turns red
B) Turns white
C) Turns blue
D) Turns pink

20. Which gas does not support combustion?
A) Oxygen
B) Hydrogen
C) Nitrogen
D) Air

Section B: Short Answer Questions (10 marks)

Answer all questions in the spaces provided. Each question is worth 2 marks.

21. State two physical properties of hydrogen gas.

-
-

22. Give one use of each gas:

- Hydrogen:
- Oxygen:

23. Write the word equation for the reaction between calcium and hydrochloric acid.

24. Name one acid and one base commonly used in the laboratory.

- Acid:
- Base:

25. Describe how you would collect dry oxygen gas in the lab.

Answer Key and Marking Scheme

Section A: (1 mark each)

1. D
2. C
3.
4. C
5. C
6. B
7. A
8. C
9. C
10. B
11. C
12. C
13. C
14. C
15. B
16. C
17. C
18. B
19. B
20. D
21. C

(**Total = 20 marks**)

Section B: (2 marks each)

21. - Colourless, odourless, lighter than air (any 2)
22. - Hydrogen: Used in balloons or fuel
- Oxygen: Used in welding or respiration
23. Calcium + Hydrochloric acid → Calcium chloride + Hydrogen
24. Acid: Hydrochloric acid; Base: Sodium hydroxide (any reasonable lab examples)
25. Collect over water using hydrogen peroxide and manganese(IV) oxide, use a gas jar and delivery tube

(**Total = 10 marks**)

Appendix II: Student Questionnaire

I, the undersigned, have been informed about the purpose, procedures, and benefits of this study titled "Influence of Computer Simulations on Students' Academic Performance in Chemistry in Selected Secondary Schools in Kapseret Sub-County, Kenya." I understand that participation is voluntary and that I may withdraw at any time without penalty. I consent to participate in this study.

Name: ____________________

Signature: _________________

Date: _____________________

This study aims to gather quantitative and qualitative data on students' experiences and perceptions regarding using computer simulations to learn atomic structure.

Demographic Information:

- **Gender:**
  - Male ☐
  - Female ☐
- **Age:**
  - Indicate your age in years…………………
- **School Type:**
  - Public Mixed Boarding
  - Public Girls Mixed
  - Public Mixed Day
  - Public Mixed Day & Boarding

Section A: Experience with Computer Simulations

Rate the following statements on a scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Sn	Items	1	2	3	4	5
1	I found the computer simulations easy to use.					
2	The computer simulations captured my attention and kept me engaged.					
3	The simulations helped me understand the concepts better.					
4	I feel more confident about the topic after using the simulations.					
5	Using the computer simulations motivated me to explore the topic further.					

Each question can be rated on a 1-5 scale:
1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

Section B: Comparative Learning Experience

Responses can be rated on a 1-5 scale:
1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

Sn	Item	1	2	3	4	5
1	I understand the concepts better through simulations than through conventional teaching methods.					
2	The computer simulations were more engaging than conventional classroom instruction.					
3	I feel more motivated to learn when using simulations than conventional teaching approaches.					
4	The simulations provided clearer explanations of the material than conventional methods.					
5	Using simulations improved my ability to apply concepts in practice more effectively than conventional teaching.					

Section C: Open-ended Questions

What specific features of the computer simulations were most beneficial to your learning experience?
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Were there any challenges you encountered while using the simulations? How did you address them?
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Compare your experience using computer simulations to conventional teaching methods. What differences stood out to you?
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How did the simulations enhance your motivation or interest in the subject?

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………

How could the computer simulations be improved to support your learning better?

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Appendix III: Interview Guide for Teachers

- **Experience and Perception:**

How did you integrate computer simulations into your teaching practice?……………………………………………………………………………
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………………………………………………………………………………………
…………………

What differences did you observe in student performance and engagement?…………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………………

- **Challenges and Solutions:**

What challenges did you encounter while using simulations?…………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………………

How did you address these challenges, and what would you suggest to improve this teaching method?
………………………………………………………………………………………
………………………………………………………………………………………
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………

Support needed

What forms of support do teachers need to integrate computer simulations effectively?
………………………………………………………………………………………
………………………………………………………………………………………

How do school policies and infrastructure affect your use of simulations?
………………………………………………………………………………………
………………………………………………………………………………………

What challenges have you experienced in implementing simulation-based lessons?
…………………………………………………………………………………………
…………………………………………………………………………………………

Appendix VI: Map of Study Area

Fig 2: Map of Kapseret Sub-County.

Appendix VII: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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Date of Issue:**03/January/2025**

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