AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

IMPACT OF COMPUTER SIMULATION ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPAL

ISAAC OWUSU

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Isaac Owusu

Signature: ……………………………… Date: …………………………………….

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

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Signature: ……………………………… Date: …………………………………….

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Last but not the least, I am thankful to all researchers and authors whose works have been cited in this study.

However, I solely assume responsibility for any defect or shortcoming, marginal or substantial that may be found in this study.

DEDICATION

I gladly dedicate this work to my wife, Dorcas Dwamena, my children, Abena Ampong Owusu and Adwoa Agyekumwaa Owusu for their love, care, and continual support while in school.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAIP	Computer Aided Instructional programs
DNA	Deoxyribonucleic Acid
ELT	Experiential Learning Theory
ICT	Information Communication Technology
MOOC	Massive Open Online Course
PCK	Pedagogical content knowledge
PhET	Physics Education Technology
PCR	Polymerase chain reaction
WAEC	West African Examinations Council

ABSTRACT

This study investigated the impact of computer simulations on the teaching and learning of genetics in senior high school students in the Kwadaso Municipality. The study adopted a mixed-methods approach within a quasi-experimental research design, specifically employing the non-equivalent control group pre-test and post-test design. The target population comprised Form Three biology students in public senior high schools in the municipality. Using purposive and simple random sampling techniques, a sample size of 206 students and 2 teachers were selected for the study. Three main instruments were used for data collection: a structured questionnaire to assess students' attitudes, a performance test to evaluate academic achievement, and an interview guide to explore implementation challenges. Data were analyzed using both descriptive and inferential statistics, as well as deductive thematic content analysis. The findings revealed that students exposed to computer simulations demonstrated significantly improved academic performance in genetics compared to those taught using conventional methods. Additionally, students exhibited a generally positive attitude towards the use of computer simulations in learning, appreciating its interactive and visual appeal. However, challenges such as inadequate ICT infrastructure, lack of teacher training, and limited access to simulation tools were also identified. The study concludes that computer simulations can be a highly effective pedagogical tool in genetics education when implemented under the right conditions.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter focuses on the background to study, problem statement, study objectives, research questions, justification of the study, significance of the study, limitation of the study, delimitation of the study, and organization of the study.

1.1 Background to the Study

Technological advancement is contributing immensely to educational development in the 21st century. In reward of Ouahi et al. (2022), technology in education enable learners control their own learning process, as well as offer them ready access to a vast amount of information over which the teacher has no control. Tebabal and Kahssay (2011) see these benefits, as the reasons why most educational systems are adapting to the changes brought about by today's technological advancement. While most educational systems across the world are changing and modernizing the content of learning, technological adaptation may not be successful unless the teaching models are based on information resources.

Teaching models do not only offer practical education; they also enhance understanding. Computer Aided Instructional programs (CAIP) is one of the teaching models based on the use of information system resources. Computer-Aided Instructional Programs are software designed to facilitate and enhance learning experiences through computer-based instruction. They include educational tools, simulations, interactive tutorials, quizzes, and multimedia presentations.

Among Murugesan, (2021) observed that Computer simulations provide dynamic and interactive environments that allow users to explore concepts, practice skills, and experiment with various scenarios (Murugesan, 2019). These simulations help imitate real-world phenomena or abstract concepts, providing learners with a hands-on, experiential learning that complements traditional instructional methods. Simulation is a representation or model of an event, object, or some phenomenon (Thompson et. al., 1996). Akpan and Andre (1999) used computer simulation to model dynamic systems of objects in a real or imagined world in science education. These computer simulations gave students the opportunity to observe a real-world experience and interact with it. According to Strauss and Kinzie (1994), simulations are most useful for modelling labs that are impractical, expensive, impossible, or too dangerous to run. Simulations are useful in many other ways, including contributing to conceptual change (Stieff, 2003); providing open- ended experiences for students (Kevogo et al., 2013) and problem-solving experiences (Murugesan, 2019).

In the 21st Century, especially in advance countries, computer simulations have become more significant tool than other educational materials such as text books, novels, film and television, radio programs and podcasts in the classroom (Akhigbe et al., 2020). Its popularity is partly due to the fact that simulations are quite easy to introduce especially in today's curriculum. Many educators are using simulations for its efficiency (Morris, 2020). Again, in the field of genetics, computer simulations have revolutionized the teaching and learning of genetics by offering dynamic, interactive platforms that engage students in hands-on exploration (Rutten et al., 2012). These simulations provide a visual representation of complex genetic concepts to students, allowing them to manipulate variables, observe outcomes, and gain a deeper understanding of genetic principles. In the view of Gruner (2012), simulating genetic processes such as Mendelian inheritance, genetic recombination, and population genetics, can help students experiment with various scenarios, speeding up their comprehension and retention of genetic concepts.

Moreover, making mistakes in science labs can be very consequential for students. But computer simulations foster a culture of experimentation and critical thinking by offering a safe environment for students to make mistakes and learn from them without the fear of consequences. Again, genetics education has been made accessible by computer simulations which enhances diverse learning styles and help students with visual or auditory learning preferences benefit from the visualizations and interactive features of simulations, while those who struggle with abstract concepts grasp genetic principles through concrete, hands-on exploration (Akhigbe et al., 2020). From the foregoing, it can be said that simulations can help address problems with individual learning preferences with regard to learning paces and abilities, providing personalized learning experiences for students.

Furthermore, due to the flexibility of computer simulations educators are able to incorporate real-world examples and current research findings into their teaching (William et al., 2016). This helps to keep the curriculum relevant and engaging. Students ‘approaches to course contents have significant impact on their learning abilities. As a result, evaluating students ‘attitudes toward teaching and learning genetics may give educators, curriculum designers, and students information that will help them to conduct better lessons. According to Dziubaniuk et al. (2023), most students exhibit positive attitude to the use of computer simulations in the classroom.

The interactive and visual nature of simulations are well appreciated as students benefit from the clarity of complex genetic concepts and processes. Researchers have observed that simulations present learners with many advantages, including the exploration and experiment with different scenarios, making learning more engaging and enjoyable, and appreciating the hands-on approach to learning (Morris, 2020). According to Howden (2012), some students ‘express enthusiasm for the ability to manipulate variables and observe the effects on genetic outcomes, which deepens their understanding of genetic principles. They also value the opportunity to work at their own pace and repeat simulations as needed, which helps to reinforce their learning (Howden, 2012). On the other hand, other studies also reveal challenges and limitations of the simulations. Aykaç (2014) observed that the difficulties and expense of creating software during development, the time needed to create software appropriate for each acquisition, and the challenge of choosing and implementing a model that is exact to reality are some of the issues that hinder the use of simulations in education. Besides, the simulation model can suffer from increased system complexity in terms of time and cost aspects (Koç-Ünal, 2019). Other challenges associated with simulations include malfunctions or breakdowns due to human error and power interruptions (Bıçak, 2019), absence of real-life situations, lack of definitive answers, artificially over-simplicity, partial distortion of truth, among others. These challenges need to be resolved in order for simulation-based applications to achieve the desired result.

Empirically, Akwee et al. (2012), Asedillas et al. (2019), William et al. (2016), studied the effectiveness of integrating technology in their field of specializations.

Their studies showed positive outcomes in teaching-learning process. Also, Cakir found that simulations increase teachers and learners' potential of discovering more knowledge and how to apply it (Karagoz & Cakir, 2011). Theoretical teaching and learning lead students to lose motivation since they are unable to relate the material to real-world situations (Sifuna, 2016). This is corroborated by Mengistu and Kahsay (2015), who demonstrated that employing virtual simulations to teach enhances students' comprehension by offering a level of realism that is impossible to attain when utilising conventional teaching techniques. As a result, students who engage with computer simulations are motivated, comprehend various phenomena, and manage these in a variety of scenarios. Furthermore, students improve their cognitive skills, practise and study better inquiry, which is said to be a necessity for studying science, and use simulations to mimic real-world scenarios.

From the studies above, it could be deduced that there are limited studies on the impact of computer simulation on the teaching and learning of genetics in senior high schools and the studies done differs in methods, study area and findings, hence the purpose of this current study. Therefore, it is against this background that this study seeks to unearth the impact of using computer simulations on the teaching and learning of genetics in senior high schools in the Kwadaso Municipal Area.

1.2 Statement of the Problem

Since computer simulations provide visual and interactive representations of complex biological processes, they have become significant tool in teaching genetics in recent years. Most studies recognize simulation as an effective strategy for enhancing students understanding as well as igniting students interests in exploration and experimentation (Dziubaniuk et al., 2023, Morris, 2020). Despite this potential, many biology teachers in Ghana still prefer traditional teaching methods to the adoption of simulation technologies. In view of Ouahi et al. (2021) and Zumyil et al. (2022), this attitude may be attributed to a lack of training, limited access to technological resources, and insufficient pedagogical support. Recent reports issued by the West African Examinations Council (WAEC) (2019-2024) showed that students do not perform well in genetics-related questions. For instance, in 2020, the Chief Examiner's report attributed student's difficulty with questions involving gene formation and changes to abstract teaching approaches. Also, the WAEC (2019) report was not different as it emphasized that teachers' inability to effectively illustrate genetic concepts in teaching, contributed to students' difficulties in grasping the subject matter.

Many studies including Akigbe and Ogufefere (2020) and Okino (2023) have observed that integrating computer simulations in teaching can improve students' understanding and performance in genetics. Despite the increasing use of computer simulations in advance countries, the use of such technologies in biology classrooms by teachers remains limited in Ghana. Many schools do not have computers , suitable educational software, and adequate teacher training in technology integration.

Moreover, while there is a clarion call for the adoption of computer simulations in teaching genetics in Ghanaian schools, there is a dearth of localized, empirical research examining the effectiveness of these technologies in teaching. The extent studies offer mixed results, prompting the need for further investigation. Even the few studies, such as Okino (2023) which found that students taught using computer-assisted instruction performed better than those taught via traditional lectures are yet to be corroborated.

Due to the numerous challenges saddled with the traditional methods of instruction and learning genetics in Senior high schools, and the potential benefits to be derived from the use of simulation-based instruction, it is crucial to explore how computer simulations can enhance teaching effectiveness and student performance in genetics in Ghanaian senior high schools. Therefore, this research seeks to unearth the impact of computer simulations on the teaching and learning of genetics in senior high schools in the Kwadaso Municipal Area.

1.3 Objectives of the Study

1.3.1 Main Research Objective

The main objective for this study is to assess the impact of computer simulation on the teaching and learning of genetics in Senior High Schools in the Kwadaso Municipality, Kumasi.

1.3.2 Specific Research Objectives

This study addressed the following specific research objectives; to:

1. determine the attitudes of students towards the use of computer simulations to teach genetics.
2. explore the challenges of integrating computer simulations in genetics instruction from the perspective of teachers and students in senior high schools.

3. determine the impact of computer simulations on academic performance of students in genetics.

1.4 Research Questions

This following research questions guided the study:

1. What is the attitude of students towards the use of computer simulations in teaching genetics?
2. What are the challenges of integrating computer simulations in genetics instruction from the perspective of teachers and students in senior high schools?
3. What is the impact of computer simulations on academic performance of students in the teaching and learning in genetics?

1.5 Justification of the Study

Though computer simulation in teaching genetic is gaining acceptance, it appears introducing it in teaching genetics in senior high schools in Ghana and its impact on learning outcomes such as academic performance in genetics and engagement in learning genetics have is underexplored in Ghanaian senior high schools. Almost all the studies on computer simulations (for example, Akhigbe & Ogufere, 2022; Ouahi et al., 2021; Tolga, 2011; Okino, 2023) were done in countries other than Ghana. The study by Amafu (2015), Koomson et. al (2020) in Ghana were done in the area of chemistry, different from biology, and specifically genetic, hence, less is known in the use of computer simulation in teaching and learning genetics and its impact in Ghana. This study, therefore, bridges this gap in literature by focusing on computer simulation for teaching genetics and its impact of learning outcomes such as academic performance in genetics.

1.6 Significance of the Study

Studying the impact of using computer simulations in the teaching and learning of genetics in senior high schools in the Kwadaso Municipal Area has significance for educational policy makers, teachers and students. This study would bring to bear the significance and challenges of computer simulation for teaching and learning genetics in senior high schools in Ghana. This information would help educational policy makers to know whether to integrate computer simulation into teaching genetics in senior high schools and if so, how the computer simulation can be integrated into the biology curriculum. Also, the study would inform biology teachers whether computer simulation is a relevant pedagogical method in teaching biology in senior high schools. This would help biology teachers to know whether to adopt computer simulation for teaching genetics and how they can use computer simulations to achieve its intended purpose. Also, by identifying the strengths and limitations of using simulations in the classroom, biology teachers could refine their teaching approaches to better meet the diverse learning needs of students. This may involve integrating simulations into a broader inquiry-based learning framework or incorporating them into collaborative learning activities that promote critical thinking and problem-solving skills.

Finally, the study is significant for researchers in biology and other science disciplines. The study lays the foundation for research in computer simulation and its relevance in science education in Ghana. The findings from this study could serve as a springboard for other science researchers to research into computer simulation, its integration and impact in other science areas, helping to have a broad evidence-based knowledge about relevance of computer simulation in teaching and learning of science in Ghana.

1.7 Limitation of the Study

First of all, the study was conducted only in public senior high schools within the Kwadaso Municipal Area. As such, the findings may not be generalisable to other regions or private institutions where resources, teacher expertise, and student demographics may differ. Also, not all teachers involved in the study were equally trained or comfortable with using computer simulations. Lastly, variations in students‘ prior exposure to computers and their levels of digital literacy might have influenced how effectively they interacted with the simulations, potentially skewing the results related to both performance and attitude.

1.8 Delimitation of the Study

The study focused on computer simulation and its impact on teaching and learning of genetics. Though, there are many computer simulations, this study focused on Biology Simulations from PhET Interactive Simulations since it is the common computer simulation for teaching genetics. Also, in the area of teaching and learning, this study considered academic performance in genetics. The study was carried out in public senior high schools in the Kwadaso Municipal Area

1.9 Organization of the Study

This study was organized into five related chapters. Chapter one was on the introduction. Chapter two was the literature review, comprising the theoretical review, review of key concepts and empirical review. Chapter three was the methodology, detailing the research methods, how the data will be collected and analyzed. Chapter four focused on the results and discussion. Chapter five presented the findings from the study, and made conclusions and recommendations about the use of computer simulations for teaching and learning genetics in Ghanaian senior high schools.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter focused on theoretical reviews, definitions of key concepts, and empirical reviews for the study.

2.1 Theoretical Framework of the Study

2.1.1 Experiential learning theory

Experiential Learning Theory (ELT), developed by David Kolb (1984), emphasizes the importance of experiences in the learning process, positing that knowledge is created through the transformation of experience. Moreover, it uses experience to describe its vital difference from cognitive learning theory, which focuses on cognition and behavioral learning theory. This theory ignores the possible role of subjective experience in the learning process‖ (Cherry, 2019). The model of ELT (Figure 2.1) shows the process and sequence of experiential learning with its concepts, constructs, and proposition.

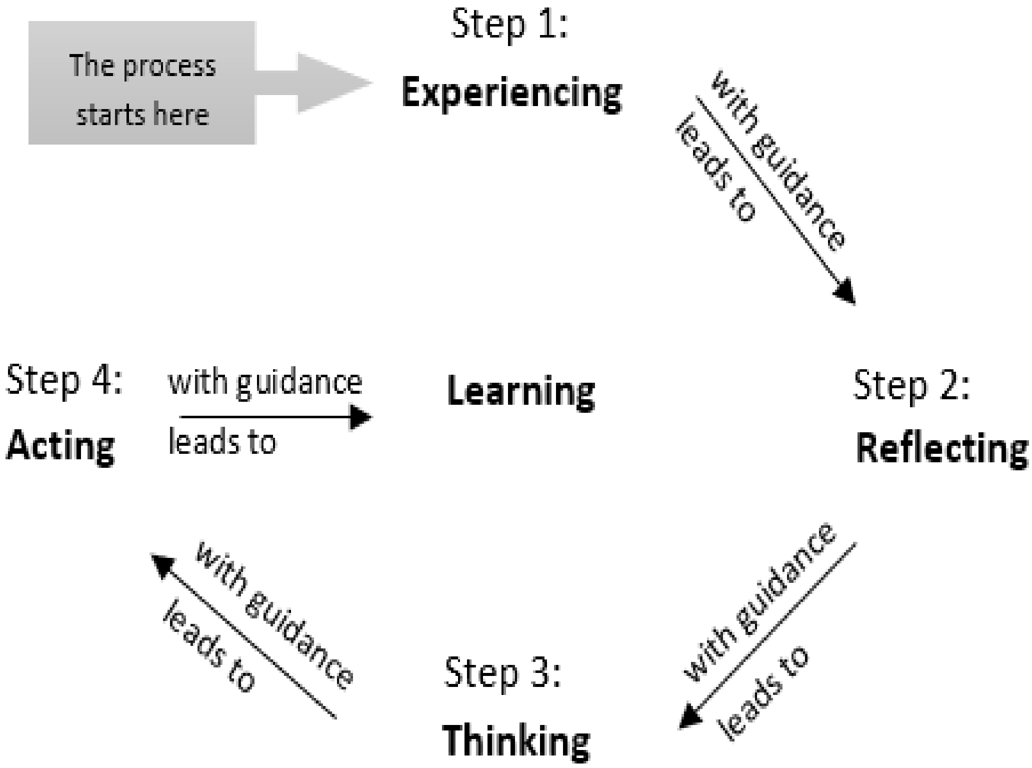

Figure 2.1: Model of Experiential Learning Theory (ELT)

The four primary ideas of the theory are experiencing, thinking, reflecting, and acting on an experience. These ideas deal with the phases of ELT, which begin when students encounter something novel. Following a "real" event, students might think back on it and go to the following phase, where they consider how to make accommodations for the experience. After being given the opportunity to reflect and ponder, students can turn their ideas into actions that produce new experiences and/or the learning construct, which allows them to repeat the process. (Manolis et al., 2013). According to ELT, any experience may be turned into a trustworthy source of information. The four-stage process experiencing, reflecting, thinking, and acting should be followed by students in order to make an experience a more significant and trustworthy source of information. Learners can acquire knowledge in a more significant way by doing this.

Among the benefits of computer simulations is that, it gives changing interactive environments, where learners can engage directly with the material, helping make abstract concepts concrete and observable. In view of Guthrie and Jones (2012), this direct engagement aligns well with ELT's four-stage cycle of learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. With regard to teaching and learning, ELT’s emphasis on concrete experience becomes particularly important in computer simulations. Also, Simulations enable students’ experiment with virtual scenarios that replicate real-world processes and events. For instance, during a biology class, students can use a simulation to observe cellular processes in action, manipulating variables and seeing immediate effects, which constitutes the concrete experience (Howden, 2012). This helps learners build a deeper, more spontaneous understanding of complex concepts, making the learning process more understandable and memorable (Morris, 2020).

After having concrete experience of a phenomenon, learners then move the next stage of ELT which is reflective observation. At this stage learners can review their actions and the outcomes, considering what happened and why. McDonald and Spence (2016) see this reflective practice as significant for solidifying knowledge and understanding. For example, after running a simulation on photosynthesis, students might reflect on the relationships between sunlight, carbon dioxide and water in the preparation of glucose which enhances their comprehension through critical thinking and analysis.

Moreover, through thinking, a process of abstract conceptualization in ELT, learners form theories and models using reflections and experiences obtained in the earlier stages of ELT. Computer simulations aid this process by providing a safe environment for experimentation and hypothesis testing. According to Manolis et al. (2013), learners are able to develop and refine their theoretical understanding of scientific phenomenon through modification of parameters and observation of outcomes. For instance, computer simulations offer chemistry students a risk-free environment to explore acids, bases, and salts with the use of abstract concepts, and manipulation of variables in order to gain a deeper understanding of reactions at different levels of experimentation.

Furthermore, Kolb explains how learners apply their newly acquired knowledge is real life situation in the last stage of his learning cycle. He calls this stage active experimentation. Manolis et al. (2013) shows how computer simulations facilitate this by offering varied scenarios and problems to solve, thereby allowing students to test their theories and apply concepts in diverse contexts. For example, in an economics course, students might use simulations to test how non-price factors affect demand and supply of product in a virtual economy, observing the outcomes and refining their understanding of economic principles.

Numerous research that employ experiential learning theory as a theoretical framework to examine its efficacy in the learning process have made it a focal point. For instance, Lai et al. (2007) examined the use of technology in experiential learning using ELT as a framework. They thought about how technology might be used to facilitate and offer experiential learning. According to their findings, students' knowledge improved when they used technology during the four-stage process (described above); stressing the value of experience allows students to act and think back on their choices.

Alkan (2016) also looked into how student teachers' performance in chemistry and their knowledge of the scientific method were affected by experiential learning. According to Alkan (2016), the phases and procedure of experiential learning can enable students to be aware of their professional identities, question their actions and note the importance of their suspicions. Alkan (2016), concluded that because experiential learning encourages students to go through a process of experiencing, reflecting, thinking, and acting upon their own experiences, it can have a good impact on their academic attainment and learning outcomes.

Furthermore, ELT served as the theoretical foundation for Arnold and Paulus's (2010) investigation of pre-service teachers. By utilising and experiencing technology firsthand, the aspiring educators gained insight into how their prospective pupils could use it in the classroom. They gained knowledge on how their future pupils would utilise that technology as a result. Additionally, the ELT process gave them the opportunity to consider and reflect on any difficulties their students might encounter

2.1.2 Connectivism Learning Theory

Connectivism learning theory is the second theory used in this study. This theory throws light on how crucial technology and social networks are to education. George Siemens developed it in 2005 to describe how knowledge is dispersed over networks and how it can be acquired through the recognition and navigation of those networks. According to the proponents of Connectivism, such as Bonk and Lee (2017), the acquisition of knowledge in the 21st Century goes beyond traditional means such as textbooks or lectures to include other source, such as digital communities, online social networks, and other technological mediums. Again, Kop and Hill (2008) see learning as a continuous process of investigation and insight, occurring both within and outside formal educational institutions. Since there are multiple sources of information available to learners, Connectivism posits that learners must be able to discern what is reliable and relevant. Besides, in order for Learners to develop new insights and apply them in different situations, they must have the ability to connect and synchronise different sources of information and knowledge. Despite Connectivis‘s expansion of the scope of learning, the critics have posited that the theory's focus on technology and social networks overshadows other important considerations, such as motivation, individual learning variations, and the impact of teachers. (Bonk & Lee, 2017).

In their response to criticisms, the proponents of Connectivism argue that the theory represents a new and innovative approach to learning that acknowledges the changing nature of knowledge and the importance of technology in contemporary society. This approach of learning recognizes the changing landscape of education in the digital age. In the nutshell, the Connectivist learning approach provides a valuable new perspective on learning and highlights the merit of social media and technological resources in the knowledge acquisition process. Learners who embrace the key tenet of this theory, can obtain the skills and understanding on how to thrive in a fast-paced world for the purposes of learning.

This theory is particularly relevant to the utilization of computer simulations in teaching and learning because it aligns with the idea that knowledge is distributed across a network of connections and learning consists of the ability to construct and traverse those networks (Turner, 2014). Computer simulations, as an educational tool, embody this principle by providing a dynamic and interactive environment where learners can explore complex systems and relationships. In the context of Connectivism, computer simulations facilitate learning by allowing students to engage with and manipulate variables within a simulated environment. This interaction helps them to see the immediate consequences of their actions, fostering a deeper understanding of the subject matter. For example, in a physics simulation, students can change parameters such as gravity, mass, or velocity and observe the results in real-time. This experiential learning aligns with the Connectivist idea that knowledge is actively constructed through engagement with the environment, rather than passively absorbed from a teacher or textbook (Turner, 2014).

Furthermore, computer simulations often incorporate elements of networked learning, where students can collaborate and share insights with peers (Dziubaniuk et al., 2023). This aspect is crucial in Connectivism, which posits that learning is a process of connecting specialized nodes or information sources. Simulations can be integrated with online platforms where learners discuss their findings, share strategies, and collectively solve problems. This collaborative approach not only enhances individual understanding but also builds a learning community, reflecting the Connectivist view that learning is a social and connected activity.

Another significant aspect is that computer simulations can adapt to the learners' needs and provide personalized feedback, which is essential in Connectivist learning. This feedback loop allows students to reflect on their learning process, adjust and deepen their understanding. For instance, in a business simulation, students can receive instant feedback on their decisions, helping them to understand complex economic principles and the interconnectivity of different business factors. This immediate and adaptive feedback supports the continuous, evolving nature of learning proposed by Connectivism (Al-Maawali, 2022).

Research by Kop and Hill (2008) investigated Connectivism's effectiveness in a professional development setting. Their findings indicated that Connectivism successfully facilitated the acquisition of new knowledge and skills, as well as the development of professional networks. Notably, Connectivism helped learners overcome time and space constraints, allowing them to learn at their own pace.

Similarly, Siemens and Tittenberger's (2009) study on a Connectivism-based Massive Open Online Course (MOOC) found that participants gained new knowledge and skills, which they could apply in practical situations. These studies demonstrate Connectivism's potential as a learning approach.

2.2 Conceptual Framework of the Study

The integration of computer simulation in science education, particularly genetics, has reshaped how concepts are taught and learned in senior high schools. This framework is grounded in constructivist learning theory, which posits that learners actively construct knowledge based on experiences (Piaget, 1972; Vygotsky, 1978), and is further supported by cognitive load theory, suggesting that well-designed simulations can reduce extraneous cognitive load, thereby enhancing learning efficiency (Sweller, 2011; Mayer, 2017). In the context of genetics—a subject often perceived as abstract and complex—computer simulations serve as interactive tools that allow learners to visualize, manipulate, and experiment with genetic processes, such as meiosis, DNA replication, and Mendelian inheritance (Akpan & Beard, 2019; Sarkar & Biswas, 2021). The framework assumes that computer simulations (independent variable) affect multiple dimensions of the teaching and learning process (dependent variable). These include students' conceptual understanding, engagement, and academic performance. Teachers also play a mediating role by integrating simulations effectively into pedagogy, thereby influencing the extent of the simulation's impact (Bello et al., 2023). Moreover, technological access and teacher competency are considered as moderating variables factors that may strengthen or weaken the effect of simulation use. According to recent studies, the use of computer simulations improves inquiry-based learning and enhances retention of complex scientific knowledge (Yusuf & Afolabi, 2020; Boateng et al., 2022). Simulations make it possible for students to repeat virtual experiments, get immediate feedback, and learn at their own pace, fostering deeper understanding (Effah et al., 2021). As such, this framework positions computer simulation as a transformative instructional strategy, especially when aligned with clear learning objectives, teacher support, and access to digital resources. Figure 2.2 depicts the diagram of the conceptual framework of this study.

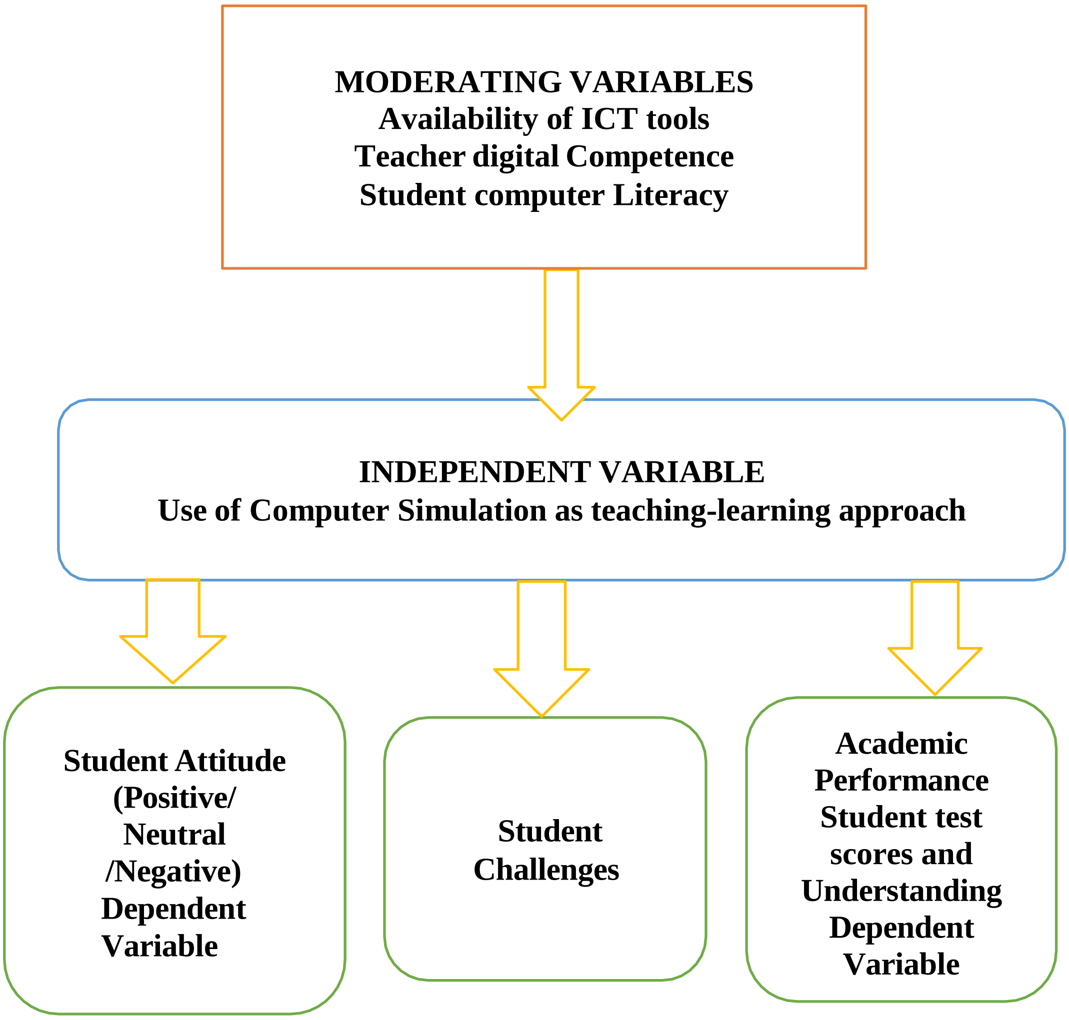

Figure 2.2: Conceptual framework of the study

This conceptual framework is structured around the central idea that computer simulation, when used as a teaching and learning tool, can influence students'academic performance, attitudes, and overall instructional effectiveness in genetics at the senior high school level. It also considers various challenges and moderating factors that shape the success of simulation integration in classroom settings. At the heart of the framework is the independent variable: the use of computer simulations. This variable encompasses the deployment of digital tools such as virtual labs, interactive simulations, and visual modeling platforms to teach abstract concepts in genetics. When simulations are properly integrated into instruction, they are expected to enhance learners' visualization, interaction, and experimentation, which are essential for internalizing complex biological concepts (Mayer, 2017; Sarkar & Biswas, 2021).

The first outcome variable is student's attitude towards computer simulations, which includes their interest, enthusiasm, and perceived usefulness of simulations in learning genetics. Positive student attitudes are crucial because they can increase engagement, motivation, and willingness to participate actively in simulation-based learning (Effah et al., 2021). The second outcome centers on the challenges faced by students. These include limited ICT infrastructure, inadequate training, time constraints, and lack of technical support. These challenges act as intervening variables that can either hinder or facilitate the successful implementation of simulations (Bello et al., 2023). Understanding these barriers is essential for improving the effectiveness of the intervention. The third outcome is students' academic performance in genetics, measured through test scores, conceptual understanding, and application of genetic knowledge. Simulations are expected to improve these outcomes by providing repeated practice, instant feedback, and interactive visualization of genetic processes (Yusuf & Afolabi, 2020). Finally, the framework identifies moderating variables such as the availability of ICT tools, teacher digital competence, and students' digital literacy, which influence the strength of the relationship between simulation use and learning outcomes. The collective effect of these components determines the overall effectiveness of teaching genetics using computer simulations.

2.2.1 Concept of Computer Simulations

Computer simulation, a computer model, or a computational model is a computer program, run on a single computer, or a network of computers, that attempts to simulate an abstract model of a particular system. Computer simulation refers to a computer crossing point creates a heightened sense of presence, allowing users to feel immersed in the simulated environment (Hong, 2010). Research by Zacharia and Anderson (2003) shows that computer simulations enhance students' ability to articulate and apply what they have learned. Computer simulations are powerful tools used across various fields to model complex systems and phenomena.

At its core, a computer simulation is a digital representation of a real-world process or system, created and manipulated through algorithms and mathematical models. These simulations enable students, researchers, engineers, scientists, and decision-makers to explore, analyze, and understand the behavior of systems in a controlled virtual environment (Sifuna, 2016). Computer simulations have become an integral tool in mathematical modeling across various natural systems, including physics (computational physics), astrophysics, chemistry, and biology, as well as human systems in fields like economics, psychology, social science, and engineering (Egara et al., 2022). Running a system's model is what constitutes simulation. This approach enables exploration and discovery of new technologies, as well as performance estimation for systems that are too complex to solve analytically. Computer simulations can range from brief, minute-long programs to extensive, hour-long network-based simulations, and even prolonged simulations that run for days. The scope of events simulated by computers has surpassed what's feasible with traditional mathematical modeling methods. (Ouahi et al., 2022). One key aspect of computer simulations is their ability to mimic real-world scenarios with a high degree of accuracy. By inputting relevant data and parameters into the simulation software, users can replicate the behavior of intricate systems, ranging from physical phenomena like weather patterns and fluid dynamics to socio-economic processes such as market behavior and population dynamics (Smetana & Bell, 2012). Through iterative refinement and validation against empirical data, simulations can become increasingly reliable representations of reality.

Another crucial feature of computer simulation is their versatility and scalability. Simulations can range from simple models running on a single computer to complex, multi-scale simulations distributed across high-performance computing clusters. This scalability allows researchers to tackle problems of varying complexity, from exploring fundamental scientific principles to optimizing industrial processes and designing advanced technologies (Rutten et al., 2012).

Furthermore, computer simulations offer a safe and cost-effective means of experimentation. Instead of conducting expensive and potentially hazardous real-world experiments, researchers can simulate scenarios virtually, manipulating variables and observing outcomes without risk (Mengistu & Kahsay, 2015). This aspect is particularly valuable in fields like medicine, where simulations can aid in drug development and treatment optimization without endangering patients. Additionally, simulations facilitate hypothesis testing and scenario analysis by allowing users to explore "what-if" scenarios and assess the consequences of different decisions or interventions (Nkemakolam et al., 2018). This capability is invaluable in fields such as disaster management, where simulations can help predict the outcomes of various response strategies and mitigate potential risks. Moreover, computer simulations play a crucial role in education and training, providing students and professionals with interactive learning environments to explore theoretical concepts and gain practical experience (Kumar & Kumar, 2017). Simulations can simulate complex systems and processes in a way that is engaging and easily comprehensible, fostering deeper understanding and skill development (Kara et. al, 2017).

2.2.2 The History and Development of Simulations

The development of computer simulation paralleled the rapid advancement of computers, with its first major application during the Manhattan Project in World War II, where it was used to simulate nuclear detonation using a Monte Carlo algorithm with 12 hard spheres. Today, computer simulation is frequently employed as a complement to, or replacement for, modeling complex systems that defy simple analytical solutions (Winsberg, 2019). Various types of computer simulations exist, but they all share a common goal: to generate representative scenarios for a model when exhaustively listing all possible states is impractical or impossible. For years, teachers have utilized non-computer-based simulations in classrooms through science labs and demonstrations. Before computers became a staple in schools, educators created hands-on activities to illustrate real-life scenarios, often due to limitations such as cost, safety concerns, or the impossibility of direct observation (Gruner, 2012). Examples include modeling radioactive decay, microscopic phenomena, or large-scale processes like evolution. These hands-on simulations are essential for science teachers to create an effective learning environment.

Merely lecturing students about scientific theories is seen as insufficient, as it does not encourage them to reflect on and adjust their own understanding of the world. According to Khaled et al. (2014), while hands-on simulations are valuable, they have limitations. For instance, creating these activities can be time-consuming for teachers, and some simulations require a large number of participants, which can limit flexibility and pose logistical challenges, especially if the simulation spans multiple days (Kevogo et al., 2013).

To overcome these limitations, computers have been integrated into science education to design and create simulations. Computer simulations enable students to explore complex scenarios, repeat trials instantly, and manipulate variables to understand their effects (Kara, 2018). With computers, students can conduct multiple experiments quickly, receive immediate feedback, and observe graphical representations in real-time, all within a flexible environment that allows them to test their own hypotheses (Kiboss et al., 2004). Computer-based simulations expose students to complex scenarios that would be challenging to replicate with hands-on activities. These simulations offer variety, novelty, and engaging visuals, including 3D graphics, making learning more immersive and realistic (Kara et al., 2017). With advancements in graphics, educational simulations can now rival the engaging quality of non-educational activities, potentially replacing some hazardous pursuits. Research has consistently shown that computer simulations enhance learning outcomes (Rutten et al., 2012), with studies demonstrating significantly higher effectiveness compared to traditional methods (Kara et al., 2017). These findings highlight the potential of computer simulations to boost student learning and provide teachers with innovative ways to connect with modern learners.

2.2.3 Teaching and Learning Genetic

Teaching genetics typically begins with foundational concepts such as Mendelian genetics, which explores the basic principles of inheritance through traits governed by single genes. Students learn about dominant and recessive alleles, Punnett squares, and inheritance patterns such as autosomal and sex-linked traits (Sugumar, 2024). This foundational knowledge serves as the building blocks for understanding more complex genetic phenomena. As students' progress, they delve into molecular genetics, which focuses on the structure and function of genes at the molecular level. This includes DNA replication, transcription, translation, and regulation of gene expression. Understanding these processes is crucial for grasping how genetic information is encoded, transmitted, and expressed in living organisms.

Additionally, modern genetics education incorporates the study of genomics, which involves analyzing entire genomes to understand the organization, function, and evolution of genes within an organism or population (Akwee et al., 2012). With advancements in technology such as next-generation sequencing, students have the opportunity to explore genome-wide analyses and their implications for fields like personalized medicine, agriculture, and conservation biology. Teaching and learning genetics also involve practical laboratory experiences where students gain hands-on skills in techniques such as PCR (polymerase chain reaction), gel electrophoresis, DNA sequencing, and genetic engineering. These laboratory exercises not only reinforce theoretical concepts but also foster critical thinking, problem-solving, and experimental design skills essential for scientific inquiry. Furthermore, the ethical, social, and legal implications of genetics are integrated into the curriculum to encourage discussions on topics such as genetic testing, gene editing, genetic discrimination, and biotechnology regulation (Kevogo et al., 2013). By examining these issues, students develop a deeper understanding of the broader societal impacts of genetic research and applications. Overall, teaching and learning genetics encompass a diverse array of topics ranging from classical Mendelian genetics to cutting-edge genomic technologies and ethical considerations (Kiboss et al., 2004). By engaging students in a multifaceted approach that combines theoretical knowledge with practical experimentation and critical thinking, educators can cultivate a deep understanding of genetics and its implications for society.

2.2.4 Impact of Computer Simulations on Students Learning

Computer simulations are powerful tools in science education, offering a range of benefits (Blake & Scanlon, 2007; de Jong & van Joolingen, 1998). By visualizing and interacting with dynamic models, students can gain a deeper understanding of complex phenomena. According to Holec et al. (2004), simulations can accurately convey dynamic information and enhance visualization. They allow students to explore phenomena that are otherwise difficult to observe, such as processes that are too fast, too slow, or hidden (Widiyatmoko, 2018). By manipulating variables and repeating experiments, students can develop a more nuanced understanding of relationships between concepts (Widiyatmoko, 2018). Simulations also enable students to interact with objects and processes that are typically beyond their control in the natural world (de Jong et al., 2013), making them a valuable tool for scientific inquiry

2.2.5 Enhancing Conceptual Understanding

Computer simulations create dynamic, interactive environments that can model complex systems and phenomena as this interactivity allows learners to manipulate variables and observe the outcomes in real-time, providing a deeper and more intuitive grasp of abstract concepts (Akwee et al., 2012). For instance, in physics, students can experiment with simulations of projectile motion, changing angles and velocities to see the direct effects on the trajectory. This hands-on experience is often more impactful than passive learning methods, such as reading textbooks or listening to lectures. Furthermore, computer simulations can visualize phenomena that are otherwise invisible or difficult to observe directly. In fields like chemistry and biology, simulations can illustrate molecular interactions, chemical reactions, and biological processes at the microscopic level. By making the invisible visible, these simulations help learners to form mental models of how these processes work, which is essential for a robust conceptual understanding (Ouahi et al., 2021). This visualization also aids in retaining complex information, as it leverages the human brain's strength in processing visual information.

Additionally, computer simulations provide a safe and cost-effective way to conduct experiments and explore scenarios that would be impractical, dangerous, or expensive in the real world. For example, medical students can use simulations to practice surgical procedures, gaining valuable experience without the risk of harming patients. Similarly, engineers can test the structural integrity of buildings under various conditions, such as earthquakes or high winds, without the need to build and destroy physical models. This practical experience reinforces theoretical knowledge and prepares learners for real-world applications. Moreover, computer simulations can be tailored to individual learning needs, offering personalized learning experiences. Adaptive simulations can adjust the level of difficulty based on the learner's performance, providing immediate feedback and additional challenges as needed (Kevogo et al., 2013). This customization ensures that learners remain engaged and are appropriately challenged, which is vital for deep learning. It also allows for differentiated instruction, accommodating diverse learning styles and paces within a single classroom or training environment.

2.2.6 Engaging and Motivating Students

Computer simulations have become a pivotal tool in modern education, particularly in engaging and motivating students. These digital representations of real-world processes offer an interactive and immersive learning experience, which traditional teaching methods often lack (Kevogo et al., 2013). By simulating complex systems and scenarios, students can visualize and manipulate variables in a controlled environment, fostering a deeper understanding of the subject matter. This hands-on approach not only enhances comprehension but also keeps students actively involved in their learning journey. One of the primary ways' computer simulations engage students is by making abstract concepts tangible.

For instance, in physics, simulations can demonstrate the principles of motion and force in a visual and dynamic manner, allowing students to see the immediate effects of changing variables such as mass or acceleration. This visual representation helps demystify challenging concepts, making them more accessible and easier to grasp (Kiboss et al., 2004). As a result, students are more likely to remain interested and invested in their studies, reducing the disengagement often associated with difficult subjects. Moreover, computer simulations provide an element of experimentation that is often impractical or impossible in a traditional classroom. For example, chemistry students can conduct virtual experiments that might be too dangerous or costly to perform in real life. This ability to experiment safely and repeatedly allows students to learn from trial and error, an essential aspect of scientific inquiry (Ouahi et al., 2022). The immediate feedback provided by simulations helps students understand the consequences of their actions and decisions, reinforcing learning through practice and experimentation.

Additionally, the interactive nature of computer simulations caters to diverse learning styles, making education more inclusive. Visual learners benefit from graphical representations, while kinesthetic learners engage through interactive elements. Auditory learners can gain from accompanying sound effects or narrations. This adaptability ensures that all students, regardless of their preferred learning style, can benefit from the same educational content. By accommodating different learning preferences, simulations help maintain student interest and motivation (Ouahi et al., 2022).

Furthermore, the gamification aspect of many computer simulations adds an extra layer of motivation. By incorporating elements such as points, levels, and challenges, simulations can make learning feel like a game rather than a chore. This gamified approach can significantly increase student motivation, encouraging them to spend more time and effort on their studies. The sense of achievement and progression inherent in these gamified simulations can boost students' confidence and foster a more positive attitude towards learning.

2.3 Empirical Studies on Impact of Computer Simulation on Teaching and Learning of Genetics

Some of the selected studies on computer simulations and its effects on teaching and learning of genetics are shown in Table 2.1.

Table 2.1: Selected Studies on Computer Simulations and Teaching and Learning of Genetics

Author	Date	Title	Findings
Akhigbe, & Ogufere.	2020	Effect of Computer Simulation Instructional Strategy on Students' Attitude and Academic Achievement in Genetics	The study's findings showed that incorporating computer simulations as a teaching tool significantly enhanced students' academic performance and fostered a more positive attitude towards biology. Notably, the simulations were particularly effective for low-ability learners, who demonstrated greater improvement compared to their medium- and high- ability peers. Moreover, the results indicated that the use of computer simulations eliminated any significant differences in attitude and achievement between male and female students, suggesting that this instructional approach can help bridge the gap between genders
Kotoka	2012	The impact of computer simulations on the teaching and learning of electromagnetism in grade 11: a case study of a school in the Mpumalanga Province	Results showed that students taught with simulations outperformed those taught with traditional teacher-centered methods, achieving significantly higher post-test scores. The simulation-based approach encouraged active learning, with students engaged in

			predicting, observing, discussing, and explaining concepts. The simulations also provided scaffolding support, enhancing the learning experience. Both teachers and students expressed a strong acceptance of using computer simulations to teach and learn electromagnetism, highlighting its potential as an effective instructional too.
Ouahi et al.	2021	The Effect of Using Computer Simulation on Students' Performance in Teaching and Learning Physics: Are There Any Gender and Area Gaps?	The results showed that the experimental group, which used simulations, performed better on the post-test than the control group. While there was no significant difference in performance between males and females in the experimental group, urban students outperformed rural students regardless of whether simulations were used. Nevertheless, the study suggests that simulation software can be an effective tool for improving middle school students' performance and recommends its widespread adoption and practice
Tolga Gök	2011	The effects of the computer simulations on students' learning in physics education	It was found that there was a significant difference in conceptual test between groups' scores in favor of the treatment group. Also, it could be concluded that the courses with computer based-activities have a positive effect on students' attitude.
Okino Victor	2023	The development of computer aided instructional package (CAIP) in genetic concepts and its effects on	A major finding of the study shows that the students taught using CAIP performed significantly

		biology students' academic achievement in Kogi State, Nigeria	better than those taught using lecture method
Olumuyiwa et al.,	2014	The use of computer simulation in science teaching and its effect on students' academic performance in biology	The findings of the study showed that the performance of students exposed to Computer Simulation were better than their counterparts exposed to the conventional classroom instruction. However, no significant difference existed in the performance of male and female students exposed to Computer Simulation. Based on the research findings recommendations were made on the need to develop relevant Computer Simulation packages for teaching Biology and other sciences in Nigerian secondary schools.
Amafu	2015	The effect of using computer simulation in teaching chemical bonding on the cognitive achievement of SHS 1 chemistry students: a case study at bishop Herman college, Kpando.	The findings indicate that computer simulations offer feedback that makes abstract concepts more concrete. Additionally, the study showed that participants developed a more positive attitude towards chemical bonding and chemistry in general.
Olalekan, & Oludipe, O.	2016	Effects of Computer Simulation Instructional Strategy on Biology Students' Academic Achievement in Dna Replication and Transcription	Result showed that there is a significant main effect of computer simulation on students' mean achievement score in DNA replication and transcription. There was also a significant effect on the retention ability of students but no significant effect on gender was observed. The computer simulation was effective in enhancing students' achievement scores and

			retention ability therefore, computer simulation is recommended as a means of teaching Undergraduate Biology students in Nigerian university other tertiary institution.
Olumide, O. J.	2013	Computer Simulation Package and Gender as Predictors of Students' Achievement in Biology	Students exposed to computer simulation performed better with higher adjusted posttest achievement mean score than their counterparts who were taught with the conventional teaching method
Smetana, L. K., & Bell, R. L	2012	Computer Simulations to Support Science Instruction and Learning: A critical review of the literature	The findings suggest that simulations can be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based and/or physical hands-on) instructional practices in promoting science content knowledge, developing process skills, and facilitating conceptual change. As with any other educational tool, the effectiveness of computer simulations is dependent upon the ways in which they are used.
Akwee et al.,	2012	Effectiveness of Computer Based Technology Integration in Teaching and Learning of Gene Concept among High School Students, Kenya.	The findings in the study showed that the integration of computer-based technology in teaching and learning improved students' achievement scores and understanding of the gene concept.

Akhigbe and Ogufere (2020) conducted a study on the effect of Computer Simulation Instructional Strategy on Students' Attitude and Academic Achievement in Genetics. The results showed that utilizing computer simulation as a teaching tool substantially enhances student achievement and fosters a positive attitude towards biology. Likewise, the findings indicated that computer simulation instruction considerably improves the performance of low-ability learners, who demonstrated higher mean gains compared to medium- and high-ability learners. Furthermore, no significant differences were found in attitude and achievement between male and female students, suggesting that computer simulations can bridge the gap in both areas.

A study by Kotoka (2012), investigated the impact of computer simulations on teaching and learning electromagnetism to grade 11 students in Mpumalanga Province. The results showed that students in the experimental group who used simulations scored significantly higher on the post-test compared to the control group taught with traditional methods. These students were more engaged, actively predicting, observing, discussing, and explaining concepts. The simulations also provided necessary scaffolding support, enhancing the learning experience. Both teachers and students expressed strong support for using computer simulations in electromagnetism education.

Ben Ouahi et al. (2021) conducted a study on the effect of Using Computer Simulation on Students’ Performance in Teaching and Learning Physics. The results indicate that the experimental group outperformed the control group on the post-test. Notably, there was no performance difference between genders in the experimental group. However, urban students consistently outperformed rural students, regardless of whether simulations were used. The study recommends utilizing simulation software to enhance middle school students' performance. Tolga (2011) In research examining the impact of computer simulations on physics students' learning outcomes results showed a significant difference in conceptual test scores between groups, with the treatment group scoring higher. Additionally, the study concluded that incorporating computer-based activities into courses had a positive impact on students' attitudes. Okino (2023) study on the impact of a Computer-Aided Instructional Package (CAIP) on genetic concepts found that students in Kogi State, Nigeria, who used CAIP achieved significantly higher academic performance compared to those taught with traditional lecture methods." Olumuyiwa et al. (2014) in a study on the utilization of computer simulation in science teaching and its effect on students' academic performance in biology. The findings of the study showed that the performance of students exposed to Computer Simulation were better than their counterparts exposed to the conventional classroom instruction. However, no significant difference existed in the performance of male and female students exposed to Computer Simulation. The study's findings led to recommendations for developing relevant Computer Simulation packages for Biology and other science instruction in Nigerian secondary schools.

Kwami (2021) in a study on the effect of using computer simulation in teaching chemical bonding on the cognitive achievement of SHS 1 chemistry students: a case study at bishop Herman College, Kpando. The findings suggest that computer simulations offer feedback that reduces abstractness. Additionally, the study found that participants developed a positive attitude toward chemical bonding and chemistry overall. Olalekan, and Oludipe (2016) in a study on the Effects of Computer Simulation Instructional Strategy on Biology Students Academic Achievement in Dna Replication and Transcription. Result showed that there is a significant main effect of computer simulation on students mean achievement score in DNA replication and transcription. There was also a significant effect on the retention ability of students but no significant effect on gender was observed. The computer simulation was effective in enhancing students' achievement scores and retention ability therefore, computer simulation is recommended as a means of teaching Undergraduate Biology students in Nigerian university other tertiary institution. Olumide (2013) also in a study on Computer Simulation Package and Gender as Predictors of Students' Achievement in Biology. The study revealed that students exposed to computer simulation performed better with higher adjusted posttest achievement mean score than their counterparts who were taught with the conventional teaching method. Smetana and Bell (2012) conducted a study on computer Simulations to Support Science Instruction and Learning: through a critical review of the literature. The findings suggest that simulations can be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based and/or physical hands-on) instructional practices in promoting science content knowledge, developing process skills, and facilitating conceptual change. As with any other educational tool, the effectiveness of computer simulations is dependent upon the ways in which they are used. Akwee et al. (2012) conducted a study on the effectiveness of computer-based technology integration in teaching and learning of gene concept among high school students, Kenya. The findings in the study showed that the integration of computer-based technology in teaching and learning improved students‘ achievement scores and understanding of the gene concept.

2.4 Assessing the Attitude of Students toward Using Computer Simulation for Teaching Genetics

2.4.1 Conceptual Review

In recent years, the integration of technology in education has become increasingly prevalent, with computer simulations emerging as a powerful tool for enhancing the learning experience across various disciplines. In the field of genetics education, where complex concepts and processes can be challenging to visualize and understand, computer simulations offer a unique opportunity to engage students and improve their comprehension. This conceptual review aims to explore the current landscape of research on student attitudes toward using computer simulations in genetics education, examining the potential benefits, challenges, and factors influencing their effectiveness.

2.4.2 Computer Simulation in Genetic Education

Genetic education has evolved significantly alongside advancements in genetic knowledge and science teaching methodologies. In the context of this study, the focus is on using computer simulations as an innovative approach to teaching genetics and assessing student attitudes toward this method. Bernarducci (2017) defined computer simulations as a technique that educates people on a subject by modeling or mimicking it. Although this definition reflects most aspects of simulations, it fails to detail the interactive and manipulative elements now considered crucial characteristics of most educational simulations.

Collins (2018) posited the interactive component, which identified computer simulations as programs that contain a model of a system (natural or artificial; e.g., equipment) or process. They stress that through simulations, learners can log in to another set of values and view the results while in genetics education, the most effective way to illustrate phenotypic variations is by altering values that have varying effects. Genetic education according to Cotner et al. (2017) might refer to the process of educating or learning or processes involving heredity and variation in living organisms. However, the genetics education of the present age has evolved to incorporate molecular genetics, biotechnology, and corresponding ethical dilemmas (Whitley et al., 2020). Fauzi et al. (202) offer a broader definition where genetic education is defined as the mechanism of trait transmission, basic information about DNA, gene regulation and impact of genetics' technology socio- culturally. This definition takes into account modern genetics, its multi-faceted nature, and social context which are features that can be easily described by means of computer simulations. Mocan (2021) defined genetic literacy as knowledge concerning genetic content, its uses, and its implications to individuals and societies. This perspective is most similar to using computer simulations to show application realms and potential ethical dilemmas of genetic technologies. Unlike Bao et al. (2018) who pay attention to the building of student's conceptual understanding, highlighting the relevance of linking concept development to practical implementations. Computer simulations that incorporate scenario-based education elaborates in this aspect because they offer the student synthetic systems within which he/she can manipulate genotypes, phenotypes, and even observed effects in equal measure.

From the perspective of the present research, genetic education refers to constructing knowledge about heredity, molecular genetics, genes, gene expressions, and gene regulations. This definition includes the understanding of genetic technologies in use today, how they are currently being used, and related ethical/legal/social implications. The principal goal is to prepare students for decision response with regard to genetics pertaining to society and their lives. In these educational aims, computer simulations are useful because they allow the visualization of complex genetic processes and the consequent effects of genetic intervention. In view of these considerations, the following research question is posed: how can the attitudes of the students towards these simulations be used to determine their viability as a teaching aid and their ability to improve the interest and understanding of genetic education.

2.4.3 The Role of Computer Simulations in Teaching Genetic and Student Attitudes

Genetics, being the foundational concept in biology, is often a problematic area to teach since the ideas themselves are recondite and the phenomena take place at the molecular and even sub-molecular level. However, conventional forms of class and tutorial instruction can lack the effectiveness to convey the full measure of genetic action. This gap has seen the incorporation of computer simulations, as a useful tool in the portrayal of these genetics concepts as dynamic and realistic (Lavin et al., 2021). Modern technologies in genetics education include computer-simulated genetics from some simple moving images to some complex three dimensional and virtual laboratories. That is why such tools let a student control variable, manage processes, and evaluate results that would be unfeasible to model in a classroom environment. For example, workflow can stunningly illustrate DNA replication, gene expression, and population genetics dynamically making it easier for students to grasp concepts that may otherwise seem abstract (Tibell & Harms, 2017).

Thus, using computer simulations in genetics education has numerous advantages; among them is encouraging active learning. It is convenient to work with components and not lose time on the sequence, allowing students to develop unique strategies, even practicing genetic phenomena solely (Collins, 2018). This interactivity is particularly helpful when it comes to understanding more information on issues like Mendelian inheritance, gene mutation, and gene control. According to de Jong et al. (2018) such a form of learning fosters understanding, and higher-order thinking skills acquisition on the part of the learners, they make use of theories learned to solve real-life problems. Computer simulations also have the opportunity to provide an individual approach for learners where everybody can choose the type of learning he or she needs. Since most of these learning modules can be in large portions, these programs are flexible since they can suit students of different knowledge levels (Bernarducci, 2017). Since information and communications technology (ICT) based learning is not proscriptive, learners can move forward gradually; revisit or review the content, and/or re-simulate processes that may have been difficult the first time around. This adaptability makes simulations particularly good for students with different learning needs, which different students may have (Makransky et al., 2016). Additionally, computer simulation relieves several drawbacks of conventional lab experiences including time limitations, availability of materials, equipment, or safety issues. While virtual learning in modern genetics curricula applies the best of both worlds, these real inherent limitations of apprenticeship traditions became the original learning impediments that virtual learning erases (Makransky et al., 2019).

Additionally, to determine the usefulness of simulations as instructional aids in genetics it is also critical to look at the tendencies of students towards computer simulations. There are the following factors: first, students‘ readiness to use technology in learning environments; second, perceived advantages for comprehending genetic ideas. Observing the levels of engagement that traditional forms exercise and the simulation techniques applied can determine how these affect learning. Also, the perspectives of students regarding the realism and relevance of the genetical processes modeled within the frames of simulations as well as potential disadvantages or shortcomings contribute to the understanding of the role of the simulations in the learning process. Knowledge of these factors can be useful in designing the implementation of simulations into genetics teaching and learning.

Thus, the assessment of these components allows the recognition of the pattern of how computer simulations influence the learning achievements of students in genetics. This information can be used to further improve the approaches to teaching, adjust and build better simulations, and improve the overall quality of genetic education.

2.4.4 Assessing Student Attitudes Toward Computer Simulations in Genetics Education

This study identifies students’ attitudes toward computer simulations as an important factor in effectively implementing computer simulations in teaching genetics. These attitudes play a huge role in participation, motivation, and learning. According to Rutten et al. (2012), students approach computer simulations in natural sciences, including genetics, with positive attitudes. Industry experience, student status, prior use, perceptions of interactivity and realism, and confidence in the program contribute to positive attitudes toward computer simulations in genetics education. Although it can be normal to be worried that the utilization of hi-tech, kinetic, and elaborate models surpasses ordinary approaches in capturing trainee attention and enhancing knowledge that remains in their long-term memory, based on the research findings by Smetana and Bell (2012).

Using simulations that enable the student to role-play the genetic processes and proportions, there is enhanced understanding and acquisition of knowledge as postulated by Levy (2013). Hence, performing simulations at the student's own pace and with self-controlled activities increases their confidence resulting from repetitive practice (Lin & Suh, 2021). Also, like Computer-aided Process Simulations, it offers students an opportunity to practice in a virtual setting because of which the actual problem can be solved without major concerns (Makransky et al., 2016). Nevertheless, it is necessary to realize that student's attitudes are conditioned by certain factors, such as interest in the material to be learned, prior experience with technologies, and the approach to the use of simulations (Makransky et al., 2019). The findings of the study are in line with those of Nsabayezu et al. (2022) who found that using computers in the teaching and learning process facilitates students to understand scientific phenomena since they visualize complex concepts. In addition, the integration of ICSs in teaching and learning science subjects particularly chemistry improves student's cognitive and affective domains. de Hoop et al. (2024) conclude that it is the right decision to integrate technology in the education system since students acquire a diverse set of skills that respond to the nation's need to achieve developmental goals.

Students‘ attitudes towards these lessons were understood to be the attitude of students towards chemistry. Compared to conventional instruction, which is teacher-centred and uses the lecture method, research on the effects of some novel instructional approaches on students' attitudes towards chemistry has produced inconclusive results (Chan & Bauer, 2015). Kattayat et al. (2016) proposed incorporating computer simulations into classroom instruction to enhance students' attitudes toward physics, which in turn improves their performance. Similarly, Sarı et al. (2017) discovered that interactive computer simulations in scientific inquiry yield more positive attitudes toward physics compared to traditional teaching methods

Abou-Faour and Ayoubi's (2017) study shows that computer simulations substantially influence students' attitudes and perceptions of physics. Aşıksoy and İşlek (2017) found that computer simulation lab experiences have a positive effect on students' physics attitudes. Çetin's (2018) research revealed that cooperative simulation-based learning has a significantly greater impact on students' physics attitudes compared to traditional methods. Additionally, Kattayat et al. (2016) discovered a strong correlation between students' physics achievement and their attitude toward the subject when simulation-based training is used. Furthermore, Sari et al. (2019) discovered that computer-based labs and virtual applications enhanced students' attitudes. The use of Computer Simulations (CSs) enables students to conduct virtual experiments, manipulating variables to observe different outcomes (McDonald, 2016; Widiyatmoko, 2018).

These virtual experiments allow students to model real-world systems, exploring various inputs, processes, and outputs, which is beneficial in science education.

Consequently, simulations have significant potential to spark students' curiosity, foster creativity, and develop critical thinking skills, and encourage them to learn by doing. They allow students to experience and interact with natural events, challenge them, and provoke reactions (Council, 2011). Consequently, simulations can customize learning to fit each student's needs, pace, interests, and abilities within an interactive virtual environment. Additionally, research has shown that simulations positively affect students' interest and attitude toward science (Sari et al., 2019; Kattayat et al., 2016). Notably, Sari et al. (2019) discovered that virtual applications and computer-based labs have a positive impact on students' attitudes and motivation.

Further research showed that technology in labs enhances student learning and attitudes (Oymak & Ogan-Bekiroglu, 2017). Bozkurt and Ilik (2010) found that simulations boosted students' physics achievement and beliefs. Kattayat et al. (2016) noted that simulation-based instruction in the classroom fosters more positive attitudes toward physics among students, leading to improved academic performance in the subject.

Further, the antecedents of students perceptual attitudes have been identified as computation literacy, perceived usefulness, integration within the curriculum, perceived support of the instructor as well as perceived quality of the simulation used in genetics education. There is usually a more positive attitude toward computer-based learning tools exhibited by students who have higher computer literacy (Eksail & Afari, 2020). Prospective learners who feel that simulations will help improve academic performance in genetics and understanding are also more supportive of simulations (Rezvani et al., 2022). Instructional simulations that have been integrated into the course learning goals are likely to be more embraced by students than simulations that are randomly incorporated into a course (Rutten et al., 2012).

Teacher interest and support have an impact on students' use of simulation; teachers showing interest and supporting the students increase their confidence level and real-life positive attitudes towards the use of simulations (Kafle, 2023). Realistic and easy-to-navigate simulations of genetic processes tend to have more positive effects on attitudes (Lanjekar et al., 2021) and negative effects with inaccurate and poorly designed simulations (Villena-Taranilla et al., 2022).

These factors should be taken into consideration when measuring student attitudes toward computer simulations in genetics education. Questionnaires, interviews, or focus groups could be developed to measure students' attitudes towards or perceptions about the utility of simulations in the learning environment, their perception of how simulations improve their knowledge of genetics, easiness, navigability of the simulations, compatibility of the simulations to their genetics curriculum, the support their instructors provide in the use of the simulations, and their level of satisfaction when using the computer simulations.

In this way, the mentioned aspects, are to be comprehensively evaluated to increase the educators' and researchers' understanding of students' attitudes regarding the use of computer simulations in genetics content. This information may help to refine the approaches used in simulation development and application strategies regarding genetics education, as well as general learning methods, which eventually will contribute to the development of educational programs and raise student achievements.

2.4.5 Challenges and Considerations in assessing Students' Attitudes towards Computer Simulations in teaching Genetics

Despite these advantages addressed earlier, several issues related to computer simulations can affect students' attitudes towards these technologies, within genetics teaching and learning contexts. It is invaluable in deciding student's views on applying simulations in teaching genetics.

Low-fidelity simulations attempting to portray comprehensive genetic processes might flood the students with information that they hardly manage to process due to information overload. According to Evans et al. (2024), this leads to frustration and alienation which if left unchecked, may breed a negative attitude towards the tool. This shows how students perceive the simulation, whether challenging, easy, or difficult for a student to process information within a simulation activity, apart from the ratio of challenge to understanding within a simulation design.

Evans et al. (2024) further emphasized that technical factors which include software failures, slowness, or inaccessible hardware can make a massive difference in students' participation and perceptions. These problems might give the negative impression of poor simulation quality, thus, allowing their engagement approach to the content. When using attitude assessments consider how often technical problems are experienced, the extent to which they interrupt learning experience and engagement, and the extent to which useful technical support is available and effective. A task that has created a lot of debate is the place of practical experience in science learning. According to de Jong et al. (2018), simulations give achievement of a large audience and high economy, but some aspects of learning and specific measurement outcomes could not be compared with those of a physical lab. When measuring students‘ attitudes, ask questions about real simulations and physical labs, about perceived advantages and disadvantages of each option, and about the ratio of theory to practice.

Additionally, it may also limit learners‘ creativity by offering comparative views of real genetic experiments to the simulated ones. Olympiou and Zacharia (2018) reported that students sometimes have humanitarian attitudes toward simulations as they argue they are close to real-life labs. Outcomes related to students‘ attitudes should incorporate realism and authenticity of simulation together with possible impact on general attitudes toward using simulation in genetics education and direction for enhancing perceived authenticity of simulations.

One of the reasons could be the depth and way in which simulations are incorporated into conventional methods of teaching and learning. It may be useful to gather students‘ opinions on the recovery role of simulations to ordinary genetics knowledge, as well as their perceptions of how simulations contribute to or harm their learning process, and their particular choices of the proportion of simulations and regular classes (de Jong et al., 2018).

There are some issues and concerns that have to be considered and discussed when assessing students‘ attitudes towards computer simulations in teaching genetics.

Questionnaires, interviews, or focus groups may be developed to examine students' experiences in terms of the load they experienced during genetics simulations, the frequency and the effects of the technical problems they may encounter in simulations, their comparisons and perceptions between virtual simulations and physical laboratory activities, their perceptions regarding the realism and authenticity of the simulations and their ideas and perceptions of simulation combined with conventional instructing methodologies (Olympiou & Zacharia, 2018). According to different research by Nguyen et al. (2022), time limits, technological difficulties, human resources, and student disengagement are the main obstacles to simulation-based teaching. Isiaq and Jamil (2018) gathered opinions regarding simulation features from teachers or students through focus groups and semi- structured interviews.

A few students brought out the fact that several simulation exercises were not fully supported by the teachers. In order to create relevant learning environments, students also anticipated that teachers would use suitable pedagogical techniques and have a better understanding of their learning requirements (Isaiq & Jamil, 2018). Additionally, one teacher disclosed that they had done less preparation since they believed that the majority of the work was done by simulation tools. Since the module leader handled the majority of the session design phase, the teacher had minimal involvement in the simulation proposal (Isaiq and Jamil, 2018). All participants in the qualitative focus group research conducted by Kolanczyk et al. (2019) were asked to fill out an anonymous survey. There were eight questions in the poll, and one of the most important topics was the obstacles to using simulation. The authors discovered that having the right faculty members or facilitators was crucial to the success of simulation exercises. The availability of facilitators was cited by several participants as a difficulty. The necessity for more faculty members with the right knowledge and abilities was another point raised by the participants. According to Katoue and Ker (2019), one difficulty in clinical instruction based on simulation was the need for qualified instructors or facilitators. According to Jamil (2018), a frequent difficulty was a technical glitch, particularly when there was an issue with network connectivity.

In their study, Amin et al. (2013) collected opinions from seasoned instructors or trainers who made recommendations for bettering the preparation of simulation training. Over one-third (36.4%) displayed a number of teaching difficulties, including technical ones. Furthermore, many inexperienced instructors discovered that using high-fidelity simulators and other simulator equipment was costly due to the purchase and operation costs, which restrict the availability of simulators to simulation centres. On the other hand, part-task trainers are very cheap, but they are unrealistic and unpractical.

In this way, such aspects are studied thoroughly so that researchers and educators have a broad view of students‘ attitudes toward the use of computer simulations within genetics education. The findings from this study can inform recommendations for refining simulation models, the processes by which the models are integrated into the curriculum, and, more generally, how genetics instruction is administrated and organized, all to improve student learning.

2.5 Empirical Review of Computer Simulations

Computer simulations have proved popular in genetics education over the years, with researchers focusing on the potential of computer-based simulations and, students views on the use of simulations. This empirical literature review consists of a presentation of research related to student’s perceptions of computer simulations as instructional tools for the understanding of genetics and includes methodological strategies, results, and implications for practice. Olumide (2019) examined the effect of computer simulations and Institutional digital puzzle packages on students' problem-solving ability as well as their attitude towards ecology and genetics for secondary school. In a quasi-experimental design with a cross-sectional pre-test-post-test control group, the study suggested improvement in student performance in terms of computer simulations in comparison with conventional techniques and a positive shift in their attitude towards this approach. Combining simulations and puzzles also proved to improve problem-solving skills to great measure as the use of active learning approaches in genetics teaching was demonstrated.

In the same way, Akhigbe and Ogufere (2020) argued that computer simulations enhanced students‘ attitudes and performance in genetics, especially low-achieving students. As much as the two studies, stress that when teaching science, and technology, especially through computer simulations, students get more involved and perform better in complex concepts. Stemming from such findings are implications that the use of simulations to teach genetics can aid in ensuring that achievement gaps are bridged due to associated positive learning dispositions and that efforts to individualize simulation should continue by acknowledging skill differences among students. In Dodoo's (2015) study, the author assessed the impact of computer simulation on JHS learners' performance and perceived learning readiness towards Integrated Science. With an action research design employing a quasi-experimental method, the research engaged 88 JHS 2 students. The study also revealed that students using computer simulations as teaching aids scored higher content knowledge and had a positive attitude toward Integrated Science than the students taught with traditional teaching aids. According to the study, it was suggested that teachers should be trained in ICT skills to enhance the implementation of simulations in science teaching; thus, enhancing the use of more computers in teaching science. The cross-sectional study of Wilmot (2020) investigated the pedagogical content knowledge (PCK) of Senior High School biology teachers in genetics teaching in Ghana. Based on the Magnusson et al. (1999) PCK framework, the study used structured questionnaires that were administered to 149 teacher.

Owusu et al. (2023) in their study titled; A Study of the Impact of using Information and Communication Technology (ICT) in the Teaching of Genetics in selected senior high schools in Ghana‖. The researcher established that students taught with ICT tools scored better than students taught through conventional methods. This study agrees with the kind of instruction that integrates computers, and simulations in an endeavor to help students grasp and improve their knowledge regarding ideas in genetic make-up.

Kumauh et. al., (2024) examined the perceived motivational factors as influences on the interest and participation of undergraduate students towards genetics ‘reaction at the University of Education Winneba. Their cross-sectional survey of 150 students showed that perceived relevance for genetics was the most powerful predictor of engagement, particularly where topics linked to health global problem-solving were involved. It was also discovered that instructional methods determined the extent of perceived interest in congruent teaching styles that involved the presentation of practical and compelling skills and yielded improved results. These findings emphasize the need to engage in the development of instructional strategies including computer simulations that illustrate real-world applications of genetics and correct misconceptions that reduce the students interest in genetics lessons.

As in previous works, the present research has shown that computer simulations and ICT are effective in genetics education in improving students' performance and attitudes While consensus exists in the literature on the effectiveness of computer simulations and ICT in genetics education in improving student's performance and their attitudes towards the subject, some research questions still exist on factors of students and activities which may make up an effective package in using multiple teaching and learning strategies in Ghana. These gaps are likely to be filled by the current study, which focuses on instructional strategies, with specific emphasis on computer-based tools and their effects on student's learning and mastery of genes. As such, this research aims at offering a specific yet holistic evaluation of the way to extend genetics education in Ghanaian Schools, concerning the function and popularity of computer simulations in the process.

2.6 Summary of Literature Review

The literature review explores the impact of computer simulations on the teaching and learning of genetics in senior high schools, anchored in Experiential Learning Theory (ELT) and Connectivism Learning Theory. ELT emphasizes a four-stage learning cycle experiencing, reflecting, thinking, and acting which aligns well with computer simulations that offer interactive and visual experiences for students. Connectivism, on the other hand, views learning as a process of connecting to digital networks and resources. Simulations reflect this by enabling students to explore genetic concepts through real-time feedback, collaboration, and manipulation of variables. Computer simulations serve as effective tools for modeling complex genetic concepts such as DNA replication, gene expression, and Mendelian inheritance. They make abstract concepts more concrete and enhance student engagement, understanding, and performance. The conceptual framework identifies simulations as the independent variable influencing three major outcomes: student attitude, academic performance, and learning challenges. These relationships are shaped by moderating factors such as technological access, teacher digital competence, and student ICT literacy.

Empirical studies show that students exposed to computer simulations perform significantly better than those taught using traditional methods. Simulations are particularly effective for low-achieving students and show no gender bias in performance. Students also demonstrate more positive attitudes towards learning genetics when simulations are integrated effectively. Challenges include limited infrastructure, lack of training, and occasional technical failures, which can negatively affect learning outcomes and student attitudes. However, when well-implemented, simulations support differentiated instruction, real-world application, and foster critical thinking. Overall, simulations are shown to be a transformative tool in improving genetics education.

CHAPTER THREE

METHODOLOGY

3.0 Overview

The chapter entailed the research paradigm, research design, research population and sampling, sample size, instruments for data collection, validity and reliability of instrument, interventions, data analysis and ethical consideration.

3.1 Study Area

Kwadaso Municipal is located in the central part of the Ashanti Region of Ghana (Fig. 3.1). It was formerly part of the Kumasi Metropolitan Assembly until November 2017, when it was elevated to municipal status by Legislative Instrument (L.I. 2292) and officially inaugurated on March 15, 2018. The municipality shares boundaries with Atwima Nwabiagya Municipal to the north and northeast, Atwima Kwanwoma District to the south, and Kumasi Metropolitan Assembly to the east. The municipal capital is Kwadaso, from which the municipality derives its name.

Covering a land area of approximately 42.4 square kilometers, Kwadaso Municipal makes up about 20% of the original Kumasi Metropolitan area. According to the 2021 Population and Housing Census, the municipality has a total population of 154,526, comprising 75,205 males and 79,321 females. The area has a relatively high population density, indicative of its urban characteristics. Kwadaso Municipal consists of about 36 communities organized into 15 electoral areas and five sub-municipalities. It is situated within Greater Kumasi, a rapidly urbanizing zone that blends residential neighborhoods with commercial and institutional infrastructure.

The municipality is characterized by mixed land use patterns, including education, health, and small-scale trading activities. Its compact size and urban setting make it a strategic location for educational research, particularly studies focused on the integration of digital tools like computer simulations in teaching and learning. The availability of educational institutions, digital infrastructure, and diverse student populations provides a suitable environment for examining the impact of educational technology on science instruction.

Figure 3.1: Geographical Map of Study Area

3.2 Research Design

This study used quasi- experimental design. This design allows the study to establish a cause-and-effect relationship between the intervention (in this case, the use of computer simulations) and its outcomes (improvement in teaching and learning of genetics) (Maciejewski, 2020). While true experimental designs involve random assignment of participants to control and experimental groups, quasi-experimental designs are more feasible in educational settings where randomization might not be possible due to logistical or ethical constraints (Shadish & Luellen, 2012). Specifically, the study used non-equivalent control group pre-test and post-test design as shown in Figure 3.2.

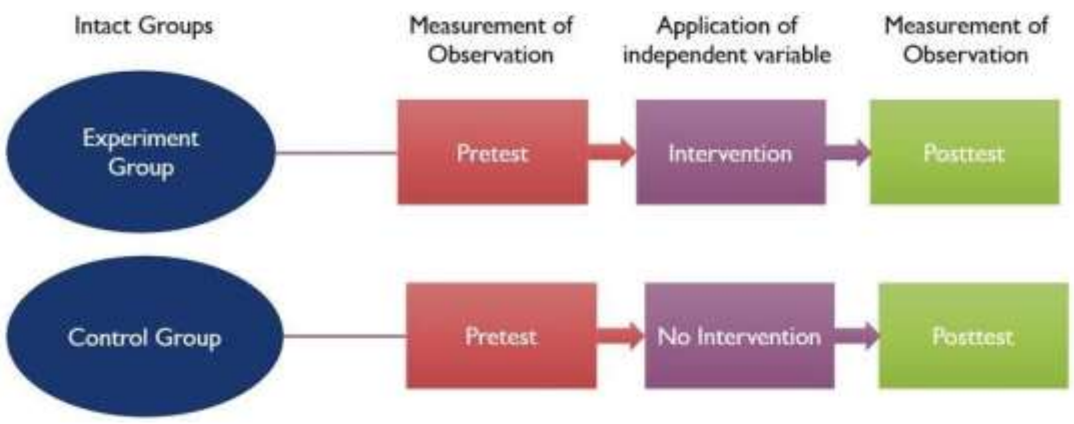

Figure 3.2: Non-equivalent Control Group Pre-test and Post-test Design

In non-equivalent control group pre-test and post design, the study classified the accessible schools into experiment school and control school. The participants in the experiment school received the computer simulations whiles the participants in the control used the traditional method of teaching. The study used pre-existing biology classes in both experiment and control schools. The use of pre-existing biology classes helps to minimize threats to internal validity that can arise from participant selection biases (Litim, 2000). There is a less risk of systematic differences between groups when participants are not randomly assigned to groups (Higgins et al., 2013).

The study used pre-test and post-test on both the experimental group and control group. The researcher administered the instrument on both the experimental and control groups before the intervention (computer simulation) teaching begun.

According to Berry (2008), pre-test study serves as baseline study. Therefore, with pre-test, the study was able to assess the initial performance of the participants in genetics and their engagement in genetic lessons. The post-test on the other hand was used to measure any changes in the participants‘ performance and engagement as a result of the intervention (computer simulations) (Dimitrov & Rumril, 2003).

3.3 Research Paradigm

This study best fit the pragmatic paradigm. According to pragmatic paradigm, a value of research depends on practical application and its usefulness to deliver a desired outcome (Sarantakos, 2005). The study adopted pragmatic paradigm because in the context of computer simulations, pragmatic paradigm helps to understand how computation simulations are used in teaching genetics and its effect on teaching and learning. Pragmatic paradigm helps to understand practical implications of computer simulations for teaching and learning biology and their challenges.

In consonance with pragmatic paradigm, the study used mixed method where both quantitative and qualitative research approaches were used. Mixed research method helps to gain deeper understanding of a research topic such as computer simulation. The quantitative method helped to assess the impact of computer simulations on teaching and learning of genetics. The quantitative approach, offers the opportunity to collect and analyze numerical data to estimate the impact of computer simulations on teaching and learning genetics. Cooper and Schindler (2011) noted that quantitative approach is undertaken when the primary emphasis is to depict, clarify or forecast, while the investigator distances himself from the research to prevent skewing the findings. Therefore, through the quantitative research approach, findings in this study were objective and true reflection of reality (Cooper & Schindler, 2011). Moreover, the qualitative approach helped to provide detailed insight into experiences and challenges of using computer simulations to teach and learn genetics. This study adopted a mixed-method approach, which combines qualitative and quantitative methodologies to collect and analyse data (Creswell & Tashakkori, 2007). Mixed-methods research integrates quantitative techniques such as experiments and surveys with qualitative approaches like interviews and focus groups (Creswell, 2003). According to Teddlie and Tashakkori (2009), mixed-method research approach can take various forms, including sequential explanatory design, sequential exploratory design, concurrent triangulation design, concurrent nested design, and concurrent transformative design. This study employed the sequential explanatory design, which begins with the collection and analysis of quantitative data, followed by qualitative data collection and analysis. This approach was selected to allow the quantitative findings to be clarified and enriched by the qualitative data, providing deeper insights into the research questions. Creswell and Clark (2011) stated that the sequential explanatory design is a two-stage mixed method design. This design first begins with the collection and analysis of quantitative data and followed by the collection and analysis of qualitative data.

3.4 Population and Sample Size

The target population involved form three senior high school students in Kwadaso Municipal Area who pursue biology. Kwadaso Municipal Area has four public senior high schools. However, one of the schools is a non-science school. Also, one of the schools is a category C school whiles the remaining two are category A schools. Therefore, to ensure uniformity, the accessible schools for the study were the category A schools. The population of biology students in the accessible senior high school in the Kwadaso Municipal Area are provided in Table 3.1.

Table 3.1: Form Three Biology Students Population

No.	Senior High School	Students Population	Number of Classes	Students per Class
1	School A	520	10	52
2	School B	517	10	51

Source: Academic Office of the Schools, March, 2024

The study used purposive sampling to sample two form three classes from experimental school and control school each. Purposive sampling is used when a study required a specific number of unit or information (Obilor, 2023).

In this study, two biology classes were needed in each experimental school and control group. In this vein, the study contacted heads of science department in each school to ask for two form three biology classes that were available for the study. The availability of a class depended on whether the biology teacher for the class was available and willing to support the study during intervention period (computer simulation period). Therefore, classes whose biology teachers were available and willing to support the study during the intervention period were selected using simple random sampling. Therefore, in all, four biology classes (two from experimental school and two from control schools) were used in the study. Based on the selection of the classes from the schools, the sample size in both experimental and control schools are shown in Table 3.2

Table 3.2: Form Three Biology Students Population

No.	Senior High School	First Class Selected	Second Class Selected	Total
1	School A (Experimental School)	52	52	104
2	School B (Control School)	51	51	102

Source: Author's Construct, 2024

The study further purposively sampled two Biology teachers who were involved in the experimentation of Computer Simulation in the experimental school. Also, the two biology students in the experimental school were purposively sampled for interview.

3.4 Instrument for Data Collection

3.4.1 Questionnaire

The study used structured questionnaire. The questionnaire was prepared in accordance with the research objectives or questions and the study variables. The questionnaire had three sections. Section I consist of personal information of the participants and this had only one item and that was sex of the participants. The Section II focused on attitudes of students towards computer simulation in genetic class. The items under this section were adapted from Ouahi et.al (2022) and had 13 items. Section III also considered challenges of using computer simulations for teaching genetics. Items under Section III were adapted from Abiasen and Reyes (2021) and had 12 items. The detailed questionnaire is shown in Appendix 1.

3.4.2 Genetics Performance Test (GPT)

The study followed Biology Syllabus for genetics and set three key questions that were used for the pre-test and post-test. The questions were in essay form where the participants provided their own answers to each question. Each question carried equal marks to ensure equal weight for each question. The detailed performance test questions are shown in Appendix 2. Marking scheme was prepared for each question to guide marking to ensure uniformity of marks awarded to answer provided by the participants. The marking scheme for the questions are at Appendix.

3.4.3 Interview Guide

The study further conducted interviews with biology teachers for the classes selected for the study. The study used unstructured interview guide. The study used unstructured interview guide because, it provided flexibility for interview questions where the researcher can ask follow up questions based on the initial response provided by a participant to help gather rich information to address the research questions. Also, unstructured interview guide gave the participants the opportunity to provide varied responses, leading to gathering of more relevant data for the study. The interview guide focused on effect of computer simulations on academic performance of students in genetic, attitudes of students towards computer simulation and challenges of using computer simulation for teaching genetics. The detailed interview guide is shown at Appendix 4.

3.5 Validity of the Instrument

Face and content validity were carried out where the expert advice of both academics and practitioners was sought to validate the items or questions on the face of the questionnaire, performance test and interview guide. Accordingly, five academics and practitioners (including the project supervisor) were consulted to assess the questionnaire, performance test and interview guide based on their relevance, appropriateness of items, factual inaccuracies, grammatical errors, and whether the content align with the syllabus. Therefore, items were rated as essential or non-essential. Afterwards, Lawshe's (1975) content validity ratio (CVR) was used to determine the content validity of the GPT questionnaire and interview guide. To determine the CVR, Content Validity Index (CVI) was calculated for each item on the instrument. CVI is determined by dividing the total number of experts who evaluated the items by the number of experts who rated the items as essential (Ayre & Scally, 2014). After determining the CVI for each item, the CVI is calculated for the entire instrument. This is the mean of all individual CVIs (Almanasreh et al., 2018). The CVRs of the GPT, questionnaires and interview guide were then determined by dividing the overall CVI by the total number of items.

Table 3.3: Content Validity Index and Content Validity Ratio of GPT

Item	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Agreement	CVI
1	X	X	X	X	X	5	1.00
2	X	X	X	X	X	5	1.00
3	X	X	X	0	X	4	0.80
CVR							0.93

O =non-essential X= essential

CVI = Content Validity Index = $\frac{NE}{N}$

CVR = Content Validity Ratio = $\frac{CVI}{total\ number\ of\ items}$

N = total number of experts

N_E = Number of experts indicating items as essential.

According to Almanasreh et al. (2018), CVR varies between 1 and −1, where high values of CVR indicate the agreement of experts on the relevance of an item in the instrument. Therefore, as seen from Table 3.3, the CVR value for GCT was 0.93, which indicates a valid instrument. Table 3.4 also shows the CVI and CVR for the questionnaires.

Table 3.4: Content Validity Index and Content Validity Ratio of GPT

Item	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Agreement	CVI
1	X	X	X	X	X	5	1.00
2	X	X	X	X	X	5	1.00
3	X	X	X	X	X	5	1.00
4	X	X	X	X	X	5	1.00
5	X	X	0	X	X	4	0.80
6	X	X	X	X	X	5	1.00
7	X	X	X	0	X	4	0.80
8	X	X	X	X	X	5	1.00
9	X	X	X	X	X	5	1.00
10	X	X	X	X	X	5	1.00
11	X	X	X	X	X	5	1.00
12	X	X	X	X	X	5	1.00
CVR							0.97

As revealed in Table 3.4, the CVR value for the questionnaire was 0.97, which also indicates a valid instrument according to Almanasreh et al. (2018).

Table 3.5: Content Validity Index and Content Validity Ratio of Interview Guide

Item	Panel1	Panel 2	Panel 3	Panel 4	Panel 5	Agreement	CVI
1	X	X	0	X	X	4	0.80
2	X	X	X	0	X	4	0.80
3	X	X	X	X	X	4	0.80
4	0	X	X	X	X	4	0.80
5	X	X	0	X	X	4	0.80
CVR							0.80

As revealed in Table 3.5, the CVR value for the interview guide was 0.80, which also indicates a valid instrument according to Almanasreh et al. (2018).

3.6 Reliability of the Instrument

For the reliability, the questionnaire was piloted on 15 biology students in SIMMS SHS. The study used the pilot test data to check for the reliability of the questionnaire, using Cronbach's Alpha test which. The output of the reliability and validity of the instrument is shown in Appendix 6. The questionnaire was deemed reliable because Cronbach's Alpha Score of the pilot test data of 0.7 was supported. The study used Cronbach’s Alpha test because of its ability to test for different categories. Moreover, the study used inter-rater reliability coefficient, to test for reliability of the Performance Test and coefficient of at least 0.7 was accepted as the test being reliable.

Table 3.6: Inter-Rater Reliability of Genetic performance Test

	Value		Approximate Significance
Measure of Agreement	Kappa	.704 15	.001 N of Valid Cases

According to Kottner et al. (2011), as a rule of thumb, values ≤ 0 indicate no agreement and 0.01–0.20 as none to slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, 0.61–0.80 as good or substantial agreement, and 0.81–1.00 as perfect agreement. In this study, the value of Kappa‘s measure of agreement as seen from Table 3.6 was 0.704 which is a substantial agreement, according to Kottner et al. (2011). As a result, from Table 3.6, the Kappa measure of agreement of the score of the two raters for the GCT was 0.704, which Kottner et al. (2011), interpretes it as a substantial agreement. This suggests that the instrument was a trustworthy tool for the primary investigation.

Table 3.7: Reliability of the Research Questionnaire

Reliability Statistics	
Cronbach's Alpha	No. of Items
.826	15

As represented in Table 3.7, the Cronbach Alpha value, which measured the internal consistency of the questionnaire items was 0.826. This value, according to Pallant (2011) indicates a preferable internal consistency of the questionnaire. This means that the internal consistency of the questionnaires was reliable.

3.7 Intervention

The intervention in this study was the use of computer simulation for teaching and learning genetic. Computer simulations are valuable tools for teaching genetics in schools, providing students with interactive and engaging experiences that help them understand complex genetic concepts (Barberousse, Franceschelli, & Imbert, 2009). In this study, Biology Simulations from PhET Interactive Simulations was used. The PhET Interactive Simulations offer various biology simulations that cover genetics topics suitable for senior high school (SHS) students. The topics covered include interactive activities on Mendelian inheritance, Punnett squares, DNA replication, transcription, translation, and genetic mutations. Studies (for example, Najib, Md-Ali, & Yaacob, 2022; Adams, 2010) have shown that Biology Simulations from PhET Interactive Simulations is effective for teaching genetics; hence its deployment in this current study.

Simulation Screenshots

Figure 3.2: Simulation screenshot of Structure of DNA

3.7.1 Transcription

Do you recognize this molecule? This is DNA — short for Deoxyribonucleic Acid. By the end of this video, you will be able to identify the key structures of DNA, understand its components, and explain why it is vital to all living organisms. DNA is often visualized as a twisted ladder, also known as a double helix. The sides of the ladder are made up of sugar and phosphate groups, while the rungs are formed by pairs of nitrogenous bases.

These bases are:

- Adenine (A)

- Thymine (T)
- Cytosine (C)
- Guanine (G)

They always pair in a specific way:

- A pairs with T
- C pairs with G

This complementary base pairing ensures that DNA can replicate itself accurately, allowing genetic information to be passed from one generation to the next. DNA is located inside the nucleus of eukaryotic cells, tightly coiled into structures called chromosomes. Each section of DNA that codes for a specific protein is called a gene. And those genes? They are the instructions that tell your cells what to do—how to grow, how to repair, and how to function.

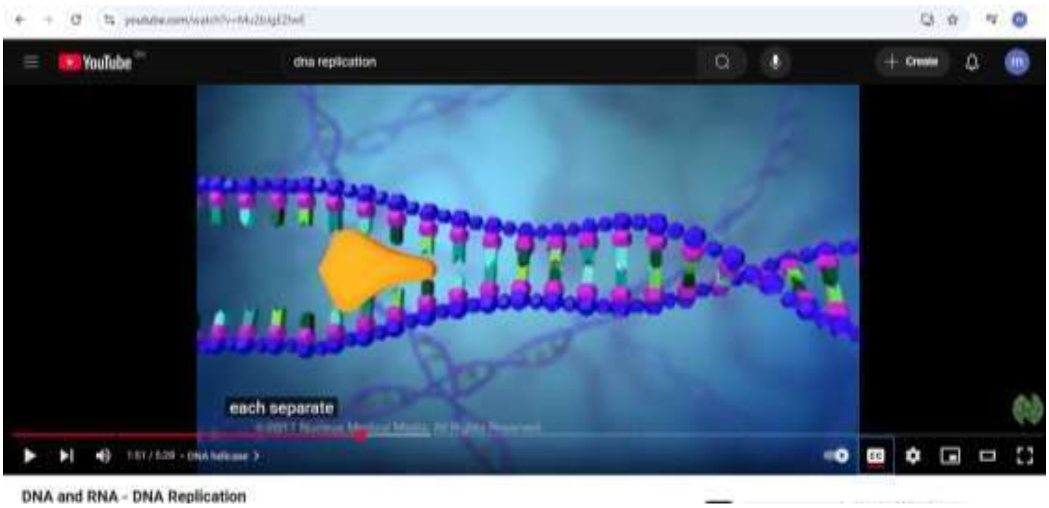

Figure 3.3: Simulation Screenshot of Replication of DNA

3.7.2 Transcription

Let‘s take a closer look at DNA replication—the essential process in which DNA copies itself. But why must this happen? Before a cell divides during mitosis, it must duplicate its DNA to ensure that both daughter cells receive an identical set of genetic instructions.

This critical event occurs during the S phase of the cell cycle standing for synthesis, or to make.

Inside the nucleus, DNA appears as a double helix two strands twisted together and held by hydrogen bonds between nitrogenous bases.

The process begins with the enzyme helicase, which unwinds and separates the strands by breaking those hydrogen bonds. Now exposed, each strand acts as a template for a new strand.

Next, the enzyme DNA polymerase steps in. It adds free-floating nucleotides in the nucleus to each template strand, using the base-pairing rule:

- Adenine (A) pairs with Thymine (T)
- Guanine (G) pairs with Cytosine (C)

This creates two new complementary strands, forming two identical DNA molecules—each one a perfect copy of the original.

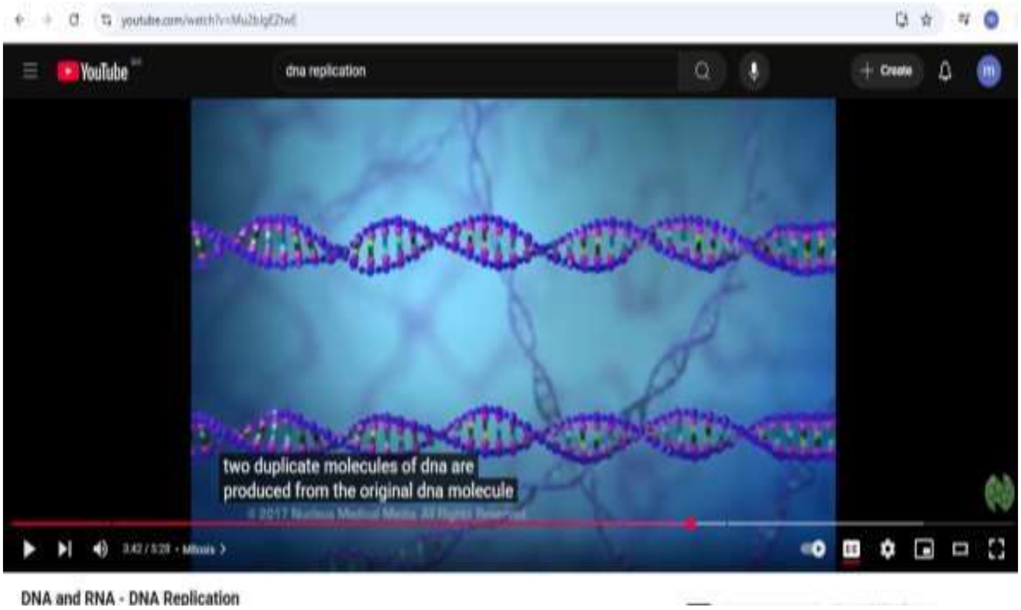

Figure 3.4: Simulation screenshot of mitosis

3.7.3 Transcription

In this lesson, we dive into the M phase of the cell cycle the moment of cell division which includes mitosis and cytokinesis. But first, a quick review: The G_1, S, and G_2 phases make up interphase, the cell‘s growth and preparation time. The M phase is where the action happens cell division begins. Let‘s start with mitosis, the division of the nucleus. Mitosis unfolds in four stages: Prophase, Metaphase, Anaphase, and Telophase.

In prophase, the longest stage, chromatin condenses into chromosomes, and the nucleus disappears. Each chromosome is made of sister chromatids joined at a centromere. Meanwhile, spindle fibres begin forming from centrioles, which move to opposite poles of the cell. The nuclear membrane dissolves, and spindle fibres attach to the centromeres. Next is metaphase. Here, chromosomes align at the equator of the cell, pulled by spindle fibres. A sister chromatid lines up on either side.

Anaphase follows. Spindle fibres shorten, separating the sister chromatids at the centromere and pulling each new chromosome to opposite poles. The chromosomes now move in a distinct V-shape.

Then comes telophase the final stage of mitosis. Nuclear membranes reform around each group of chromosomes, the chromosomes uncoil into chromatin, and the nucleus reappears. The division of the nucleus is now complete.

But the job‘s not done until cytokinesis, the division of the cytoplasm. In animal cells, the cell membrane pinches inward until two identical daughter cells form. In plant cells, which have rigid walls, a cell plate forms along the centre, eventually becoming new cell walls that divide the two daughter cells. With replication complete, the cell is now ready for mitosis.

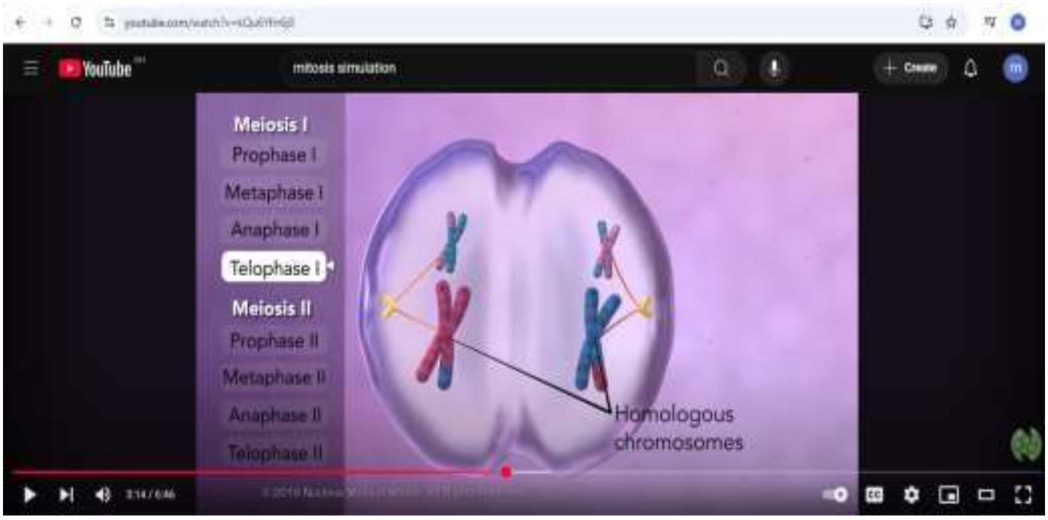

Figure 3.5: Simulation Screenshot of Meiosis

3.7.4 Transcription

In this lesson, we will explore the fascinating process of meiosis, also known as reduction division the type of cell division that produces gametes: sperm cells in males and egg cells in females.

Meiosis is divided into two stages: Meiosis I and Meiosis II, each with four phases: Prophase, Metaphase, Anaphase, and Telophase.

Let‘s begin with Meiosis I.

In Prophase I, we start with a diploid cell containing chromatin with DNA from both parents. After DNA replication, the chromatin condenses into X-shaped chromosomes made of identical sister chromatids.

Here, a unique process called synapsis occurs—homologous chromosomes pair up to form a tetrad (four chromatids total). This sets the stage for crossing over, where chromatids exchange alleles, creating new genetic combinations. This recombination introduces genetic variety, making each gamete, and therefore each offspring, genetically unique.

As prophase continues, the nuclear membrane dissolves, spindle fibres form, and centrioles move to opposite poles.

In Metaphase I, homologous chromosome pairs align at the cell‘s equator.

In Anaphase I, spindle fibres pull homologous chromosomes apart—each moves to opposite poles, while the sister chromatids remain together.

During Telophase I, nuclear membranes reform, and cytokinesis divides the cell. The result? Two genetically different haploid cells, each with chromosomes made of paired sister chromatids that are no longer identical due to crossing over.

Now on to Meiosis II, which does not involve another round of DNA replication. In Prophase II, nuclear membranes disappear again, and spindle fibres form.

In Metaphase II, chromosomes line up at the equator.

In Anaphase II, the sister chromatids separate and move to opposite poles, now becoming individual chromosomes.

Finally, in Telophase II, nuclear membranes reform, cytokinesis occurs, and the process ends with four genetically different haploid gametes—each with just one set of chromosomes

Plate 3.1: Simulation Screenshot of Mendel’s Law of Segregation

3.7.5 Transcription

In this section, we‘re diving into Mendel‘s Law of Segregation—a foundational principle of genetics. Mendel began his experiments with seed shape, which could be either round or wrinkled. He conducted what's known as a monohybrid cross, meaning he focused on just one trait at a time. He started by crossing a true-breeding round-seeded plant with a true-breeding wrinkled-seeded plant. The result? All offspring had round seeds. From this, Mendel concluded that the round trait is dominant, while wrinkled is recessive. The next year, he let these round-seeded plants self-fertilize. This produced over 7,000 seeds: about 5,474 round and 1,850 wrinkled. That‘s a 3:1 ratio, confirming the reappearance of the recessive trait.

Let‘s break this down using generations:

- The P_1 generation: round × wrinkled (true-breeding)
- The F_1 generation: all round (but genetically mixed)
- The F_2 generation: results from crossing F_1 with F_1, giving 75% round and 25% wrinkled seeds.

To predict these outcomes, we use a tool called the Punnett Square—a grid that shows all possible combinations of alleles from the parents. Each parent contributes one allele. Dominant alleles are represented with a capital letter (R), and recessive with a lowercase letter (r).

So in the F_2 generation:

- RR: round
- Rr: round
- rR: round
- rr: wrinkled

Only the rr offspring show the recessive wrinkled trait. This supports Mendel's Law of Segregation:

- Each gene is made of two alleles, which separate during gamete formation.
- Each gamete gets only one allele, and when fertilization occurs, the offspring gets one allele from each parent, re-forming a pair.

Now, let's explore another example using earlobe attachment, which is also governed by dominant and recessive alleles:

- Free earlobes (F) are dominant.
- Attached earlobes (f) are recessive.

In one scenario:

- A man with FF (free) mates with a woman with ff (attached).
- All children inherit Ff—they all have free earlobes, because the dominant F masks the f.

In a second case:

- Both parents are heterozygous (Ff)—they each have one dominant and one recessive allele.
- Using a Punnett Square, we get:
    - FF (1 child) – free
    - Ff (2 children) – free
    - ff (1 child) – attached

That is a 3:1 phenotypic ratio again: three free, one attached.

3.8 Data Analysis

The Researcher cleaned the data, coded them and entered them into STATA version 16.0 for descriptive and inferential analysis. The Researcher first described or provided summary statistics of all the study variables, using mean and standard deviation. Also, Principal Component Analysis were used to decomposed attitudes and challenges into their appropriate components. The study then used descriptive analysis such as mean and standard deviation to assess the attitudes of students towards the use of computer simulations to teach genetics and also the challenges of integrating computer simulations in genetics instruction from the perspective of teachers and students in senior high schools. To determine the impact of computer simulation, the study first used Paired Sample t-test to compare the performance of students in each school before and after the intervention. The study used Paired Sample t- test because, it helps to measure performance of students under two different conditions. In this study, the conditions are teaching genetics in School A using computer simulations and teaching the same genetic topics in school B using traditional method and the performance of the students in genetics in the two schools are compared. The analysis of the interview data is as follows. The study transcribed interview data verbatim, coded, and used thematic and narrative methods for its analysis. Thematic analysis was the main method used. Inductive coding was used to code the transcribed data. With inductive coding, themes, and patterns emerged directly from the transcribed data. Thematic analysis is used due to a high degree of flexibility (Boyatzis, 1998). The qualitative analysis followed the processes provided by Braun and Clarke (2006) as follows; firstly, the researcher familiarized himself with the interview data.

The researcher listened to recorded data two times each day for two days to have a better understanding of the responses provided. In addition, the study used narrative analysis to help provide vivid illustrations of some of the themes, based on responses provided by the participants. Additionally, the descriptive analysis was carried out using the statistical program for social sciences (SPSS) 23 and shown as sample means, standard deviation, skewness, and kurtosis. The five-point Likert scale's interpretation is shown in Table 3.8.

Table 3.8: Likert Scale

Responses	Score	Weighted Average Range	Implication
Strongly Disagree	1	1.0 – 1.49	Disagreement to Statement
Disagree	2	1.50 – 2.49	Disagreement to Statement
Neutral	3	2.50 – 3.49	Neutral to Statement
Agree	4	3.50 – 4.49	Agreement to Statement
Strongly Agree	5	4.50 – 5.50	Agreement to Statement

According to Sullivan and Artino, 2013.

3.9 Ethical Consideration

Several ethical concerns were made for this research, just like for any other research project in literature. Only participants who offered their time entirely out of self-interest were considered for data collection. Each participant was free to leave the study whenever they choose. After learning all the details, the respondents likewise concurred. As a result, the participants got enough information and guarantees before participating. The promises were made in order to let the participants comprehend the ramifications of their involvement and give them the freedom to decide whether or not to participate. The respondents' right to privacy and anonymity was of utmost importance. The literature sources included in the study were properly cited, and the research was undertaken with the greatest impartiality feasible.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

The study presents the results from the data gathered on the impact of using computer simulations on the teaching and learning of genetics in senior high schools in Kwadaso Municipality. The study assesses the attitude of students towards computer simulations in teaching genetics, challenges of integrating computer simulations in genetics instruction and the impact of using computer simulations on the teaching and learning of genetics in senior high schools.

4.1 Results of the Study

4.1.1 Results for Research Question 1

What is the attitude of students towards the use of computer simulations to teach genetics?

Table 4.1: Components of Attitude of Student on the use of computer simulation

Component

	Statements	1	2	3	4
Positive and and Proactive	The use of interactive simulation makes it simple easier for me to study genetics	.885			
	Using interactions simulation instead of traditional methods do not scare me.	.875			
	I like interactive simulations because they can help me learn on my own at home with my computer	.861			
	Lessons become more interesting when interactive simulations are used.	.719			
Analytic and experiential	The simulations were highly effective due to its engaging features like clear visuals and graphics		.857		
	Simulations were beneficial because it allowed us to conduct experiments and observe them realistically		.819		
	I understood the content of genetics better with the help of the interactive simulations.		.805		
Enthusiastic and visual	The simulations' colourful and dynamic design made it useful for learning			.859	
	The simulation is helpful because it allows you to visualize the experiment.			.827	
Practical and engaging	The use of interactive simulation makes it simple and easier for me to study genetics.				.894
	I found the simulations we used were appealing.				.858
	With interactive simulations I can finish homework faster				.816
	Students get interest in genetics when interactive simulations are used in teaching.				.664

Source: Field Data (2024)

Table 4.2: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings
Comp	Total	% of Variance	Cumulative %		% of Variance	Cumulative %	Total
1	4.357	33.516	33.516		33.516	33.516	3.611
2	2.254	17.341	50.856		17.341	50.856	2.593
3	1.646	12.658	63.515		12.658	63.515	1.685
4	1.037	7.976	71.491		7.976	71.491	3.057
5	.774	5.958	77.449				
6	.534	4.106	81.555				
7	.521	4.011	85.566				
8	.450	3.462	89.028				
9	.404	3.106	92.134				
10	.376	2.889	95.023				
11	.289	2.226	97.249				
12	.204	1.571	98.820				
13	.153	1.180	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

The Eigenvalues presented in Table 4.2 indicate that there are four categories or components of attitudes towards computer simulations. The first component explains 33.5% of attitude of students towards computer simulation, the second component explains 17.3% and third component 12.6% and the fourth component explains 7.9% of attitude towards computer simulation. The study assessed the attitudes of students by first decomposing the attitude items into components using Principal Component Analysis (PCA). The PCA results shows the Total Variance Explained in Table 4.2.

Table 4.3: Attitude towards the Use of Simulations in Teaching Genetics

Categories	Statements	N	Mean	Std. Dev
Positive and Proactive	The use of interactive simulation makes it simple and easier for me to study genetics	104	3.76	.704
	I am not afraid to use simulation instead of traditional methods.	104	3.65	.747
	I like interactive simulations because they can help me learn on my own at home with my computer.	104	3.72	.717
	Lessons become more interesting when interactive simulations are used.	104	3.41	.732
Analytic and experiential	The simulations were highly effective due to its engaging features like clear visuals and graphics	104	3.85	.553
	Simulations were beneficial because it allowed us to conduct experiments and observe them realistically.	104	3.62	.612
	I understood the content of genetics better with the help of the interactive simulations	104	3.48	.638
Enthusiastic and visual	The simulations' colourful and dynamic design made it useful for learning	104	3.83	.492
	The simulations were helpful because they allowed me to visualize the experiments.	104	3.85	.553
Practical and engaging	Using interactive simulation makes it easier for me to study genetics	104	3.76	.661
	I found the simulations we used very appealing	104	3.76	.661
	With interactive simulations I can finish my homework faster	104	3.74	.668
	Students get interest in genetics when interactive simulations are used in teaching.	104	3.86	.645
	OVERALL		3.71	0.073

Source: Field Data (2024)

The overall mean score for students‘ attitudes toward the use of computer simulations in teaching genetics is 3.71 with a standard deviation of 0.073. According to the Likert scale interpretation by Sullivan and Artino (2013), a weighted average in the range of 3.50 to 4.49 indicates an agreement with the statements, reflecting a positive attitude. This suggests that students generally perceive the use of computer simulations as beneficial and engaging in the context of learning genetics. The relatively low standard deviation also indicates that there was a high level of agreement among respondents, with responses showing little variability. This consistency implies that most students share similar positive perceptions of simulation tools, likely due to the interactive, visual, and practical learning support these tools provide. Therefore, it can be concluded that students hold a positive disposition toward the integration of computer simulations in genetics instruction, recognizing its value in enhancing comprehension and stimulating interest in the subject.

4.2. Qualitative Analysis on Attitude of Students towards the Use of Simulation

Participants from the schools were included in the study to ascertain their attitude towards the use of simulation in teaching genetics. The responses given by the participants were positive as the students in School A exhibited enthusiasm towards the use of simulation in their learning routine. One participant indicated that;

―The software is remarkable and it makes it easier to understand the concept of genetics. I have gotten a visual representation of how genes change and I do not think that I will ever forget such a phenomenon‖ (Student Participant 1).

Another participant stated that he is able to study better when simulations are used in class and that the interactive nature of the simulations makes the lessons more interesting. He stated emphatically that;

The software is in fact a significant advantage in ensuring that we the students understand what is being taught in the classroom. I think that if we are to use simulation in every lesson, our performance will sky rocket because it is very difficult to forget illustrations made in the simulation as compared to if the traditional method of teaching was used. (Student Participant 2).

The teachers exhibited enthusiasm in using the simulation software to teach as they indicated that teaching certain abstract concepts such as genetics can be very challenging for students to understand. However, the use of computer simulation has really simplified the concept of genetics making it easier for students to understand and making the teachers workload quite lesser for them too. Teachers do not have to stress so much as the software is able to break down concepts from the bare minimum until students understand the concept entirely. One teacher participant revealed that;

> *The simulation software has made this lesson a success and I think I like the feedback. When I compare the feedback, I had during the use of the traditional method of teaching to the feedback I had after the simulation software was used to teach, you could see a significant difference in the performance of the students. I am very happy because the students were in smiles and nodding in affirmation to what was being taught, making the lesson interesting and easier for me too (Teacher Participant 1).*

Another participant indicated emphatically that;

> ―*You know it is very rare to have this software in the current educational system of this country due to the lack of ICT infrastructure. This software if it were to be available in each and every senior high school in the country, I do not think that we*

would have been discussing poor performance of the students when they write their external exams. This simulation software is really helpful………

In fact, what I really like about the simulation software is that the graphics used in the software helps the students to visualize experiment made in the software. Its colourful nature makes it much exciting to use. The students themselves are able to interact with the simulation software and helps them observe them as if they were actually real. I am really impressed about the software and its influence on performance of the students. (Teacher Participant 2).

4.2.1 Discussion on Attitudes

The findings of the study are in line with those of Nsabayezu et al. (2022) who found that using computers in the teaching and learning process facilitates students understanding of scientific phenomena since they visualize complex concepts. In addition, the integration of ICSs in teaching and learning science subjects particularly chemistry improves students cognitive and affective domains. de Hoop et al. (2024) conclude that it is the right decision to integrate technology in the education system since students acquire a diverse set of skills that respond to the nation's need to achieve developmental goals. Compared to conventional instruction, which is teacher-centred and uses the lecture method, research on the effects of some novel instructional approaches on students' attitudes towards chemistry has produced inconclusive results (Chan & Bauer, 2015). Kattayat et al. (2016) proposed incorporating computer simulations into classroom instruction to enhance students' attitudes toward physics, which in turn improves their performance. Similarly, Sarı et al. (2017) discovered that interactive computer simulations in scientific inquiry yield more positive attitudes toward physics compared to traditional teaching methods.

Abou Faour and Ayoubi's (2017) study shows that computer simulations substantially influence students' attitudes and perceptions of physics. Aşıksoy and İşlek (2017) found that computer simulation lab experiences have a positive effect on students' physics attitudes. Çetin's (2018) research revealed that cooperative simulation-based learning has a significantly greater impact on students' physics attitudes compared to traditional methods. Additionally, Kattayat et al. (2016) discovered a strong correlation between students' physics achievement and their attitude toward the subject when simulation-based training is used.

Furthermore, Sari et al. (2019) discovered that computer-based labs and virtual applications enhanced students' attitudes. The use of Computer Simulations (CSs) enables students to conduct virtual experiments, manipulating variables to observe different outcomes (McDonald, 2016; Widiyatmoko, 2018). These virtual experiments allow students to model real-world systems, exploring various inputs, processes, and outputs, which is beneficial in science education. Consequently, simulations have significant potential to spark students' curiosity, foster creativity, and develop critical thinking skills, and encourage them to learn by doing. They allow students to experience and interact with natural events, challenge them, and provoke reactions (Council, 2011).

Consequently, simulations can customize learning to fit each student's needs, pace, interests, and abilities within an interactive virtual environment. Additionally, research has shown that simulations positively affect students' interest and attitude toward science (Sari et al., 2019; Kattayat et al., 2016). Notably, Sari et al. (2019) discovered that virtual applications and computer-based labs have a positive impact on students' attitudes and motivation.

Further research showed that technology in labs enhances student learning and attitudes (Oymak & Ogan-Bekiroglu, 2017). Bozkurt and Ilik (2010) found that simulations boosted students' physics achievement and beliefs. Kattayat et al. (2016) noted that simulation-based instruction in the classroom fosters more positive attitudes toward physics among students, leading to improved academic performance in the subject.

Results for Research Question 2

What are the challenges of integrating computer simulations in genetics instruction from the perspective of teachers and students in senior high schools?

Table 4.4: Components of Challenges of integrating computer simulation

	Statements	1	2	3	4
Technical and pedagogical	Teachers struggle to familiarize themselves with specific simulation software or platforms	.897			
	Inadequate availability of ICT equipment is a challenge to integrating computer simulation into teaching genetic	.897			
	Challenges of teachers having a deep understanding of the subject matter to select or design simulations that effectively illustrate key concepts	.872			
	Challenge of finding appropriate simulations that align with specific curriculum standards and learning goals	.850			
Integration and assessment	Challenges in integrating simulations with other technologies used in the classroom	.	.920		
	Challenge of developing assessment methods that accurately measure student learning and understanding from simulations	.	.901		
	Lack of skills in troubleshooting technical issues can hinder the smooth execution of lessons involving simulations	.	.780		
Instructional design and engagement	Challenge to design lessons that effectively incorporate simulations while still achieving learning objectives			.777	
	Poor internet access is a challenge to integrating computer simulation into teaching genetics			.626	
	Challenges of facilitating discussions and learning around simulations, ensuring that students engage critically with the content.			.624	
Contextualisation scenarios and contexts	Challenge to connect the abstract presented in simulations to real-world				.809
differentiation challenge	Challenge of adapting simulations to meet the diverse learning needs of students				.602

Source: Field Data (2024)

Table 4.5: Total Variance Explained

Comp	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %	Rotation Sums of Squared Loadings[a] Total
1	3.388	28.232	28.232	3.388	28.232	28.232	3.286
2	2.417	20.142	48.374	2.417	20.142	48.374	2.462
3	1.579	13.159	61.534	1.579	13.159	61.534	1.664
4	1.155	9.621	71.155	1.155	9.621	71.155	1.349
5	.827	6.888	78.043				
6	.690	5.747	83.790				
7	.604	5.034	88.824				
8	.377	3.144	91.968				
9	.313	2.609	94.577				
10	.294	2.447	97.024				
11	.203	1.689	98.712				
12	.155	1.288	100.000				

Source: Field Data (2024)

4.3 Analysis of Challenges of Using Computer Simulation for Learning Genetics

The study also analyzed the challenges of using computer simulations for learning to address research question two. To guide the analysis for clearer understanding, the study used PCA to decomposed the items under challenges into their appropriate components and the results from Total Variance Explained are shown in Table 4.5.

The Eigenvalues presented in Table 4.5 indicate that there are four categories where statements under attitude of students towards computer simulations in teaching genetics can be grouped. The first component explains 28.2% of challenges of students towards computer simulation, the second component explains 20.1% and third component 13.2% and the fourth component explains 9.6% of attitude towards computer simulation. The items under each component is shown in Table 4.4. In Table 4.4, based on the items under each component, the study named component 1 technical and pedagogical challenge (4 items), component 2 was named as integration and assessment challenges (3 items), component 3 was named as instructional design and engagement challenges (3 items) and component 4 was named as contextualization and differentiation challenges (2 items). The study, therefore, assessed the challenges using these components. The items under each component were measured using Five-point Likert Scale from 1 to 5 where 1 was strongly disagree and 5 was strongly agree. In view of this, the study used mean scores and standard deviation determine the whether the respondents considered an item under a given component as a challenge or not and the results are shown in Table 4.6.

Table 4.6: Challenges of Integrating Computer Simulation in Genetics Instruction

Categories	Statements	N	Mean	Std. Dev.
Technical and pedagogical	Teachers struggle to familiarize themselves with specific simulation software or platforms	104	3.90	.830
	Inadequate availability of ICT equipment is a challenge to integrating computer simulation into teaching genetic	104	3.88	.816
	Challenges of teachers having a deep understanding of the subject matter to select or design simulations that effectively illustrate key concepts	104	4.05	.793
	Challenge of finding appropriate simulations that align with specific curriculum standards and learning goals	104	3.83	.818
Integration and assessment	Challenges in integrating simulations with other technologies used in the classroom	104	4.03	.886
	Challenge of developing assessment methods that accurately measure student learning and understanding from simulations	104	4.13	.867
	Lack of skills in troubleshooting technical issues can hinder the smooth execution of lessons involving simulations	104	4.37	.813
Instructional and engagement	Challenge to design lessons that effectively design incorporate simulations while still achieving learning objectives	104	4.12	.851
	Poor internet access is a challenge to integrating computer simulation into teaching genetics	104	4.35	.773
	Challenges of facilitating discussions and learning around simulations, ensuring that students engage critically with the content.	104	4.21	.900
Contextualisation and differentiation challenge	Challenge to connect the abstract scenarios presented in simulations to real-world contexts	104	2.56	.694
	Challenge of adapting simulations to meet the diverse learning needs of students	104	4.11	.975
	OVERALL		3.96	0.071

Source: Field Data (2024)

Based on the data presented in Table 4.6, the overall mean score for the challenges associated with integrating computer simulations into genetics instruction is 3.96, with a standard deviation of 0.071. Referring to the Likert scale interpretation by Sullivan and Artino (2013), a mean score between 3.50 and 4.49 suggests that respondents agree with the statements, indicating that these challenges are widely acknowledged among the participants. The high mean implies that teachers perceive several significant obstacles to effectively implementing computer simulations, including technical limitations, inadequate ICT resources, insufficient pedagogical training, and difficulty in aligning simulations with curricular goals. The relatively low standard deviation shows a strong consensus among the respondents, reinforcing the idea that these challenges are not isolated but rather common and systemic. Therefore, it can be concluded that while students have a positive attitude toward the use of simulations, they are equally aware of the substantial barriers that hinder its full integration into genetics instruction, particularly issues related to infrastructure, teacher preparedness, and instructional design.

4.3.1 Qualitative Analysis on Challenges of Use of Simulation

During the use of simulation to teach genetics, few challenges were met by the students and the teachers. The students in the first few minutes were having challenges about how the software was going to help them but the teachers were able to ease them into the use of it. However, it was evident that the teachers were not having mastery over the use of the software. In one instance, it became very clear that the software was making it easier for the students to comprehend genetic principles than as the teacher himself would have taught the concept because the teachers themselves were not having a deep understanding of the subject matter to select or design simulations that will effectively illustrate certain key concepts in genetics. The lack of mastery of the software proved a significant challenge for the teachers. Also, when the lesson objectives were observed, it was clear that incorporating the simulation software to attain the lesson objectives as stated in the curriculum was a challenge. Teachers found it particularly difficult to design lessons that effectively incorporate simulations while still achieving learning objectives as certain points in the concepts were not examinable per what was presented in the syllabus. The teachers shared their challenges in using the simulation software and indicated that;

> ―*It is quite a challenge to use the simulation software to meet the diverse learning needs of students that participated in the lesson. I believe that the use of simulation will have significant benefits to visual learners as compared to other forms of learners. About three of the students who I know are very good audio learners could not perform very well in the post-test and I think that the simulation did not entirely help them as much as it did for the visual learners‖ (Teacher Participant 1).*

Another participant stated clearly that;

> ―*My problem was much technical than content-related. I struggled very much to be familiar with the simulation software and it resulted in the waste of time. I was having trouble troubleshooting technical issues that occurred during the lesson and it disrupted the flow of the lesson which was not helpful.‖ (Teacher Participant 2).*

The participants noted that the major challenge that the simulation software could face is the inadequacy of ICT equipment to integrate the computer simulation to teach in the school. Basic ICT infrastructure such as computers, spacious laboratories, furniture, projectors and internet access are inadequate in most schools across the country. Therefore, the integration of computer simulation into teaching genetics in the school would be extremely difficult even though it is helpful.

4.3.2 Discussion on Challenges

The findings are in line with those of Khmelnytska and Tkachenko (2023) who indicated that technical limitations and lack of training of teachers to use simulation methods and tools in the educational process are the main factors that complicate the implementation of simulation technologies in the educational process. According to different research by Nguyen et al. (2022), time limits, technological difficulties, human resources, and student disengagement are the main obstacles to simulation-based teaching. Isiaq and Jamil (2018) gathered opinions regarding simulation features from teachers or students through focus groups and semi-structured interviews.

Few students brought out the fact that several simulation exercises were not fully supported by the teachers. In order to create relevant learning environments, students also anticipated that teachers would use suitable pedagogical techniques and have a better understanding of their learning requirements (Isaiq and Jamil, 2018). Additionally, one teacher disclosed that they had done less preparation since they believed that the majority of the work was done by simulation tools. Since the module leader handled the majority of the session design phase, the teacher had minimal involvement in the simulation proposal (Isaiq & Jamil, 2018). All participants in the qualitative focus group research conducted by Kolanczyk et al. (2019) were asked to fill out an anonymous survey. There were eight questions in the poll, and one of the most important topics was the obstacles to using simulation. The authors discovered that having the right faculty members or facilitators was crucial to the success of simulation exercises. The availability of facilitators was cited by several participants as a difficulty. The necessity for more faculty members with the right knowledge and abilities was another point raised by the participants. According to Katoue and Ker (2019), one difficulty in clinical instruction based on simulation was the need for qualified instructors or facilitators. According to Jamil (2018), a frequent difficulty was a technical glitch, particularly when there was an issue with network connectivity. In their study, Amin et al. (2013) collected opinions from seasoned instructors or trainers who made recommendations for bettering the preparation of simulation training. Over one-third (36.4%) displayed a number of teaching difficulties, including technical ones. Furthermore, many inexperienced instructors discovered that using high-fidelity simulators and other simulator equipment was costly due to the purchase and operation costs, which restrict the availability of simulators to simulation centres. On the other hand, part-task trainers are very cheap, but they are unrealistic and unpractical.

Results for Research Question 3

What is the impact of computer simulations on academic performance of students in genetics?

4.4 Impact of Computer Simulations on Performance of Students in Genetics This section of the chapter focuses on presenting analysis on the impact of computer simulations on performance of students in genetics. The analysis was conducted using Paired Sample t-test to compare the performance of the students in School A and School B before and after the intervention (computer simulation). The computer simulation was introduced in School A for teaching genetic topics while in School B, the traditional method of teaching was used to teach same topic. The performance of the students in genetics examination before the interventions (baseline performance) is shown in Table 4.7.

Normality Test for Pretest and Post-test Scores

The normality test was used to assess whether non-parametric or parametric analysis should be performed on the pretest and posttest data that were gathered from the experimental and control groups. The outcomes are displayed in Table 4.7.

Table 4.7: Results for Normality Test for Pretest and Post-test Scores

		Kolmogorov-Smirnov[a]		
	GROUP	Statistic	Df	Sig.
PRETEST	Experimental	.093	51	.200*
	Control	.077	51	.200*
POSTTEST	Experimental	.114	50	.198
	Control	.106	50	.200*

*. This represents the genuine significance's lower bound.

a. Correction to Lilliefors Significance

Mishra et al. (2019) state that the Kolmogorov-Smirnov test is suitable for samples with 50 or more participants ($n \geq 50$). The null hypothesis asserts that the data are drawn from a normally distributed population, according to Mishra et al. (2019). When the data is normally distributed and the accepted probability value shown in Table 4.7 has sig $p > 0.05$, the null hypothesis is accepted. As a result, Table 4.7 indicates that the experimental and control groups' pretest and post-test scores had p-values 0.200 and 0.200 respectively. The null hypothesis is so accepted. Therefore the experimental and control groups' pretest and post-test results follow a normal distribution therefor parametric tool was used.

				99% Confidence Interval		
School	Mean Performance	Std. Dev	Performance Difference	Lower	Upper	T
Posttest	83.6154	5.739	33.307	30.955	35.660	2
Pretest	50.3077	6.679	47.346		36.246	

The data in Table 4.8 presents the impact of computer simulation on students‘ performance in genetics by comparing their scores before and after the intervention in the experimental group. The pretest mean score was 50.31 with a standard deviation of 6.68, while the posttest mean score increased significantly to 83.62, with a standard deviation of 5.74. The mean performance difference between the pretest and posttest is 33.31, indicating a substantial improvement. The 95% confidence interval for the difference ranges from 30.96 to 35.66, suggesting that the true average improvement lies within this range. The high T-value of 28.418 and the p-value of .001 (which is less than 0.05) confirm that this improvement is statistically significant. This result demonstrates that the use of computer simulations in teaching genetics had a positive and significant effect on students‘ academic performance, enhancing their understanding and mastery of the subject matter.

4.4.3 Discussion of Effect of Computer Simulation on Performance

The results of this study are in line with those of Akhigbe and Ogufere (2020) showed that using computer simulations as a teaching tool substantially enhances students' achievement and attitude in biology. The study also found that computer simulations significantly improve the performance of low-ability learners, who showed greater gains than medium- and high-ability students. Additionally, the results indicated no significant gender differences in attitude and achievement, suggesting that computer simulations can bridge the gap between male and female students' performance and attitudes Again, the findings are in line with those of Kotoka (2012) discovered that students in the experimental group, who were taught with simulations, scored significantly higher on the post-test compared to those in the control group, who received traditional teacher-centered instruction. Both educators and students expressed acceptance and support for incorporating computer simulations into teaching and learning. Ouahi et al. (2021) also assessed the effects of using computer simulation on students‘ performance in teaching and learning of physics and found that the experimental group register the best performances after the posttest than the control.

Also, a study by Gok (2011) found that there was a significant difference in conceptual test between groups‘ scores in favor of the treatment group that the courses with computer based-activities have a positive effect on students‘ attitude. Okino (2023) also discovered that students instructed with CAIP outperformed those taught using the lecture method. This finding by Okino (2023) is similar to what was found in this study as the lecture method used for teaching genetics did not improve students‘ understanding and performance in genetics as compared to simulation. Similarly, Pellas, and Vosinakis (2018) showed that the performance of students exposed to Computer Simulation were better than their counterparts exposed to the conventional classroom instruction. However, no significant difference existed in the performance of male and female students exposed to Computer Simulation. Also, Kwami (2021) showed that the participants exhibited a favorable attitude toward chemical bonding and chemistry overall. Another study by Olalekan and Oludipe (2016) revealed a significant impact of computer simulation on students' average achievement scores in DNA replication and transcription. Additionally, computer simulation had a significant effect on students' retention ability, but no significant difference was found between male and female students.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter presents the summary of the findings of the study as analysed and explained in the preceding chapter. The importance of computer simulation, implications of the findings of this present research as well as suggestions for future research are given. Also featured in this chapter are conclusions based on the findings of the study. The main aim of this study was to assess the impact of using computer simulation on the teaching and learning of genetics in senior high schools in the Kwadaso Municipal Area.

5.1 Summary of Findings

The study revealed that the use of computer simulations significantly improved student's academic performance in genetics compared to traditional teaching methods. Students who engaged with simulations demonstrated a better understanding of complex genetic processes, which was reflected in their post-test scores. Additionally, the study found that students exhibited positive attitudes toward the use of computer simulations, appreciating their interactive, visual, and self-paced nature, which enhanced their attitude and performance. However, the study also identified key challenges affecting the integration of simulations, such as inadequate ICT infrastructure, limited access to appropriate educational software, inconsistent electricity supply, and insufficient teacher training. The findings further emphasized that the success of simulation-based instruction is highly dependent on teacher competence and support, highlighting the need for professional development and institutional investment in digital teaching resources.

5.2 Conclusions

The study concludes that computer simulation significantly improved performance of students in genetics as simulation made lessons more interesting, generated discussions in class and developed positive attitude among the students. However, the study noted that computer simulation had not been fully integrated in the study genetics due to inadequate ICT resources, such as computers and internet, teachers‘ inability to design simulations that effectively illustrate key concepts, difficulty in finding appropriate simulations that align with specific curriculum standards and learning goals, lack of requisite knowledge to use simulations technologies in the classroom as well as develop assessment methods that accurately measure students understanding and performance from simulation application. Finally, the study concluded that due to low integration of computer simulations in the study of genetics, students were neither able to connect the abstract scenarios presented in simulations to real-world contexts nor adopt simulations to meet their diverse learning needs.

5.3 Recommendations

The study sought to assess the impact of using computer simulation on the teaching and learning of genetics in senior high schools in the Kwadaso Municipal Areas. The study based on the findings provide the following recommendations:

1. The study recommends that simulation software should be integrated into lessons to make them more interesting and enhance classroom experience. The integration of simulation in the teaching of genetics will significantly improve student's interaction with the teacher and students can be able to recall experiences and content that have been taught.
2. The study recommends that school administrations should see to it that ICT infrastructure is working to effectively incorporate simulations while still achieving learning objectives. There should be adequate internet access and ICT equipment to ease facilitation and enable the students to have a deep understanding of the subject matter.
3. The study recommends that facilitators should be given adequate training to equip themselves to select or design simulations that effectively illustrate key concepts. Teachers must be trained to familiarize themselves with specific simulation software or platforms. This will enable them to find appropriate simulations that align with specific curriculum standards and learning goals.

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APPENDICES

APPENDIX 1: QUESTIONNAIRE

IMPACT OF USING COMPUTER SIMULATIONS ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPALITY

Introduction

I am a Masters' Degree Pursuant at AKENTEN APPIAH MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURSHIP DEVELOPMENT and I am conducting research on the topic ―IMPACT OF USING COMPUTER SIMULATIONS ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPALITY‖.

You are invited to participate in the study. You are assured of strict confidentiality and anonymity. Any data you will provide shall be used solely for this study only. You can proceed to answer the questions.

Thank You.

SECTION I: RESPONDENT DATA

1. Sex: 1=Male [ ] 2=Female [ ]

SECTION II: ATTITUDE TOWARDS THE USE OF SIMULATIONS

The statements in table below relate to the attitude of students towards computer simulations in teaching genetics. To what extent do you agree or disagree to each of the statements, using the scale below;

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

Statements	SD	D	N	A	SA
Lesson become more interesting when interactive simulations are used					
Students get interest in genetics when interactive simulations are used in teaching Using interactive simulations in class enhance my comprehension in genetics					
With interactive simulations, I can finish my homework faster					
Using interactive simulation instead of traditional method does not scare me					
The use of interactive simulation makes it simple and easier for me to study genetics					
I like interactive simulations because they can help me learn on my own at home with my computer					
I found the simulations we used appealing.					
I understood the content of genetics better with the help of interactive simulations					
The simulations‘ colourful and dynamic design made it useful for learning					
The simulation was highly effective due to its engaging features like clear visuals and graphics					

The simulation was helpful because they allowed me to visualize the experiment					
Simulation was beneficial because it allowed us to conduct experiments and observe them realistically.					

Source: Adapted from Mhamed Ben Ouashi, Taoufik Hassouni and El Mehdi Albrami, 2022

SECTION III: CHALLENGES OF INTEGRATING COMPUTER SIMULATIONS IN GENETICS INSTRUCTION

The statements in the table below relate to the challenges of integrating computer simulations in genetics instruction. Kindly use the scale to pick the response that you deem appropriate.

1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree

Statements	SD	D	N	A	SA
Inadequate availability of ICT equipment is a challenge to integrating computer simulation into teaching genetic					
Poor internet access is a challenge to integrating computer simulation into teaching genetics					
Teachers struggle to familiarize themselves with specific simulation software or platforms					

Lack of skills in troubleshooting technical issues can hinder the smooth execution of lessons involving					
simulations					
Challenges in integrating simulations with other technologies used in the classroom					
Challenge to design lessons that effectively incorporate simulations while still achieving learning objectives					
Challenges of facilitating discussions and learning around simulations, ensuring that students engage critically with the content.					
Challenge of adapting simulations to meet the diverse learning needs of students					
Challenge of developing assessment methods that accurately measure student learning and understanding from simulations					
Challenges of teachers having a deep understanding of the subject matter to select or design simulations that effectively illustrate key concepts					
Challenge of finding appropriate simulations that align with specific curriculum standards and learning goals					
Challenge to connect the abstract scenarios presented in simulations to real-world contexts					

Source: Adapted from Jovalson T. Abiasen and, Gaudelia A. Reyes, 2021

APPENDIX 2:

PERFORMANCE TEST FOR GENETICS

Kindly answer all questions. Each question carries equal marks.

1. Maria has type O blood and her sister has type AB blood. The girls know that both of their maternal grandparents are type A. What are the genotypes of the girls _parents?
2. Tim and Jan both have sun spots, but their son Mike does not have, show with a Punnett square how this is possible.
3. Describe the process of DNA replication.

APPENDIX 3: MARKING SCHEME

1. Understanding Blood Types and Genotypes (3 Marks)

- Explanation of blood types (A, B, AB, O) and corresponding genotypes (e.g., AO, AA, BO, BB, OO, AB). (2 marks)
- Identifying Maria's genotype as OO and her sister's genotype as AB. (1 mark)

2. Analyzing Parental Genotypes (4 Marks)

- Explanation that to have a child with blood type O (Maria), each parent must contribute an O allele, so one parent is heterozygous AO or BO. (2 marks)
- Explanation that the parent with type AB contributed an A or B allele to Maria's sister. Therefore, the genotype of the other parent must be BO or AO. (2 marks)

3. Conclusion and Parental Genotypes (3 Marks)

- Final conclusion: One parent has blood type AB (genotype AB) and the other must have blood type A with genotype AO. (3 marks)

   Question 2: Tim and Jan both have sun spots, but their son Mike does not. Show with a Punnett square how this is possible.

1. Explanation of Sun Spots Inheritance (3 Marks)

- Explanation that sun spots are a dominant trait. (1 mark)
- The genotype for sun spots is S (dominant allele for sun spots) and s (recessive allele). (1 mark)
- For the child to not have sun spots, Mike must be homozygous recessive (ss). (1 mark)

2. Setting Up the Punnett Square (4 Marks)

- Both parents must be heterozygous for sun spots (Ss), as they both have sun spots but can pass on a recessive allele to their son. (2 marks)

S (from Tim)	s (from Tim)
SS (sun spots)	Ss (sun spots)
Ss (sun spots)	ss (no sun spots)

3. Interpretation of Results (3 Marks)

- Explanation that there is a 25% chance for offspring to be ss (no sun spots). (2 marks)
- Conclusion that this explains how Mike does not have sun spots despite both parents having the trait. (1 mark)

Question 3: Describe the process of DNA replication.

1. Introduction to DNA Replication (2 Marks)

- Brief explanation that DNA replication is the process by which DNA is copied before cell division to ensure genetic continuity. (2 marks)

2. Step-by-Step Process of DNA Replication (6 Marks)

- Unwinding of DNA: Helicase enzyme unwinds the double helix, separating the two strands. (1 marks)
- Formation of Replication Forks: The point at which the strands separate forms a "Y" shape called the replication fork. (1 mark)
- Complementary Base Pairing: Free nucleotides in the nucleus pair with exposed bases on the template strands according to complementary base pairing rules (A-T, G-C). (1 marks)

- Role of DNA Polymerase: DNA polymerase enzyme adds new nucleotides to the growing strand in the 5' to 3' direction. (1 marks)
- Leading and Lagging Strands: The leading strand is synthesized continuously, while the lagging strand is synthesized in fragments called Okazaki fragments. (1 marks)
- Joining of Fragments: DNA ligase enzyme joins the Okazaki fragments on the lagging strand. (1 mark)

3. Conclusion and Importance of DNA Replication (2 Marks)

- Explanation that DNA replication is semi-conservative, meaning each new DNA molecule contains one original strand and one new strand. (1 marks)
- Importance of DNA replication for maintaining genetic information across generations of cells. (1 mark)

APPENDIX 4: INTERVIEW GUIDE

Interview Questions

1. What was the average performance of your students in genetics before the use of computer simulation?
2. Did the use of computer simulation make any difference in the performance of your students in genetics?
3. What can you say about the attitudes of the students towards computer simulations for teaching genetics?
4. Did you face any challenge when using the computer simulation for teaching genetics?
5. If yes to Q 4, what specific challenges did you face?

APPENDIX 5: LESSON PLAN

IMPACT OF COMPUTER SIMULATION ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPAL

SUBJECT:	BIOLOGY
TOPIC:	GENETICS
SUB-TOPIC:	HEREDITY
DURATION:	120 MINUTES

Objectives:

1. Explain the concept of inheritance
2. State and explain Mendel's First and Second Law of Inheritance

Teaching Learning Materials:

- PhET Interactive Simulations software (Genetics simulations)
- Computers or laptops for students

Part 1: Introduction to Inheritance (20 minutes)

1. PhET Simulation: "Genetics" (20 minutes):

- Have students access the PhET simulation software and select the "Genetics" simulation.
- Ask students to explore the simulation and:
- Breed virtual organisms with different traits.
- Observe and record the traits of offspring.
- Guide students to identify patterns of inheritance.

Part 2: Mendel's First Law (40 minutes)

1. PhET Simulation: "Genetics" (continued) (20 minutes):

- Have students continue exploring the simulation, focusing on a single trait (e.g., flower colour).
- Ask students to:
- Breed virtual organisms with different alleles (e.g., R or r).
- Observe and record the traits of offspring.
- Guide students to identify the segregation of alleles during gamete formation.

2. Mendel's First Law (20 minutes):

- Have students analyze the simulation data to understand Mendel's First Law (Law of Segregation).
- Ask students to:
- Describe the law in their own words.
- Provide examples from the simulation.

Part 3: Mendel's Second Law (40 minutes)

1. PhET Simulation: "Genetics" (continued) (20 minutes):

- Have students explore the simulation, focusing on two traits (e.g., flower color and plant height).
- Ask students to:
- Breed virtual organisms with different alleles for both traits.
- Observe and record the traits of offspring.
- Guide students to identify the independent assortment of alleles during gamete formation.

2. Mendel's Second Law (20 minutes):

- Have students analyze the simulation data to understand Mendel's Second Law (Law of Independent Assortment).
- Ask students to:
- Describe the law in their own words.
- Provide examples from the simulation.

Part 4: Conclusion (20 minutes)

1. Reflection and Discussion (20 minutes):

- Have students reflect on what they learned from the simulation.
- Ask students to discuss:
- The concept of inheritance.
- Mendel's First and Second Laws of Inheritance.
- Encourage students to think critically about the simulation results.

Assessment

- Observe student participation and engagement during the simulation activities.
- Review student understanding through simulation-based assessments or quizzes.

IMPACT OF COMPUTER SIMULATION ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPAL

SUBJECT:	BIOLOGY
TOPIC:	GENETICS
SUB-TOPIC:	HEREDITY
DURATION:	120 MINUTES

Objectives:

1. Explain how hybrids are formed

2. Describe the process of DNA replication

Teaching Learning Materials:

- PhET Interactive Simulations software (Genetics and DNA simulations)
- Computers or laptops for students

Part 1: Hybrid Formation (40 minutes)

1. PhET Simulation: "Genetics" (40 minutes):

- Have students access the PhET simulation software and select the "Genetics" simulation.
- Ask students to:
- Breed virtual organisms with different traits (e.g., flower color).
- Observe and record the traits of offspring.

- Guide students to understand how hybrids are formed through the combination of different alleles.

Part 2: DNA Replication (40 minutes)

1. PhET Simulation: "DNA Replication" (20 minutes):

- Have students access the PhET simulation software and select the "DNA Replication" simulation.
- Ask students to:
- Observe the process of DNA replication.
- Identify the key components involved (e.g., helicase, polymerase).

2. DNA Replication Process (20 minutes):

- Have students analyze the simulation to understand the process of DNA replication.
- Ask students to:
- Describe the unwinding of DNA.
- Explain the role of enzymes in DNA replication.

Part 3: Conclusion and Reflection (40 minutes)

1. Reflection and Discussion (20 minutes):

- Have students reflect on what they learned from the simulations.
- Ask students to discuss:
- How hybrids are formed.
- The process of DNA replication.

2. Simulation-Based Assessment (20 minutes):

- Have students complete a simulation-based assessment to evaluate their understanding.
- Review student results and provide feedback

IMPACT OF COMPUTER SIMULATION ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPAL

SUBJECT: BIOLOGY

TOPIC: GENETICS

SUB-TOPIC: HEREDITY

DURATION: 120 MINUTES

Objectives:

1. Explain the concept of inheritance
2. State and explain Mendel's First and Second Law of Inheritance

Teaching Learning Materials:

- Whiteboard and markers
- Diagrams and illustrations of Mendel's laws
- Examples of inherited traits

Part 1: Introduction to Inheritance (15 minutes)

1. Introduction (5 minutes):

- Introduce the topic of genetics and heredity.
- Ask students what they know about inheritance.

2. Concept of Inheritance (10 minutes):

- Explain that inheritance is the passing of traits from parents to offspring through genes.
- Use examples of inherited traits, such as eye color or hair color.

Part 2: Mendel's First Law (30 minutes)

1. Mendel's First Law (15 minutes):
    - Explain Mendel's First Law (Law of Segregation).
    - Use diagrams and illustrations to show how alleles segregate during gamete formation.
    - Discuss the concept of dominant and recessive alleles.
2. Examples and Applications (15 minutes):
    - Provide examples of how Mendel's First Law applies to real-world genetics.
    - Discuss the importance of understanding inheritance patterns.

Part 3: Mendel's Second Law (30 minutes)

1. Mendel's Second Law (15 minutes):
    - Explain Mendel's Second Law (Law of Independent Assortment).
    - Use diagrams and illustrations to show how alleles for different genes are sorted independently during gamete formation.
    - Discuss the concept of dihybrid crosses.
2. Examples and Applications (15 minutes):
    - Provide examples of how Mendel's Second Law applies to real-world genetics.
    - Discuss the importance of understanding inheritance patterns.

Part 4: Conclusion and Assessment (45 minutes)

1. onclusion (15 minutes):

- Summarize the key concepts learned during the lesson.
- Ask students to reflect on what they learned.

2. Assessment (30 minutes):

- Administer a quiz or worksheet to assess students' understanding of inheritance and Mendel's laws.
- Review the answers as a class.

IMPACT OF COMPUTER SIMULATION ON THE TEACHING AND LEARNING OF GENETICS IN SENIOR HIGH SCHOOLS IN KWADASO MUNICIPAL

SUBJECT: BIOLOGY

TOPIC: GENETICS

SUB-TOPIC: HEREDITY

DURATION: 120 MINUTES

Lesson Plan: Genetics - Heredity and DNA Replication Duration:120 minutes

Objectives:

1. Explain how hybrids are formed
2. Describe the process of DNA replication

Materials:

- Whiteboard and markers
- Diagrams and illustrations of hybrid formation and DNA replication

Part 1: Hybrid Formation (40 minutes)

1. Introduction to Hybrids (10 minutes):

- Explain the concept of hybrids and how they are formed through the combination of different alleles.
- Use examples of hybrid organisms, such as mules or hybrid plants.

2. Formation of Hybrids (15 minutes):

- Use diagrams and illustrations to explain how hybrids are formed through the crossing of two different parental lines.
- Discuss the role of genetics in hybrid formation.

3. Examples and Applications (15 minutes):

- Provide examples of how hybrids are used in agriculture and animal breeding.
- Discuss the benefits and limitations of hybrid organisms.

Part 2: DNA Replication (40 minutes)

1. Introduction to DNA Replication (10 minutes):

- Explain the importance of DNA replication in genetics.
- Describe the basic process of DNA replication.

2. The Process of DNA Replication (20 minutes):

- Use diagrams and illustrations to explain the steps of DNA replication, including:
- Unwinding of DNA
- Synthesis of new strands
- Role of enzymes (helicase, polymerase)

3. Key Concepts (10 minutes):

- Discuss the importance of accuracy in DNA replication.
- Explain the concept of semi-conservative replication.

Part 3: Conclusion and Assessment (40 minutes)

1. Conclusion (10 minutes):

- Summarize the key concepts learned during the lesson.
- Ask students to reflect on what they learned.

2. Assessment (30 minutes):

- Administer a quiz or worksheet to assess students' understanding of hybrid formation and DNA replication.
- Review the answers as a class.

APPENDIX 6: VALIDITY AND RELIABILITY OF THE INSTRUMENT

Communalites		
	Initial	Extraction
Lessons become more interesting when interactive simulations are used.	1.000	.543
Students get interest in genetics when interactive simulations are used in teaching.	1.000	.542
Using interactive simulations in class enhance my comprehension of genetics	1.000	.807
With interactive simulations I can finish my homework faster	1.000	.711
Using interactions simulation instead of traditional methods does not scare me.	1.000	.788
The use of interactive simulation makes it simple and easier for me to study genetics.	1.000	.827
I like interactive simulations because they can help me learn on my own at home with my computer.	1.000	.753
I found the simulations we used very appealing	1.000	.790
I understood the content of genetics better with the help of the interactive simulations.	1.000	.661
The simulations‘ colourful and dynamic design made it useful for learning.	1.000	.745
The simulations were highly effective due to its engaging features like clear visuals and graphics.	1.000	.747
The simulations were helpful because they allowed me to	1.000	.694

visualize the experiments		
Simulations were beneficial because it allowed us to conduct experiments and observe them realistically.	1.000	.685
Extr action method: Pr incipal Component Analysis		

Reliability Statistics

Cronbach's Alpha	N of Items
.826	13

Communalities		
	Initial	Extraction
Inadequate availability of ICT equipment is a challenge to integrating computer simulation into teaching genetic	1.000	.810
Poor internet access is a challenge to integrating computer simulation into teaching genetics	1.000	.556
Teachers struggle to familiarize themselves with specific simulation software or platforms	1.000	.817
Lack of skills in troubleshooting technical issues can hinder the smooth execution of lessons involving simulations	1.000	.753
Challenges in integrating simulations with other technologies used in the classroom	1.000	.852
Challenge to design lessons that effectively incorporate simulations while still achieving learning objectives	1.000	.666
Challenges of facilitating discussions and learning around simulations, ensuring that students engage critically with the content.	1.000	.585
Challenge of adapting simulations to meet the diverse learning needs of students	1.000	.484
Challenge of developing assessment methods that accurately measure student learning and understanding from simulations	1.000	.841
Challenges of teachers having a deep understanding of the subject matter	1.000	.766

to select or design simulations that effectively illustrate key concepts		
Challenge of finding appropriate simulations that align with specific curriculum standards and learning goals	1.000	.732
Challenge to connect the abstract scenarios presented in simulations to real-world contexts	1.000	.676
Extraction method: Principal Component Analysis		

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.734
Bartlett's Test of Sphericity	Approx. Chi-Square	509.300
	df	66
	Sig.	<.001

Reliability Statistics

Cronbach's Alpha	N of Items
.704	12