EFFECTS OF TEACHER'S USE OF 5E INSTRUCTIONAL MODEL ON SECONDARY SCHOOL STUDENT'S ACHIEVEMENT IN BIOLOGY IN VIHIGA COUNTY, KENYA

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN SCIENCE EDUCATION OF MASINDE MULIRO UNIVERSITY

MAY 2025

DECLARATION

This thesis is my own original work prepared with no other than the indicated sources and support, and has not been presented elsewhere for a degree or any other award.

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EDS/H/01-56602/2016

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University a thesis entitled, **"Effects of teacher's use of 5E instructional model on secondary school student's achievement in biology in Vihiga County, Kenya"**

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DEDICATION

I dedicate this thesis to five special people in my life: my dear husband Sylvester Makamu for encouragement and technical assistance in proofreading this document, my sons Evans Lisiolo and Kevin Madahana for positive motivation and technical assistance in typesetting the document and my daughters Mercy Shimuli and Joan Iramwenya for moral support and encouragement without which this academic milestone would have been difficult to be achieved.

ACKNOWLEDGEMENT

Although it is not possible to thank all those who contributed to this thesis individually, special recognition and gratitude are extended to the following; First, I thank the Almighty God for good health and a sound mind throughout the period of my study. Secondly, my gratitude goes to Dr. Ong'unya Raphael and Prof. Toili William, my university academic supervisors who were readily available to provide guidance throughout the study. Their sacrifice, patience and encouragement helped shape this study in the form it is today. Secondly, all lecturers in the department of science and mathematics education for their encouragement and inspirational guidance that kept my esteem high to realize this piece of work. Third, Ms Shitiavai Evelyne my colleague for continued support and encouragement. I wish to also appreciate my family led by my dear husband, Mr Makamu Sylvester for his technical assistance and relentless encouragement when the pressure of this journey was unbearable; my children, Mercy Shimuli, Evans Lisiolo, Joan Iramwenya and Kevin Madahana for stepping in my 'big shoes' on occasions when the demands of this work restrained me from fulfilling all my obligation.

NABIE A. M.

ABSTRACT

Biology is a discipline that enables one understand nature, one self and life processes besides facilitating development of important skills that find use in specialized areas such as medicine, agriculture and environmental sciences. Biology provides the background knowledge that specialized areas of life stems from. This is however threatened by the low achievement by students at Kenya Certificate of Secondary Education (KCSE) in the subject partly attributed to the use of predominantly teacher-centered approaches of instruction (Richards, 2022). This study sought to determine the effect of teachers' use of the 5E instructional model approach on students' achievement in Biology in Vihiga County. It was guided by four objectives: to determine the effect of the 5E instructional model approach on students' achievement; find out whether there is a correlation between students' scientific skills, attitude and academic achievement; determine whether students' scientific skills and attitude interact to influence their academic achievement and determine whether students' scientific skills and attitude could predict academic achievement in cell biology. The study was anchored in constructivist theory which holds that meaningful learning results from active participation of learners and that individuals acquire knowledge and derive meaning through experiences. The study adopted a sequential mixed methods research approach comprising of quasi-experimental research design to collect quantitative data followed by focus group interviews to collect qualitative data. A sample of 550 students was selected from a population of 14,400 form three students of biology using multi-stage sampling procedure. The 12 teachers of biology for the sample classes were automatically selected to take part in the study. The dependent variable was the student performance at three levels; academic achievement, scientific skills achievement and attitude, while the independent variable was the method of instructional two levels; 5Einstructional model approach and the conventional approach. Data was collected using three achievement tests, and two questionnaires. A pilot study was carried out in two schools prior to the actual study in two schools within the area of study. The reliability of the research instruments was determined using Cronbach's alpha coefficients for internal consistence and all the instruments had a reliability coefficient above 0.7. Validity was established through consultation with research experts from Masinde Muliro University and practicing teachers. All the instruments had scores above 60%. Data was analyzed using the independent sample t-test, Pearson correlation coefficient, Standard Multiple Linear Regression and ANCOVA at $\alpha = 0.05$. The main finding was that the 5E instructional model greatly improved student's achievement in biology. In addition, student's scientific skills had a strong positive correlation with students' academic achievement in biology. The results of this study may provide a basis for improving instruction in biology as well as in other subjects to realize improved achievement by the learners.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

ASEI: Activities, Students, Experiment and Improvisation

CBAT: Cell Biology Achievement Test

FGI: Focus Group Interview

KCSE: Kenya Certificate of Secondary Education

KNEC: Kenya National Examinations Council

NACOSTI: National Commission for Science, Technology and Innovation

NECTA: National Exam Council of Tanzania

PDSI: Plan, Do, See, Improve

SAA: student academic achievement score

SAS: student attitude score

SAQ: Student Attitude Questionnaire

SSS: student scientific ability score

SPSS : Statistical Package for social Sciences

SSAT: Scientific Skills Achievement Test

WAEC: West African Examination Council

CHAPTER ONE

INTRODUCTION

1.1 Preamble

This chapter describes the background of the study, the statement of the problem, purpose and objectives of the study as well as the significance of the study. It also provides the scope of the study in terms of the limitations and delimitations, the basic assumptions and theoretical and conceptual frameworks that guided the study.

1.2 Background of the study

Biology provides an informational foundation that underpins advancements and innovation in critical areas of development in any Nation. As a science that deals with life, it influences and shapes every aspect of our daily living. Biology introduces pupils to the realm of information about themselves, their immediate environment, and the wider world as claimed by Taiwo & Emeke (2014). Through biology, students can apply scientific ideas, methods, methods, and mindsets to solve real-world problems. Knowledge of biology is useful in a variety of industries, including agriculture, nursing, medicine, and pharmacy (Allen et al., 2015).

Biology has cell biology as the basic and unifying concept for all its domains necessary to realize set objectives outlined in the secondary school syllabus. Cell biology involves the study of cells, first described by Robert Hooke in 1665. Cells have since been described as functional and morphological units of living organisms. Cell biology is therefore an important basic concept of modern biology whose comprehension is fundamental in academic achievement in biology at all levels.

Numerous research findings including those by Valverde and Schmidt (2017) in the USA, Landry (2018) in Canada, and Fonseca and Conboy (2016) in Portugal, show that low performance in biology is a global issue. To Majo (2016), secondary school pupils in East Africa, Africa, and around the world have been performing badly in biology in recent years. According to Jasman, Sulisetijono, & Mahanal (2024), biology continues to be a major challenge for the global and African education systems. Students find it difficult to understand basic knowledge about cells because the concepts are abstract and the structures are microscopic. Learners are unable to perceive metabolic, biochemical and physical processes in cells using their senses. The knowledge about cells has therefore remained fragmental and inadequately integrated on the level of cells and organisms by the learners (Babayan, 2021). This greatly contributes to poor understanding of other concepts of biology by learners leading to the low performance in biology as a subject. In standard examinations, students often do not perform well when questions require them to associate concepts or apply them to new situations. Being the basic concept in biology, low performance in cell biology implies low performance in biology.

Despite the significance of biology, consistent low scores in both internal and external tests in various regions are reported. According to the chief examiner's report from WAEC in 2014, there has been a consistent decrease in students' performance in biology over the years. This is evident from the mean scores of 35.74% in 2010, 35.61% in 2011, 33.57% in 2012, 33.94% in 2013, and 33.87% in 2014. The pattern of KCSE achievement in biology by students in Kenya is similar as illustrated in Table 1.1.

Table 1.1 KCSE Performance in biology for previous Four years in Kenya

YEAR	2016	2017	2018	2019	2020	2021	2022
Mean Mark (%)	29	18.9	25.69	25.69	25.52	28.51	28.68
Mean Grade	D	D-	D	D	D	D	D

Source: KNEC annual KCSE Reports, (2015-2019)

From Table 1.1, students mean scores in biology at KCSE is consistently low indicating that most students do not attain quality grades to pursue biology related courses necessary to realize desired growth in the country.

The KCSE performance in biology in Vihiga County is not any better as shown in the Table 1.2.

Table 1.2: KCSE performance in biology for the years under study in Vihiga County

Year	2016	2017	2018	2019	2020	2021	2022
M/Score (Country)	2.6247	1.9901	2.9320		2.926	2.923	2.984
M .Grade	D	D-	D	D	D	D	D

Source: County Director of Education- vihiga, 2023

From Table 1.2, the mean of biology in the county has remained consistently low for the period of study. Unless this is addressed, the country may not realize its vision 2030 on advancement in agriculture, healthcare and environmental sustainability.

Analysis of KCSE question papers for the period under study revealed that cell biology concepts are examined each year. Table 1.3 shows the weight of questions on cell biology concepts in the three papers of biology done at KCSE.

Table 1.3: Number and total score of cell biology questions in KCSE biology papers

YEAR	2019	2020	2021	2022
Number of questions on cell biology	5	4	5	5
Total marks	30	28	24	28

Source: KCSE biology past papers, (2019-2012)

According to Table 1.3, cell biology concepts contribute an average of 27.6 marks out of a possible 200 marks. This points to a possibility that student's poor comprehension of cell biology concepts is the cause of their poor performance in biology at KCSE.

The poor academic achievement of students in biology has been attributed to several causes that include the teaching approach employed (Owusu, Monney, Appiah, & Wilmot, 2010). According to Shan and Khan (2015), teaching techniques that focus on the teacher have not been successful in improving the development of problem-solving skills, curiosity, and critical and logical thinking among science students. Multiple pedagogical research indicate that active learning enhances students' academic performance in the classroom (Bulut & Dursun, 2019; Hendrickson, 2021; Jackson, 2002; Stephen et al., 2010; Van den Bergh et al., 2013). A number of studies have highlighted the need of fostering scientific inquiry in order to enhance students' comprehension of the subject matter (Gyllenpalm, Rundgren, Lederman, & Lederman, 2022). However, only a small number of these research offer a comprehensive understanding of how the inquiry technique should be effectively utilized. Amwe (2018) posits that the 5E learning circle model offers a structured sequence of instruction that prioritizes students in the centre of their learning experiences, fostering their ability to investigate, develop their own comprehension of scientific concepts, and connect these comprehensions to other concepts. The 5E learning model organizes learning experiences to enable students to develop their comprehension of a concept over time. Kallis (2024) also reveals that the 5E instructional model contributes to the development of critical thinking skills, adaptability, self-development and collaboration. This aligns with the principles integrated within the CBC curriculum. This investigation is predicated on the question of whether the 5E instructional model has the potential to enhance the performance of biology students. 5E instructional paradigm is founded on constructivism, which posits that learners must develop their own comprehension of novel concepts. In this model, learners are able to comprehend the information they have acquired by utilizing both their prior experience and the first-hand knowledge acquired through novel exploration (Kazempour, Amirshokoohi, & Blamey 2020). The learning circle not only enhances students' existing knowledge but also redirects the focus from the instructor to the learner and the active role they play in the learning process, Opara and Waswa (2013). This is a critical element of CBC, where one of the paradigm adjustments is the transition from "teaching to facilitating" the learning process.

The 5E Instructional Model as the name indicates constitutes five discrete elements/components each beginning with letter E as follows:

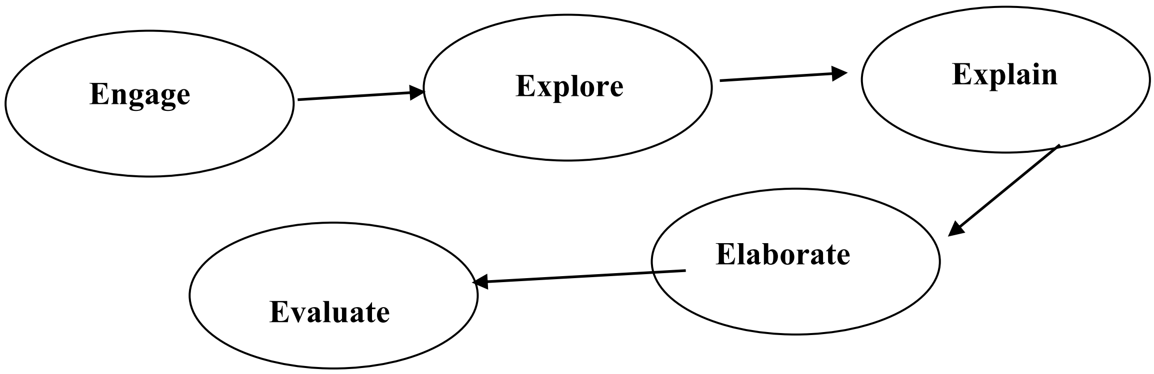

Figure 1.1. The 5E instructional Model

The Biological Science Curriculum Study (BSCS, 2015) outlines the aim of each phase from the views of both instructors and children as follows: During the engagement phase, teachers assess students' past knowledge and stimulate their interest in a new idea by using brief exercises that inspire passion and tap into their existing knowledge. The exercises establish linkages between the knowledge and abilities of the learners, revealing their pre-existing concepts, and structure their thinking towards the desired learning goals of the present subject matter. During the exploration phase, students engage in activities that promotes conceptual change. At this stage, learners provided with opportunities to actively acquire knowledge by manipulating materials, generating new ideas, exploring questions and possibilities, and conducting initial investigations. During explanation stage, students are expected to generate an explanation of the phenomenon. They are given opportunities to showcase their conceptual understanding, process abilities, or actions. This phase also offers teachers the chance to employ direct instruction to change and improve their conceptual understanding. Elaboration refers to the process of challenging and deepening learners' understanding of a topic through new experiences. These experiences help learners build a more comprehensive and profound understanding, as well as acquire extra information and skills. At evaluation, students assess their comprehension of the phenomenon. This phase facilitates learners in evaluating their comprehension and skills and also provide teachers with opportunity to review students' progress in attainment of objectives.

Many scientific studies have concentrated on instructional methods aimed at enhancing students' learning and overall academic achievement. The implementation of the 5E learning paradigm would consequently bolster the cultivation of learners' critical skills, enabling them to more effectively adjust to the requirements of the 21st century.

Multiple comparison studies indicate that the 5E instructional model is superior to other techniques in terms of assisting students in achieving mastery in science subjects (Sam, Owusu, & Anthony-Krueger, 2018). The majority of researchers have examined the aspects of practical work, motivation, attitude modification, and innovations in content delivery. Many Existing research does not provide any studies on the impact of the 5E instructional paradigm on achievement in biology, particularly in the field of cell biology. This study examined the effects of teacher's use of the 5E instructional model on secondary school student's achievement in biology.

1.3 Statement of the Problem

Biology at Secondary School level provides the basis for development of scientific skills and principles crucial for solving everyday life problems at individual, national and international levels. Through biology learners acquire important knowledge, skills, and attitudes for personal growth and national development. Biology expertise is applicable in numerous fields, including agriculture, dentistry, pharmacy, and medicine (Allen et al, 2015). These prestigious fields are critically important for any nations development which would allow a Nation to be self-sufficient in terms of human resources. However, performance of learners in the Kenyan Certificate of Secondary Examination (KCSE) reveals that student performance in biology has remained dismal both in Vihiga County and the entire country of Kenya. The low performance in Biology suggests a general shortage of manpower in critical sectors such as agriculture, medicine, industry, and education (Samikwo, 2013). This has resulted in the country importing labour force in critical fields such as medicine despite the heavy investment in the education sector by the government. Teaching method employed by teachers has been identified as a key factor that influence performance of learners (Guloba et al., 2010). The construct of attitude toward science has been recognized as a critical component of science learning with the potential to influence not only scientific views and desires, but also achievement. Research further reveals that teaching method has a significant impact on the attitude of students toward the study of scientific subjects (Taştan et al., 2018). The Kenyan government has tried to address pedagogy through international projects such as (SMASSE), however the low achievement in biology and other science subjects is still evident. Consequently, it is challenging to imagine a Nation that is dedicated to the realization of the Kenya vision 2030 with products that are incompetent in fields essential for development. This necessitates concerted effort to reverse the trend in order to achieve the anticipated economic growth. This serves as the foundation for this study.

Studies reveal that instructional methods that prioritize deep learning also enhance academic performance in terms of knowledge retention, creativity, motivation, problem-solving, and other related skills (Chang, 2010). The 5E instructional model is regarded as one of the most effective teaching methods within the constructivist learning paradigm (Ergin, Kanil & Unsal, 2008). The 5E learning model organizes learning experiences to enable students to develop their comprehension of a concept over time. The model embodies all the attributes of constructivism theory and maximizes learner engagement by involving them in a succession of activities that help them construct their own understanding. 5E model can assist learners in transitioning from comprehension of concrete experiences to the application of principles, according to Llewellyn (2007). Research further informs that the 5E instructional model is a superior inquiry-based learning strategy that not only enhances academic performance but also contributes to the cultivation of a positive attitude toward science in students. Therefore, whether the 5E instructional model approach would alleviate the low performance in biology becomes any science educationist's concern for research. The researcher conducted this study to investigate the effect of the 5E instructional model learning approach on students' performance in learning of cell biology concepts in particular and biology in general.

1.4 Broad objective of the Study

The purpose of this study was to investigate the effect of using the 5E instructional model approach of learning on students' achievement in cell biology concepts among secondary school students.

1.5 Specific objectives of the study

The study was guided by the following objectives:

i. To determine the effect of using 5E instructional model approach on students' achievement in biology

ii. To determine if there is a correlation between students' scientific skills and attitude with academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach.

iii. To determine the extent to which students' scientific skills and attitude interact to influence their academic achievement in biology when taught using 5E instructional approach and the conventional approach.

iv. To establish the extent to which students' scientific skills and attitude could predict academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach.

1.6 Hypotheses of study

The following null hypotheses were tested inferentially at $\alpha = 0.05$

HO_1: There is no significant difference in student's achievement in biology when taught using the 5E instructional approach and when taught using the conventional approach.

HO_2: There is no significant correlation between students' attitude and scientific skills with their academic achievement when taught using the 5Einstructional approach and when taught using the conventional approach.

HO_3: Students' attitude and scientific skills do not significantly interact to influence student's academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

HO_4 : Students' scientific skills and attitude do not predict students' academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

1.7 Rationale for the study

Many graduates today lack the basic competencies required for the present-day labour market. The competence-based curriculum (CBC) was introduced in Kenya in 2017 to prepare students for the demands of the 21st century. It aims at enabling students develop skills and knowledge they need to thrive in the changing world. Under CBC, inquiry-based learning approach where learners are given opportunity to construct knowledge through active participation is emphasized. Effective implementation of CBC therefore require pedagogy that allows active participation of learners to construct their own knowledge. The five stages of 5E instructional model would provide the perfect conditions for implementation of the CBC in addition to improving students' achievement from instruction.

1.8 Significance of the study

The findings of this study would be of practical and theoretical value. In terms of practical value, the findings of the study would enable teachers diversify pedagogy by embracing the 5E instructional model-based learning approach to improved performance in biology. Through active participation, learners would achieve deeper understanding of cell biology concepts which is basic to all concepts of biology subject. This would lead to improved performance in the subject that will enable learners to pursue productive careers like medicine, agriculture and engineering necessary to realize the goals of biology education in the country. The Nation would realize professionals for production industries to help realize its vision 2030. Additionally, curriculum developers would diversify pedagogies in use by including the 5E model for active learning. The ministry of education would focus on development of appropriate learning resources to improve learning. The findings would also add to the existing knowledge. In terms of theoretical value, the findings may contribute to the growth of knowledge on active inquiry through 5E instructional model.

1.9 Assumptions of the study

The study was conducted based on certain assumptions. That selected students had not yet studied the cell biology concepts under the topic of reproduction at the time of the study. That chosen sample was representative of the greater population, meaning that the students have similar mental age and average academic entry behavior. Consequently, the results of the study would be extrapolated to encompass all secondary schools within the research region. The obtained data exhibited a normal distribution, indicating that it accurately represented the larger population and allowed for parametric data analysis. Additionally, it was presumed that the selected schools had biology teachers who possessed the necessary qualifications, and that the respondents were truthful in their utilization of research instruments.

1.10 Delimitations of the study

The research was carried out in selected boarding secondary schools in Vihiga County. Students and teachers of biology in the selected schools formed the sample population. Data was collected by use of questionnaires and achievement tests administered by the researcher assistant and selected teachers in the sample schools. The researcher was limited to the 5E instructional model learning approach in teaching of selected cell biology concepts covered in secondary schools in biology in Kenya. The scientific skills investigated through practical work included; observation, measuring, recording and drawing. Academic achievement and attitude towards cell biology concepts and biology as a subject were also investigated.

1.11 Limitations of the Study

Randomization would not be fully achieved due to use of intact classed in the school setup. This was addressed by the researcher assigning the sampled classes randomly into treatment and control groups. Disparities in syllabus coverage and internal school programs in different schools also posed a limitation that would affect the efficiency of the study and the results. The researcher used boarding schools to counter adverse effects of such disparities.

1.12 Theoretical Framework

The study was based on the constructivist theory of learning, which posits that individuals acquire information and derive meaning via their experiences. Constructivism is based on the research and theories of three psychologists: Jean Piaget (1896-1980) and John Dewey , who focused on childhood development and education, and Lev Vygotsky (1896-1934), who studied the social elements of learning via experience. Piaget posited that human learning occurs through the successive building of logical structures. Dewey advocated for an education that is based on practical, first-hand encounters. In Zaitoon's (2007) perspective, the term "constructivist" denotes a method of acquiring knowledge wherein learners create fresh understandings within the framework of their existing knowledge, based on their experiences and learning environment. Through comprehension and contemplation of activities, students can harmonize novel knowledge with pre-existing concepts. Constructivism in a classroom setting necessitates that the instructor incorporates inquiry, exploration, and assessment into their educational methodology. The teacher assumes the position of a facilitator, providing guidance to pupils as they acquire new concepts. The philosophy of constructivism is founded upon three constructions, as demonstrated by Khataibeh (2008):

1) The learner constructs the meaning themselves through their cognitive mechanism, rather than receiving it from the teacher. This meaning is formed in the learner's mind through interaction with the external environment and is undoubtedly shaped by their past experiences.

2) The construction of meanings is a cognitive activity that necessitates deliberate mental exertion.

3) The learner's cognitive framework exhibits resistance to change. The learners therefore construct new knowledge structures or reconstruct their cognitive system, as the learner's experience and past information significantly influence the learning process. Constructivists believe that teaching should be centered around the idea that the learner is actively engaged in the learning process. This means that the learner is actively using their mental abilities to acquire knowledge, and they have specific goals in mind that they want to achieve in order to solve a problem, answer a question, or fulfill an internal desire. This emphasizes the significance of aligning the objectives of education with the learner's actual life, interests, and needs.

Constructivism could therefore have positive implication for teaching biology in terms of knowledge creation, learning, teaching and the role of the teacher and learner in the classroom. In terms of knowledge, constructivists believe that it is constructed by an individual through the activities that produce it; it is not transmitted. This construction is achieved through active learning or inquiry where multiple opportunities and diverse processes are provided by the teacher (Toili et al, 2019). The teacher guides and facilitates thinking of the learner through discussion and problem solving to achieve a more complete understanding. In situations where group work is used, the teacher provides opportunities where collaborative construction of socially defined knowledge occurs. The student is usually motivated into an active social participator in the learning process. The components of effective constructivist teaching include contextualization and framing of learning situation, safe classroom and constructive alignment in which learning proceeds from simple to more complex ideas and form shallower to deeper understanding. The teacher is expected to use hands-on and minds-on experiences to help learners develop meaningful experiences (Toili et al, 2019). The constructivist learning model is therefore considered as the most effective by some scholars. The primary rationale for this is that the constructivist learning model places the learner at the core of the learning process. In this model, the learner is empowered to independently construct knowledge by gathering information and data, formulating hypotheses, analyzing results and making generalizations. The learner also engages in discussions to explore solutions, ideas, and concepts, and further develops them through interactions with others.

Finally, the learner applies these findings in novel educational contexts and situations. Constructivism promotes the use of inquiry-based learning. According to Crawford (2000), inquiry learning is a method of learning that involves students actively generating their own knowledge by interacting with items in their surroundings and engaging in higher-level thinking and problem-solving activities, with the guidance of teachers. Inquiry allows students to propose intellectually stimulating questions that are typically not asked in a typical scientific classroom (Scott, 1994; Rop, 2003). Using the Constructivist Learning Model in science education can enhance student achievement and foster the development of their scientific thinking. The constructivist model aligns effectively with the five stages of the 5E instructional model.

The E-learning circle models, including 3E, 4E, 5E, 6E, and 7E, have been used at various educational levels. This study is based on the 5E educational paradigm, which was created in the mid-1980s by primary investigator Roger Bybee and his team, including Joseph Taylor, April Gardner, Pamela Scotter, Janet Powell, Anne Westbrook, and Nancy Landes. It was specifically designed for scientific programs and was utilized in the Biological scientific Curriculum Study (BSCS). The model exemplifies a structured inquiry learning circle approach consisting of five distinct phases: engagement, exploration, cooperation, explanation, and evaluation. The stages facilitate the learner's active involvement, which is essential for the formation of knowledge. The 5E teaching paradigm facilitates active learning by creating a setting where learners actively engage in the five E stages. During the Engage phase, the teacher assesses the students' existing knowledge and identifies any gaps in their understanding. In the Explore phase, the students actively investigate the new concept, enabling them to learn through practical experience. In the Explain phase, the teacher assists the students in integrating the new knowledge and providing clarifications as needed. Finally, in the Elaborate phase, the learners are encouraged to apply what they have learned, allowing them to develop a deeper understanding. This aids learners in solidifying their information before assessment. During the evaluation process, the teacher gets the opportunity to assess if the learners have a comprehensive understanding of the fundamental ideas. The technique so allows learners to develop knowledge and meaning based on their experiences.

Bybee et al. (2006) list several goals of the 5E instructional model, which is to reform science education by incorporating field testing with diverse students in varied contexts, ensuring scientific accuracy, and adhering to the principle of universal design for learning. Opara and Waswa (2013) state that the learning circle is a model that helps students build on what they already know while also moving the focus away from the teacher and onto them as active participants in their own education. Several studies have shown that the learning circle method—which has been around since the 1960s—can improve students' reasoning abilities, process skills, attitude toward science and science learning, and overall academic performance compared to more conventional methods of instruction (McComas III, 1992). Ansberry and Morgan (2007) state that the 5E learning circle model offers a structured approach to teaching that puts students in charge of their own education by guiding them to ask questions, find answers, and draw connections between different ideas in science. The 5E model is an effective strategy for education because it promotes critical thinking, flexibility, self-improvement, collaboration, and complex communication among students. Students are better able to seek out new patterns if they develop self-awareness in their reasoning and successfully apply new knowledge (Balci, Cakiroglu, & Tekkaya, 2006). Consequently, according to constructivist theory, the following are the most important aspects of learning biology: course content, instructional strategy (including problem-solving and practical activities), learning attitude, learning mode, and student achievement (including knowledge, practical skills, and self-efficacy). Learning based on the 5E model has the potential to offer active learning that may be used to measure achievement in biology.

Constructivism provides an effective way to explore complex topics, encourage creativity and allow participants make sense of their own experiences. According to constructivism theory meaningful learning results from active participation by the learners; that learners actively participate the learning process, construct their own meaning through experiences The active participation is achieved through the five steps of the 5E model; engagement, exploration, explanation, elaboration and evaluation during which the learner is guided through activities for knowledge construction. Constructivism also holds that learning progresses when prior knowledge is modified and new ideas build. This is addressed at the engagement stage where the teacher tries to establish learners' prior knowledge brought into the class. The five steps of 5E therefore aligns with the tenets if the constructivism theory

1.13 Conceptual Framework

The constructivist learning theory informed the choice of this conceptual framework. Principles of learning indicate that learning is an active process where learners use sensory input to construct meaning. Studies reveal that the instructional methods a teacher employs have an influence on academic achievement (Dudu & Vhurumuku, 2012; Minner, Levey & Century, 2010). Minner et al., (2010) further revealed that student's science conceptual understanding increased when they are actively engaged in the learning process. It is therefore imperative that learners be actively engaged for effective learning to take place. In this study, the researcher hypothesizes that the 5E instructional model approach, being an active student-oriented method will have an effect on academic achievement. This forms the basis for the first objective of the study. Attitude towards Science has also been identified as an important factor that determines students' performance and conception about the subject. Abudu and Gbadamosi, (2014), affirm that only positive attitude results in better performance in science education. (Mart 2003, Osborne et al 2003) argue that only a teacher who uses appropriate ways of instruction can assist drive positive attitude in the learner. The second objective will seek to establish the effect of the 5E instructional model approach and the conventional approach on students' attitude towards biology and student development of scientific skills.

Figure 1.1 shows the study conceptual framework. The independent variables will consist of instructional approaches used broken into the conventional approach and the 5E instructional model approach in teaching of the selected biology concepts. The dependent variables will consist of academic achievement, attitude and acquisition of scientific skills. The intervening variables will comprise of teacher's preferred teaching style, gender and support from administration.

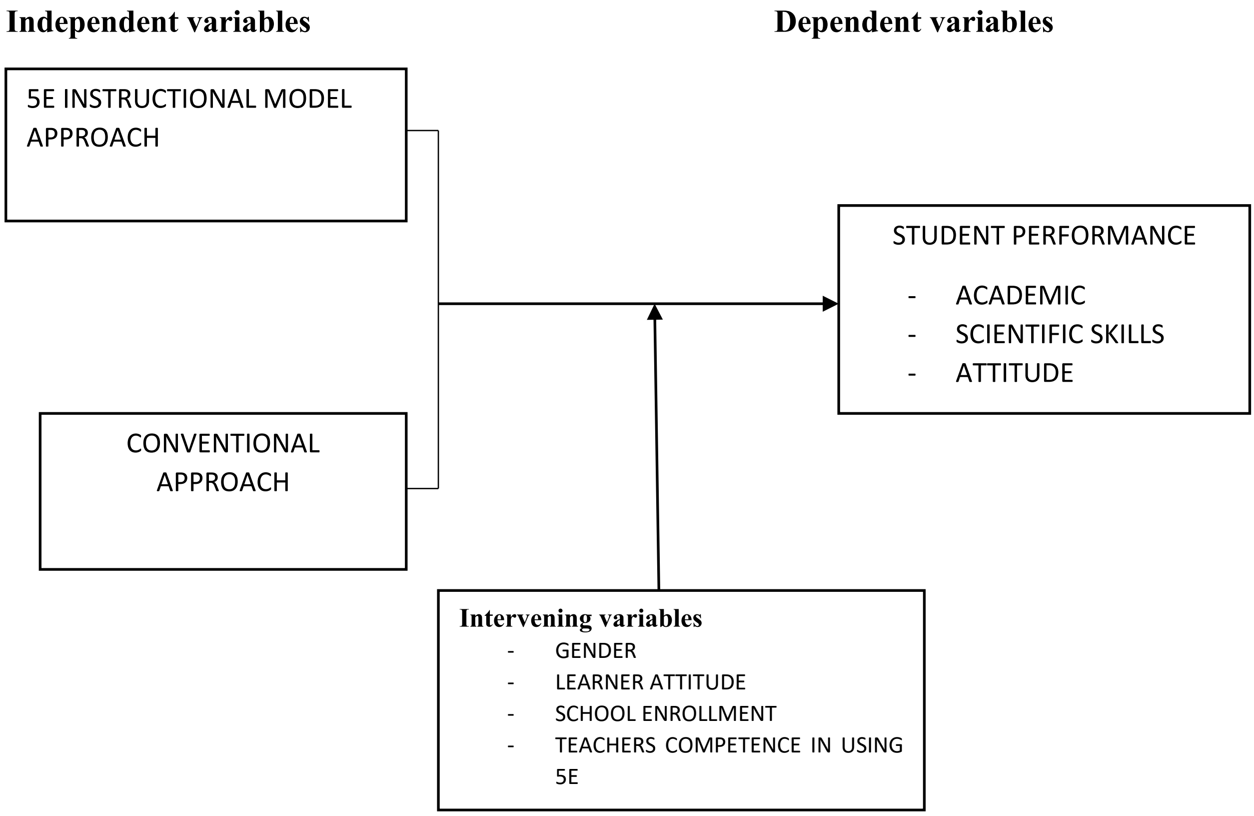

Figure 2.1: Conceptual Frame work

1.14 Operational definition of key terms

Conventional approach: -Traditional Instruction Approach that is characterized by teacher centered instruction where the learner is a passive recipient of knowledge.

5E Instructional Model approach: –Active Learning Instructional Approach that is characterized by student centered instruction where learners actively participate in knowledge construction through interactive learning guided by the 5Es; Engagement, Exploration, Explanation, Elaboration and evaluation as designed by Rodger W. Bybee in 1980s

Achievement: -Gain from Instruction as demonstrated through quality of scores (academic achievement), attitude and acquisition of scientific skills

Scientific skills: -basic science engagements that the learner undertakes with ease such as observing, measuring, recording, classifying and arranging.

Academic achievement: -student’s score in an achievement test taken after instruction.

Instructional model: teaching strategies, methods and activities used by a teacher during lesson delivery

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review addresses the following themes; student performance in science education, factors that influence student performance in science education, the 5E instructional learning approach and student learning, Performance of biology at KCSE

2.2 Student Performance in Science Education

Science education is universally acknowledged as fundamental and highly important in any curriculum. Olasehinde and Olaloye (2014) state that the purpose of science education is to lead society towards scientific literacy and provide personal satisfaction and enthusiasm. Acquiring knowledge in the field of science contributes to the advancement of a nation. The trajectory of our scientific advancements will be shaped by individuals who possess the capacity to comprehend and actively contribute to the intricate impacts of science and technology on our global society (Ungar, 2010). Research indicates that learners regard biology as the sole science subject that is meaningful to them due to its connection to life and everyday observations. Biology serves as a foundation for instructing students in the application of scientific concepts and principles to solve practical problems encountered in daily life. The course equips students with the necessary knowledge and skills to pursue further studies in practical fields such as agriculture, medicine, biotechnology, agrochemicals, and the food business (Mukachi 2005). Biology is commonly perceived as the least complex among all scientific courses, as evidenced by the higher number of students enrolled in contrast to other science subjects. Ofoeghu (2003) claimed that biology has a much higher student enrollment in comparison to all other scientific disciplines.

According to Okubuito (2004), despite biology being popular among students, there is still a significant rate of failure. The subpar level of performance is a cause for concern among all stakeholders and researchers. Research reports have also shown that poor performance by students in science subjects is mainly caused by the teacher centered method of teaching in science classroom (Ukoh & Adewale, 2014). Teacher centered methods have failed to enhance development of problem-solving skills, curiosity and critical and logical thinking among science students (Shan & Khan, 2015). Teacher pedagogy is therefore a key issue in research if performance in biology is to be revived. Is the teaching methodology a potential problem?

Although Science education is widely applied in economic growth, there is a persistent challenge of poor performance in science at both local and international levels. According to Ajaja (2008), the underachievement in Science courses in Secondary schools continues to be a significant issue for educators and the government. The underwhelming performance in science courses is widespread. According to the Science Education in Europe (2011) worldwide student assessment surveys, there has been a decline in the relative rankings of European members in terms of their performance in science disciplines. In Uganda, science courses continue to pose a challenge to the school system, despite the efforts made to enhance the academic discipline. The performance in science disciplines is comparatively worse than that in other subjects (Kiyaga 2013). Oskari (2007) reported that despite notable progress in enhancing the availability of excellent education in Tanzania, there has been a persistent lack of proficiency in Mathematics and Science disciplines. The assessment also indicated that there was a clear demonstration of inadequate academic achievement in both primary and secondary schools. These findings were further elucidated by figures from the National Exam Council of Tanzania (NECTA), which demonstrated a significant increase in the number of students failing science subjects in Tanzania.

Despite the government's efforts to address pedagogy through the SMASE project, the performance in Science disciplines in Kenya continues to stay low. Several scholars and educators have endeavored to identify the underlying cause of the subpar academic achievement in order to enhance students' performance in science education. Njuguna (2003) identified classroom management and instructional techniques as significant factors contributing to poor performance in science disciplines. Akubuito (2004) argued that the teacher's instructional approach has a substantial impact on students' achievement in biology. Students who are exposed to effective teaching methods are more likely to achieve good performance, whereas those who get inadequate instruction are likely to perform poorly.

Is it possible that the teaching methods employed by teachers are responsible for the low academic achievement in the subjects of science and biology? The SMASSE that was introduced in Kenyan secondary schools sought to address methodology, availability of resources and learners' attitude. Despite the operationalization of the project for many years, low performance in biology still lingers on. This calls for research into innovative approaches such as the 5E instructional approach. This study sought to determine whether the use of 5E instructional model would avert the situation.

2.3 Factors that influence student performance in science education

The underachievement in science subjects can be attributed to various factors, such as ineffective teaching methods that prioritize the teacher, negative attitudes caused by a lack of motivation, inadequate infrastructure, students' attitudes, insufficient skills and competencies among science teachers, and a lack of professional development opportunities for science teachers (Adepojo, 1991; Salau, 1996; Braimoh and Okadey, 2001; Olaleye, 2002). Studies have shown that instructional leadership significantly improves students' academic achievement (Musungu & Nasongo, 2008). Consequently, various factors have been associated with the academic achievement of biology students in secondary schools. Espania (2012) argues that good leadership on the part of the administration is important in educational institutions to strategically organize, synchronize, and oversee the pedagogical activities, ensuring the attainment of educational goals.

Owino, Osman, and Yungungu (2014) did a study in certain secondary schools in Nyakach, Kenya. They discovered a strong and meaningful correlation between teacher attributes and performance, performance and the availability of teaching/learning resources, and performance and motivation in KCSE Biology. Mwangi (2014) presented empirical data demonstrating the impact of learner-centered methodologies, such as Plan, Do, See, Improve (PDSI) and Activity, Student, Experimentation and Improvisation

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The nation has witnessed a public uproar and discussion on the widespread failure that has seen stakeholders shift blames of different factors. Whereas literature abound on these factors, the concern in this study was the influence of instructional methods in achievement in biology.

2.3.1 Teaching Method and Performance in Science and biology

There is a global concern that the quality of education can be enhanced by changing classroom practices, such as using effective teaching methods and utilizing teaching aids (Adeyimi 2008). The efficiency and comprehension of a lesson are contingent upon the manner in which it is delivered to the learner (Mwenda Gitaari, Nyaga, Muthaa & Reche 2013). The teaching methodology utilized directly impacts the effectiveness of Science education.

Ayeni (2011) argues that teaching is a continuous process that entails employing appropriate methodologies to facilitate the desired transformation in the learner. According to Adunola (2011), teachers should utilize the most efficient teaching methodologies for the subject matter to achieve the intended transformation in their pupils. As stated by Bharadway and Pal (2011), effective teaching tactics are tailored to the individual needs of pupils, as each learner comprehends and responds to questions in their own unique way (Change 2010). Consequently, the correlation between teaching approaches that cater for students' requirements and their chosen learning styles has an impact on students' academic achievement (Zeeb, 2004). In his study, Dewey (2011) noted that the underachievement of pupils in Science is frequently seen as indicative of inadequate learning strategies. Makgato and Mji (2006) contend that ineffective teaching approaches directly impact students' performance in science disciplines. It is advised that teachers participate in refresher courses conducted by various instructors to employ diverse tactics and acquire novel teaching techniques.

Muzah (2011) supports this assertion, stating that specific pedagogical approaches employed by science teachers limit the subject to exam preparation rather than promoting students' ability to explore topics through hands-on experiences. He says that scientific classes are tedious due to the lack of engagement from science instructors. He proposes enhancing the applicability of scientific educators to enable students to establish connections between the subject and their daily life. This requires the use of a captivating instructional approach that encourages students to apply scientific knowledge to real-life situations. The teacher-centered technique is characterized by its lack of practicality, heavy emphasis on theory, and reliance on memorization (Teo & Wong, 2001). The teaching method does not incorporate activity-based learning to motivate students in solving real-life problems using applied knowledge. This results in a decline in both engagement and comprehension. Therefore, it is essential that instruction actively engages students as the primary participants, rather than simply presenting them with rules and procedures to memorize. Since the inception of the discovery learning concept, numerous academics have employed student-centered methodologies to enhance active learning (Greitzep, 2002).

A student-centered approach must be used to encourage engagement, enjoyment, and critical thinking. Because it does not centralise the transfer of knowledge from teacher to student, this kind of approach works well. Additionally, it encourages goal-oriented behaviour and academic success. Does student participation in the learning process figure into the pedagogy of scientific teachers in schools? Could the educational strategy based on the 5E model accomplish this? According to Akubuito (2004), a teacher's approach has a big impact on how well their pupils succeed in biology. pupils who receive effective instruction are likely to do well, whereas those who receive poor instruction are likely to perform poorly. Certain teaching strategies have a greater favourable impact on students' accomplishment than others, according to research on teaching behaviour (Wenglinsky, 2000). The requirement for teachers to set up environments in the classroom where students can ask questions, conduct experiments, and uncover facts and relationships is strongly correlated with the high academic accomplishment of their pupils (Nyongesa, 2011). Thus, providing high-quality biology instruction is essential to creating citizens who are literate in science and to enhancing performance in support of sustainable development. Learners gain profound intellectual knowledge from it. The way biology and other sciences are taught in schools, however, is quite challenging. Because traditional learning methods—lectures—are being used, there isn't the required level of student engagement in laboratory investigation. Since teachers are the only source of information and students are passive, this fails the majority of students.

According to Wood (2009), the majority of biology instructors employ the conventional cookbook laboratories that are a part of numerous extensive introductory lecture courses. In contrast to scientific investigation, learners gain limited comprehension of biological concepts. Wood (2009) argues that the primary cause of failure in biology students by traditional ways is their perception that the subject consists of disconnected facts that will be easily forgotten after graduation. Engaging learners in meaningful learning tasks is essential for them to actively construct knowledge. Akiri and Nkechi (2009) argue that the lack of efficacy in instructors' classroom contact with students may be the cause of the observed low academic achievement and the well-recognized decline in educational standards.

Teacher's teaching approach is therefore an issue to address. There's need to devise an approach that will engage learners and keep them actively involved in knowledge generation. Could the 5E model instructional approach address this?

2.3.2 Scientific Skills Acquisition in Science Education

It has long been acknowledged by many that science is the driving force behind contemporary technological breakthroughs. Every country, developed and developing alike, has to strive for scientific advancements due to their application to every aspect of life. Supporting the aforementioned claim, Obialor and Osuafor (2016) asserted that science has a profound impact on society, which is likely why, in the modern era, countries everywhere, especially developing ones are working hard to advance scientifically and technologically because modern life depends so heavily on science. Given that science is essential to human progress in terms of technology and science, it is critical that kids learn about science, its methods, and the skills involved in studying it in schools from an early age. Science process skills (SPS) are a collection of cognitive abilities needed in problem-solving scientific research. Samba et al., 2020) merely described them as skills required of scientists in order to do scientific research. These are life skills that assist people understand the nature of science and advance scientific literacy, quality, and standard of living (Mbonu-Adigwe et al., 2021).

Similar to this, Ibe and Nwosu (2017) described science process skills as potentials, capacities, and technical know-how that may be acquired via experience and are applied to scientific mental and physical processes. Therefore, the term "scientific process skills" can be used to refer to the cognitive and intellectual abilities that are used to help comprehend and resolve scientific challenges during the learning process of science. The mastery of science process skills, according to Harlen (1999) and Sevilay (2011), equips students for future acquisition of content knowledge and allows them to conceptualise the content they already know at a much deeper level.

When science process skills are used in inquiry-based learning, content knowledge is learned more effectively and comprehended more thoroughly. Critical thinking, creative thinking, and decision-making abilities can all be enhanced in pupils by a science curriculum that places a strong emphasis on science process skills. These abilities are transferable to many fields of study (Meador, 2003; Halim and Meerah, 2012). The fundamental science process abilities, such as the capacity to categorise and characterise natural events and things, aid in laying the conceptual foundation for scientific investigation, according to Brotherton and Preece (1996) and Sevilay (2011). The capacity for empirical inductive reasoning or Piagetian concrete operational reasoning is linked to the application of fundamental science process abilities.

According to Sevilay (2011), the integrated science process abilities are necessary for problem-solving and conducting scientific studies. The use of hypothetico-deductive reasoning is linked to the execution of integrated science process abilities. According to Sevilay (2011), research methodologies, increased learning permanence, and the development of a sense of responsibility for one's own education are all facilitated by science process skills. Science process skills aid in the formation of positive scientific attitudes and dispositions in students, according to Opateye (2012) and Okere (1997). These include having an imaginative and inquisitive mind, as well as being enthusiastic about being interested. Science Process Skills and Method of Inquiry The idea of inquiry is emphasised in science education across the globe in science curriculum. When it comes to science, inquiry describes the skills that students need to acquire in order to plan and carry out scientific research. According to the National Research Council [NRC], 2000, inquiry in the context of instruction refers to the teaching and learning methodologies that allow concepts to be mastered through exploration and practical activity. As per Gagne's (1963) perspective, scientific investigation comprises a series of tasks that are distinguished by a problem-solving methodology, wherein a recently observed occurrence presents an intellectual challenge. Such reasoning starts with a meticulous set of systematic observations, moves on to designing the necessary measures, distinguishes clearly between what is observed and what is ideal, makes amazing leaps that are always testable, and ends with generating plausible conclusions.

Brickman et al. (2009) states that science literacy and skill development are both enhanced by inquiry-based learning. According to Maundu, Sambili, and Muthwii (2005), the inquiry method centers on fostering scientific process abilities and learning via discovery. In a laboratory inquiry, students work together to find the answer to a central question or problem posed by the teacher (Uno and Bybee, 2009, cited in Brickman et al., 2009). Students' proficiency with the scientific method is expected to increase through inquiry-based learning that incorporates a range of laboratory activities (Kim, 2007). These reasons suggest that the skills necessary to carry out scientific research are acquired through hands-on experience in a laboratory setting. After reviewing and reformulating Kenya's biology curriculum, the Kenya Institute of Education (KIE) advocated for the incorporation of inquiry-based learning within the country's educational framework. The improvement of problem-solving and scientific process abilities were two other overarching goals (KIE, 2002). In the science lab, Selilay argues, students can master the steps of the scientific method through inquiry-based learning (2011). Competent scientific inquiry necessitates not only the skills necessary to carry out the scientific process, but also the attitudes and conceptual perspectives that experience learning cultivates (Ango and Gyuse, 2002, cited in Ango, 2002). The only way to make inquiry-based learning better is to have science process skills. The practical skills in biology include the ability to follow the scientific method. These are incorporated into the biology curriculum. Activities included in the biology practical sessions might help build and acquire these skills. Practical work is one technique to examine the goals of teaching biology, according to Maundu, Sambili, and Muthwii (2005). Practical work offers an opportunity to assess scientific capabilities, manipulative ability, and the application of scientific techniques. Practical exams are used by the Kenya National Examinations Council (KNEC) to assess students' proficiency in a variety of biology-related practical abilities, which are essentially science process skills. Students must complete practical biology tasks in these exams according to predetermined guidelines. Students have performed below average in the practical biology examinations administered by the Kenya National Examinations Council.

Afolabi and Akinbobola (2010) assert that a student's performance on a practical assessment is indicative of the teaching strategy used by the instructor, particularly the process approach.

Learners should be equipped with problem-solving skills and critical analytical thinking through the resources, which ought to give them the knowledge, aptitudes, and skills required to develop and support institutions (Saad & Sankaran, 2020). This study on 5E instructional approach sought to find out how much it created opportunities for learners to develop scientific skills that naturally promote better understanding of scientific concepts and consequently improve learners' achievement in biology a science subject.

2.3.3 Role of Attitude in Science Learning

The concept of attitude is difficult and distinct; it describes a person's inclination towards certain beliefs, emotions, or preferences based on how they evaluate an object, which may or may not be real (Muazzam, Muhammad, & Naseer, 2021). Three components comprise an attitude: behavioural, emotive, and cognitive (Ahmed, Muhammad, & Anis, 2020). According to Kind (2007) and Coll-Dalgety and Salt (2002), it is also about a person's viewpoint on an item. An object can be good or terrible, harmful or helpful, comfortable or uncomfortable, important or unimportant, depending on one's point of view. These days, a lot of consideration is paid to how people feel about science and scientific education, particularly with regard to teaching and learning. The reduction in student interest in scientific achievements resulting from advances in science and technology has prompted global initiatives to revamp science education. Assessing the effectiveness of modification actions on students' attitudes is crucial in order to address this predicament. Student views towards science have a substantial influence on their choices of topics and employment. Furthermore, college students, high school students, and students in middle and primary schools are the main subjects of studies on attitudes in the field of scientific education (Turkmen, 2007). Taking into account the speed at which science and allied fields are evolving today. Students' interests are typically piqued more by subjects that are relevant to real life and its different phenomena. In this sense, the most creative science field is biology alone. Biology's basic definition is the study of life. Biology instructs us on the characteristics of living organisms, including their bodies, interactions with their surroundings, and factors that affect their longevity. Biology is the study of all living things, including people, animals, and plants. Biology, as a branch of science, contributes to the enhancement of students' practical abilities in conducting experiments. These abilities include keen observation, accurate documentation, logical deduction, and effective utilization of equipment (Hussaini, 2015).

According to Lazarowitz and Penso (1992), there are multiple factors that may contribute to students' difficulties in understanding biological concepts. According to Lazarowitz and Penso (1992), the difficulty in learning biology stems from the high level of efficiency required in biological processes and the speculative nature of its notions. On the other hand, learning science is challenging due to the inherent nature of scientific inquiry and the instructional methods employed. Other challenges to learning include overcrowded biology classrooms, the intricate and interdisciplinary nature of biological disciplines, and unreliable texts. At this point, discussions on occurrences in various educational contexts continue to centre on an individual's degree of achievement of particular goals. We refer to it as academic achievement. Many educational programmes have cognitive goals that are either critical thinking-based or linked to learning concepts in specific areas, such as art, design, history, literacy, and numeracy. Because academic achievement is such a broad topic that covers a variety of educational experiences, it should be viewed as a multifaceted idea that encompasses several areas of knowledge (Amjad, Shah, & Muhammad, 2019). It is evident that a student's mindset has a direct bearing on their future success in science. Students' academic achievement in science is influenced by their approach to the topic. In educational research initiatives, it is imperative to identify and modify the attitudes of participants (Prokop et al., 2007). Thus, educational resources play a crucial role in the effectiveness of biology instruction and learning, each of which has a unique impact on students' performance. Research conducted globally suggests that the availability of educational resources helps students convert seemingly abstract concepts into tangible realities, thereby impacting their performance in Biology (UNICEF, 2020; Gauthier, 2018; Okongo et al., 2015).

This suggests that a lot of students struggle with their biology coursework. German colonists established Rwanda's educational system, and with missionaries' help, they also established higher education in addition to basic and secondary education. These schools received infrastructure, instructional resources, and other essential educational supplies from missionaries (Bizimana & Orodho, 2014). The fact that teaching was supported for years by instructional resources is indicative. In order to produce qualified teachers, education colleges and universities that offer preservice science teacher programmes need to have a variety of instructional resources available (Nnorom & Okoli, 2014). Materials known as instructional tools help teachers help pupils grasp concepts in an easy-to-understand manner. They lessen spoken instruction while raising students' motivation, engagement, and interest in the sciences (Tuimur & Chemwei, 2015).

In Africa, subpar biology performance jeopardises educational objectives. Investments in education have been associated with the nation's speedier growth and development. In order to meet their goals, the majority of nations, particularly those in sub-Saharan Africa, are now investing in education at all levels (Kjaer & Muwanga, 2016). Increasing student enrollment and raising the standard of instruction are two tactics for getting the most out of education. Nevertheless, despite all of this, the majority of sub-Saharan nations still have poor educational systems and low academic achievement (Kioko et al., 2014). Given that many students fail biology classes, it is likely that the root reasons of inadequate teaching must be adequately addressed. The usage of biology teaching tools is important for students of all backgrounds and for preservice biology teachers. The usage of biology teaching tools is important for students of all backgrounds and for preservice biology teachers. When students work with the materials, their utilization becomes more productive

Adebule and Ayoola (2016), for example, confirmed that the usage of instructional resources in the classroom raises students' level of exploration and encourages them to learn more as they apply what they have learned. Additionally, Johnson & Cotterman (2015) discovered that preservice science teachers' comprehension of their science subject matter improved as a result of video clubs. Preservice science teachers must be trained using technology-related instructional materials because they provide the technical expertise needed to be a qualified teacher in modern digitally native environment (Oren, 2017). Furthermore, the usage of instructional resources reduces stress for both teachers and students (Arokoyu and Chimuanya, 2017). Finding the instructional materials that are available in schools is so crucial, especially in higher education institutions where students can learn by doing and seeing instructional resources, which improves learning achievement and memory levels. Kenya and Tanzania are two East African nations that continue to struggle with low biology student performance (Union, 2014). Researchers, educators, and school administrators have made the decision to tackle the low academic achievement in secondary schools by looking into factors like a shortage of teaching resources, hiring qualified instructors, admitting deserving students, teacher motivation and pay, and enhancing school-wide discipline and community involvement (Agutu et al., 2020). Research has shown that supportive factors for strong student academic performance include sufficient staffing, equipment, and resources such labs, libraries, dorms, classrooms, furniture, playgrounds, and efficient administration (Mudulia, 2012). Therefore, making these tools available would encourage improvements in Biology students' academic performance.

Studies on the relationship between academic performance and resources in Uganda in the past have declared that resources such as libraries, laboratories, and teacher preparation and experience are crucial for raising student achievement (Kasirye, 2009). Children's cognitive performance increases when they have access to classroom materials, and learning results are greatly impacted when a child has a seat (Kasirye, 2009).

The age of the students, the language they speak, the amount of time they spend on a subject, the size of the class, the textbook, and the pupil-to-desk ratio were shown to be key factors impacting learning achievement in a survey conducted in Uganda. The study also showed that students' performance is impacted by the credentials, experience, and in-service training of teachers. Additionally, it was discovered that another important element influencing learning achievement in Ugandan sixth grade was school administration (Nanyonjo, 2007). The aforementioned studies demonstrate the important relationship between resources and academic achievement in schools and point out that most of these establishments struggle with issues like a shortage of quality teaching materials. These often have a negative impact on the calibre of graduates that are generated.

The disposition of students is a crucial aspect of the learning results in secondary school. The significance of this level is based on the fact that career aspirations are developed during this stage of education. Attitude is a concept within the emotional realm that has been extensively studied by scholars over the past four decades (Aiken & Aiken, 1969; Koballa & Crawley, 1985; Koballa, 1988) and is an ongoing area of investigation. Attitude has a key role in shaping pupils' inclination towards a specific educational subject. The students' attitude serves as a driving force that encourages them to choose a certain path of study and persist in their attempts to achieve a high level of expertise in the subject area. The students' disposition towards a specific academic subject is seen in how they handle their perception and conduct towards the material being studied. Attitudes not only aid in the process of learning, but they are also outcomes of students' learning (Smith et al., 2012).

According to Oskamp and Schultz (2005), an attitude is a propensity to respond favorably or adversely to a particular object of attitude. A number of things could be included in the attitude object, including biology, biologists, biology classes, school biology subjects, inquiry-based lab experiments, research on biology education, biotechnology, biological weapons, and biology (Cheung, 2011). There were two strong arguments made for why students' attitude towards science should be improved. Success in school is first associated with one's attitude. Bennett et al. (2001) and Salta and Tzougraki (2004), among others, found that students' attitudes had a direct impact on their chemistry grades. With correlation values ranging from 0.24 to 0.41, Salta and Tzougraki (2004) discovered a positive link between students' attitude towards the topic and their performance in chemistry.

Research by Bennett et al. (2001) found that test scores in chemistry were lower for students who had a negative outlook on the subject. A strong correlation between mindset and performance was shown by Russell and Hollander (1975). However, one must not overlook the fact that achievements do not automatically constitute a positive mindset. Furthermore, they argued that a student's attitude towards a subject might influence their performance, and that a low score in a subject can be the result of a more positive attitude. While one's attitude can have an effect on their level of success, the reverse is not necessarily true. According to Stark and Gray (1999), the anticipated shift in thinking can result from a focus on priorities. According to Glasman and Albarracín (2006) and Kelly (1988), one more justification for encouraging students to have a positive outlook on science is that it can foretell how they will behave.

Kelly (1998) asserts that British student's inclination for biology, chemistry, or physics in school was based on how similar they seemed to those subjects. Although researchers have devoted significant attention to the topic for over 40 years, the significance of attitude has frequently been underestimated in relation to assessing educational results by society, curriculum planners, and instructors.

The students' disposition towards a subject should be a crucial consideration in the process of teaching and learning. It is the responsibility of teachers to observe and take note of their students' attitude towards the subject. In order for the instructor to accomplish this, they must utilize an efficient pedagogical approach. As stated by Ebenezer and Zoller (1993), the instructional technique employed by the teacher is a key factor in shaping students' perspectives and attitudes about science courses in a science classroom. According to Myers and Fouts (1992), a classroom that incorporates diverse strategies and unconventional learning activities, along with active student participation, individual support, and positive interaction among classmates, fosters a strong positive attitude in students towards science. Koballa and Glynn (2007) support this claim by stating that effective methods for improving student attitudes involve emphasizing active learning and the practical applications of science in everyday life (p. 95).

Considerable research has been undertaken to investigate students' disposition towards science, but, there is a scarcity of studies that specifically focus on students' attitude towards biology (Hussaini, et al., 2015; Prokop et al., 2007; Shuaibu & Ishak, 2020; Usak, et al., 2009). The study of students' attitude towards Biology has gained significant attention as it has been demonstrated to have a direct influence on students' academic advancement (Shuaibu & Ishak, 2020). Borghans et al. (2008) highlighted the need of conducting a comprehensive analysis of students' attitude towards learning, as it is more prone to change compared to their cognitive abilities. This is because attitude is challenging to develop, but once developed, it becomes enduring. The efficacy of pedagogy utilized by the teacher in the classroom is a pivotal determinant that impacts students' disposition towards the subject of biology. Several research papers exist that analyze the influence of various teaching approaches or pedagogy on students' attitudes (Gibson & Chase, 2002; Wong et al., 1997).

However, the results obtained from these studies demonstrate a broad spectrum of variation, reflecting the diversity of the investigations themselves. The study conducted by Koballa and Glynn (2007) and Shruba (2008) discovered that the teaching methods used in the classroom influence students' views towards the subject. Contrarily, the investigation carried out by Glynn et al. (2007) arrived to a divergent inference. This study employed two distinct collaborative teaching methods (consensus and cooperative reflective journal entries) to examine the influence of educational strategies on students' attitude towards biology.

According to Gbadamosi (2014), attitude is a cognitive evaluation that arises from a particular context and influences an individual's preference or aversion towards an object. It pertains to the cognitive preparedness for a specific action that dictates an individual's receptiveness to perceive, comprehend, or engage in certain thoughts or behaviors.

The attitude towards Science is a crucial determinant of students' performance and perception of the topic (Abudu and Gbadamosi, 2014). Exclusively adopting an optimistic attitude leads to improved achievement in Science education. A positive attitude fosters curiosity in a subject, which in turn cultivates dedication. According to Osbourne, Simon, and Collins (2003), commitment is a factor that contributes to academic accomplishment by promoting learning.

The learner's positive attitude is primarily contingent upon the teacher. (Mart 2003, Osborne et al 2003) contend that the cultivation of a positive attitude in learners can only be achieved by a teacher who possesses a positive attitude and unwavering dedication. These teachers employ diverse instructional methods, exhibit enthusiasm and confidence, and maintain a good disposition towards the science subject. Studies suggest that teachers who employ an incorrect pedagogical approach and exhibit a negative attitude towards Science contribute to subpar academic performance among students. (Abudu & Gbadamosi, 2014).

Teachers exert effect on student attitude through motivation, a crucial important factor that impacts performance. Motivation encompasses the cognitive, emotional, and behavioral signs of a learner's commitment to and involvement in education (Anand, 2004). For learners to achieve success, it is essential that they are motivated. According to Herman Tucker and Zyco (2007), some scholars believe that motivation is the sole element that directly influences academic accomplishment. All other factors, on the other hand, only impact achievement indirectly by affecting motivation. According to Zerniak and Haney (2005), science teachers have been identified as the primary catalyst for enhancing student achievement in schools. The student's motivation and attitude are determined by the teaching style, methodology, and the exhibition of the teacher's professional talents. The majority of teachers employ teacher-centered methodologies that fail to inspire pupils. Consequently, students have formed a pessimistic outlook towards science courses, which has resulted in their poor academic performance.

Attitude is one of the key factors that influence student performance in any subject in secondary school education. A study by (Nyaga, 2011) points out that negative attitude limits student performance because when motivation to learn is derailed then actual intake of concepts is inhibited. Student attitude determines their interest, ability and willingness to learn. In fact, a student is most unlikely to perform well in a subject or continue his/her education beyond what is required, if the issue of negative attitude is not properly addressed. In developed nations, the aspect of teaching and learning of science subjects is designed in such a way that it is purely interrogative, inquisitive and investigative with an aim of stimulating the learners" interest, enhancing the academic performance in the subject as well as minimizing wastage grades in the course examinations. A study by Lunetta, Hofstein and Clough (2009) show that the laboratory has been made the center of discovery in teaching and learning in the subject and this has assisted students to discover and make sense of the natural world from experimental analyses. whether 5E instructional approach could address students attitude formed part of the researcher's question.

2.3.4: Learner Attitude in Teaching and Learning of Biology

The students' disposition towards a subject is a pivotal factor in shaping their level of interest and academic achievement. Therefore, it is crucial to establish a conducive learning environment that is furnished with resources and activities that effectively engage the learners, thereby fostering their interest in the lesson (Kortam et al., 2018). In addition, according to Taştan et al. (2018), students' attitude towards learning science subjects is significantly impacted by the manner in which courses are taught. The promotion of increased scientific literacy and understanding through science education has become an important factor in the socio-economic development of several nations (Aktamiş & Hiˇğde, 2016). The shift from a knowledge-based to a competency-based curriculum has been driven by the importance of attitude, skills, and values. The purpose of the luminary curriculum is to instil in students the knowledge, attitudes, and values necessary to build a sustainable future (Nsengimana et al., 2012). According to research Kisoglu, 2018; Narmadha & Chamundeswari, (2013) there is a strong correlation between students' attitudes and their accomplishment in science. This correlation is thought to be caused by the teaching approach.

According to Narmadha and Chamundeswar, teacher-centered approaches were shown to be unhelpful in fostering a favorable attitude towards science.1. According to Hacieminoglu (2016), students' attitudes towards learning biology are impacted by the direct association between meaningful learning and academic accomplishment in the subject.methodology. Because fewer students are interested in science, scientific education has changed, with an emphasis on using more interactive methods of instruction to get students more involved in topics connected to science (Adejimi et al., 20). In order to foster an atmosphere where students actively participate with one another, instructional strategies such as inquiry-based learning were recognized as means to achieve this goal (Aulia et al., 2018).

Furthermore, it helps substantially to the process of knowledge acquisition and makes it easier for students and teachers to interact (Kang & Keinonen, 2018). Consequently, students are given opportunities to explore the new situation through the use of materials and hands-on activities so that they can develop a new perspective on biology.Students' mood is greatly improved as a result of this activity, which increases their attentiveness and curiosity (Conradty & Bogner, 20). A more learner-centered approach should replace cramming as the primary means of delivering scientific lectures (Nsengimana et al., 2017). (Bizimana et al., 2022; Vlckova et al., 2019; Hu et al., 2018) Students' attitudes towards learning science are influenced by a number of factors, including grade level, gender, parental influence, instructor influence, and the school environment. Studies have shown that biology is more appealing to girls than boys (Almasri et al., 2021). Oba and Lawrence (2014) found that students' attitudes towards learning physics were not significantly influenced by gender, with the exception of a small gender gap that was observed to favor females.

In addition, there has been an increasing trend towards learning about biology in Rwandan university labs (Mukagihana et al., 2021). Positive views regarding biology classes have been linked to the use of resource-based instruction, student-centered methods of instruction, and cooperative learning (Rabgay, 2018; Njoku & Nwagbo, 2020; Mukagihana et al., 2021). Adejimi et al. (2022) and Bizimana et al. (2022) found that students' exam scores and classroom experiences influence their overall attitude toward biology. Kisoglu (2018) and Vlckova et al. (2019) both acknowledge that biology poses challenges for students in lower and upper secondary school. Some researchers have proposed that in order to change students' attitudes toward biology, classrooms should be designed to encourage active participation from students and provide opportunities for them to contact with real animals (Kisoglu, 2018; Manishimwe et al., 2021).

Extensive research has shown that inquiry-based learning significantly impacts students' worldviews. Research has shown that students are more engaged in lessons when they are taught using inquiry-based methods (Sandika & Fitrihidajati, 2018; Nkurikiyimana et al., 2022). As students work in small groups to solve problems, they are actively encouraged to communicate with one another. Students are inspired to actively seek out information and proof in order to discover solutions through various resources, as stated by Kang and Keinonen (2018). In order to pique students' interest in scientific phenomena, teachers conduct experiments (Wu et al., 2021). The goals of the trials are to encourage students to become more interested in the material and to foster deeper relationships among them. The outcome is an increase in pupils' interest in science (Aktamis & Hiegde).

According to Sandika and Fitrihidajati (2018), students are more likely to cultivate an attitude toward science and develop their critical thinking abilities in an inquiry-based classroom. The study of living things also encourages the development of creative problem-solving abilities in the scientific community. The use of the inquiry-based method improved students' disposition toward learning biology, according to research by Tsybulsky et al. (2020). An inquiry-based learning method known as the 5Es instructional approach has been shown to increase students' attitudes towards biology through a learning cycle. According to Nyirahagenimana et al. (2022), there are five interrelated stages that make up the inquiry model. Engagement, exploration, explanation, elaboration, and evaluation make up the five stages of the teaching model. The learning cycle is characterized by student participation in the process of information generation.

Nkurikiyimana et al. (2022) state that the 5Es model of education creates a classroom environment where students are encouraged to use their existing knowledge to investigate new ideas and phenomena. Students work together to independently build their own knowledge, a principle central to the social constructivist approach to education. Engage, explore, explain, elaborate, and evaluate are the five stages that make up the 5E Instructional Model, which was created in 1987 by the Biological Science Curriculum Studies. Constructivism, the theoretical framework upon which the method is based, views learning not as a passive accumulation of information but as an interactive and contextualized process of knowledge production (Richards, 2015). Students' attitudes toward biology are affected by this participatory learning technique.

Adejimi et al. (2022) and Shin et al. (2021) found that interest in science and biology has been on the decline in recent times. Item number nine. Both Bizimana et al. (2022) and Hacieminoglu (2016) found that students who had a negative outlook on biology also performed poorly in the subject. This happens when students take on the role of passive consumers of information and the teacher takes center stage in the classroom. The biological component, however, has received surprisingly little attention in the literature. Examining how the 5E educational style affects students' perspectives on biology was one of the main goal of this research.

2.3.5 Teaching/Learning resources and performance in Science Education

Teachers utilize a diverse range of educational materials during the instructional process, also known as teaching and learning resources. The educational resources employed encompass a diverse array of tools, including charts, models, textbooks, maps, the internet, and electronic and audio-visual learning resources such as tape recorders, radios, cassettes, TVs, laptops, mobile phones, overhead projectors, computers, and classroom improvisation materials. Supplementary instructional tools consist of a range of writing resources, including erasers, pens, crayons, exercise books, chalk, notebooks, drawing books, rulers, pencils, workbooks, slates, and paper supplies (Abonyi & Luguterah, 2019). In addition to this, there are technical resources available for science disciplines, including a science laboratory equipped with essential apparatus such as test tubes, beakers, volumetric flasks, capacitors, and insulators. These resources are crucial for conducting basic demonstrations and practical tasks. According to the Ministry of Education in 2003, students require these materials both individually and at the classroom level.

Learning materials refer to instructional resources that are used in educational institutions to facilitate the process of learning and teaching (Machaba, 2013). These refer to the methods and strategies used by teachers to carry out teaching and offer students chances to achieve educational goals during activities like active learning and evaluation. They promote the consolidation of learning experiences, increasing engagement, authenticity, and interest in the learning process. Audio, visual, audiovisual, and realia are distinct modalities in which materials can be presented. Wall charts can be used to exhibit textbooks and visual materials. Audio learning technologies solely rely on the auditory sense, such as tape recorders and radios. Conversely, audio-visual learning materials involve the use of both the visual and auditory senses, such as computers, movies, and television. Many African countries, especially in rural regions, lack sufficient educational resources compared to schools in urban areas (Quansah, Sakyi-Hagan, & Essiam, 2019; Yeboah, Abonyi, & Luguterah, 2019).

According to the World Bank (2012), many African countries do not have the resources to meet their educational needs. The information was documented in a research issued by the Sub-Saharan Conference on Education for All, as indicated by Obara and Was (2020). Teaching and learning tools aid in the process of self-discovery for educators and students alike. Machaba (2013) asserts that child-centered teaching and learning methods are enhanced by the active involvement of pupils. Using instructional resources improves academic performance. According to Ashiono, Mwoma, and Murungi (2018), the use of ICT in classroom teaching improves students' involvement in learning, leading to improved cognitive memory. The study conducted by Lyimo, Too, and Kipngetich (2017) illustrates that the use of teaching materials can significantly boost teaching efficacy, facilitate the identification of individual students' unique requirements, and improve the delivery of lessons. According to Moodley (2013), these benefits have a favorable influence on both students' academic achievements and the overall effectiveness of the institution. The active participation of students in the instruction and acquisition of Integrated Science is essential for attaining these benefits. Research has shown that the availability of educational resources can have a substantial effect on the implementation of a curriculum, since learners remember 90% of information when it is presented through verbal, visual, and tactile experiences. In addition, they aid in the process of distilling intricate subjects into more easily understandable language (Maina, 2015).

UNESCO (2004) indicates that students majoring in scientific fields have a strong demand for individualized educational materials. Beyond what is provided by the school, students in an inclusive setting would need supplementary materials. According to Moodley (2013), effective science teachers may foster inclusive learning by making use of locally accessible resources. One way to reduce costs and make better use of instructional technology is to have members of the local community help out with device upkeep. Students with physical disabilities may find it easier to remain enrolled in public schools if this is implemented. Momoh (2010) looked at how different types of course materials affected students' results on the West African Senior School Certificate Examinations (WASSCE). A direct correlation between the instructional materials and students' performance on the West African Senior School Certificate Examination (WASSCE) was observed. According to his findings, the instructional materials greatly affect students memory and academic performance. According to the Ministry of Education, Science and Technology (2010), students in integrated schools do not have access to sufficient learning materials. The teachers' capacity to implement a range of subject-specific pedagogical strategies was severely hindered by the schools' inadequate supply of curricular support materials. Because of a hostile learning environment characterized by a lack of instructional personnel and adequate educational materials, public school children do worse academically than their private school counterparts (Ongaki & Musa, 2014). Learning materials and academic achievement have a significant and beneficial relationship, according to Bukoye (2018).

In order to determine if schools with more resources would be able to outperform those with less, Bukoye conducted an analysis. According to Okongo, Ngao, Rop, and Nyongesa (2015), private schools have more resources, which is why they are able to achieve better results than public schools.

The quantity and quality of instructional materials, in addition to pedagogical practices, influence students' achievement (Adalikwu and Iorkpilgh, 2013). Learning centers with sufficient resources, such as textbooks, are more effective in helping students get high test scores than schools without adequate amenities, according to the study. If training and educational resources and equipment are lacking, then poor performance could be the result. School buildings and their physical infrastructure must be consistently prioritized for maintenance and improvement by the community, parents, and sponsors. Learning becomes more difficult when these conveniences are not available. Ndirangu and Udoto (2011) found that school facilities are crucial for providing high-quality science education. Lecture halls, classrooms, administrative buildings, auditoriums, laboratories, playgrounds, speciality spaces like a clinic, conference rooms, staff apartments, dining halls, kitchens, and restrooms are all part of the physical infrastructure.

Ndirangu and Udoto (2011) contend that the efficacy of learning is heightened when there is ample provision of superior practical learning resources. From an academic standpoint, the lack of artistic magnificence, classrooms that are too full, unappealing school buildings, and a shortage of recreational spaces can all lead to subpar performance. Figueroa, Lim, and Lee (2016) contend that the structure and limitations of the school render it impractical to foster a culture that is exclusively reliant on individual achievements. The Ministry of Education, Science and Technology (2014) stresses the significance of providing sufficient and suitable teaching resources to effectively carry out Integrated Science education programs, as emphasized by Bosibori et al. (2015). In their study, Musah and Umar (2017) categorized the instructional resources utilized in biology teaching methods into three distinct groups: material resources, human resources, and physical resources. Arop et al. (2015) identified three primary classifications of materials suitable for biology instructional methods: visual, aural, and audiovisual resources. Students can employ a variety of visual aids, including flashcards, posters, charts, textbooks, tactile objects, models, chalkboards, and images, to augment their visual learning. Audio resources, such as radios and tape recorders, improve learning by applying auditory techniques. Teachers employ audiovisual materials to enhance the visual and aural experiences of students, combining visual and auditory aids in their classes. Prominent examples include computers, televisions, tape recorders, radios, and videos.

Iji et al. (2014) propose that enterprises, teachers, or students can construct them by utilizing improvisation with materials that are easily accessible in their local vicinity. This study used a distinctive method of classifying biology teaching materials into four specific categories: classroom resources, basic biology laboratory resources, library resources, and ICT (Information and Communication Technology) resources. This categorization is warranted as it encompasses the fundamental instruments employed for instructing and learning biology in tertiary educational establishments. Teaching is considered effective when it makes use of resources such as fieldwork, natural objects, graphs, charts, and laboratory practicals to clearly and convincingly convey the topic information. Nwagbo, in the year 2016. The students' enthusiasm for studying biology is enhanced, and abstract classroom material is made more concrete through the incorporation of hands-on activities. In order to facilitate a student's holistic development, it is crucial to offer them chances to engage with various materials and concepts. This will facilitate the advancement of emotional and physical learning aspects, alongside the cognitive aspect (Agbowuro, 2006). In order to improve biology education, a more successful approach is to include students in practical experimental activities rather than teaching them ideas, facts and concepts in a detached or theoretical manner. According to Alison (2013), biology revolves around problem-solving, and the laboratory is the ideal setting for undertaking meticulous observations, precise calculations, and logical reasoning.

Hence, while determining the origin and impact of any idea, it is crucial to prioritize practical exercises as the primary educational method. In his study on high school science instruction, Rughill (2011) discovered that students achieved significantly higher scores in the cognitive component when taught using the laboratory investigative technique, which he identified as an effective teaching style. Ajevalemi (2011) attributes pupils' below-average performance in biology classes to insufficient laboratory facilities. The study conducted in Tanzania's Rombo District (City, 2016) revealed that a significant number of community secondary schools in the area were deficient in essential teaching and learning tools, which had a negative impact on academic performance. The findings demonstrated that schools with more abundant resources achieved superior performance compared to those with fewer resources. The survey found that the teaching resources most commonly utilized were pre-existing materials such as posters, maps, and previous tests, which teachers did not need to generate themselves (City, 2016).

A similar study found that 70% of the secondary schools in Ondo State, Nigeria, did not have the right teaching materials. The study aimed to assess the level and distribution of available resources and the academic achievement of secondary school pupils in the state (Ehinola & Oyewole, 2011). These two researchers, however, conducted a comprehensive analysis of academic achievement across all subjects, rather than specifically investigating the influence of resources on academic success in the discipline of biology. Pareek (2019) conducted a study in India that using a descriptive survey methodology to investigate the utilization of a science laboratory for the purposes of science instruction and learning. The study's findings indicated that numerous educators faced difficulties in conducting science activities due to inadequate provisions and equipment (Pareek, 2019).

Nevertheless, the main participants in this study were students, potentially leading to the omission of vital insights from administrators and teachers. Morgan (2014) asserts that providing students with well-crafted textbooks affords them the chance to enhance the enjoyment, significance, and durability of their learning experience. It can also stimulate students' cognitive processes in various ways by employing skills such as visual processing, analytical thinking, questioning, hypothesis testing, and verbal reasoning. A study was conducted in Shinyanga municipality, Tanzania, involving six out of eighteen public secondary schools. The study utilized a quantitative technique and survey research design to investigate the factors that contribute to poor performance in scientific courses in these schools.

The study's findings indicate that a significant factor contributing to the low performance of science students was the insufficient availability of teaching and learning resources, including textbooks (Majo, 2016). Majo (2016) suggests that utilizing textbooks and other science teaching and learning tools is an effective approach to tackle the problem of low science performance in secondary schools.

However, this study did not solely concentrate on biology classes; it also investigated the influence of teaching materials on students' academic achievement in scientific courses. Adesoji and Olatunbosun (2014) conducted a second correlational survey research study to simultaneously investigate the relationship between textbook utilization and student involvement as determinants of academic progress. The results revealed a significant positive association (r=.186) between the use of textbooks, student engagement, and academic performance. The study's findings indicated that the utilization of textbooks and active student involvement were significant elements in their overall academic impact on forecasting students' academic achievement.

Learning materials are crucial in the instruction and acquisition of knowledge in Science disciplines, and they have a direct impact on the academic performance of student teachers. Researchers argue that laboratories are essential for effective science instruction, as they believe that no significant learning can take place without them. Nevertheless, the global community is greatly concerned about the significant issue posed by the scarcity of educational materials in the field of science. According to Kekgato (2017), a shortage of resources results in a failure to improve learning effectively, as the courses are only taught in principle. Consequently, learners' waning interest in the subject results in subpar performance. According to Lebata (2014), a teaching approach that is oriented around the teacher tends to boring and demotivate students. Muzah (2011), Mkakgato (2007), and Dhurumjai (2014) argue that the presence of hands-on teaching enhances understanding and strengthens scientific principles. In addition, they assert that hands-on courses not only boost learners' interest in Science, but also enhance their manipulative abilities and recollection of knowledge. Furthermore, these practical lessons make the subject more relevant and help learners develop valuable skills. Additionally, they promote discipline and assist learners in problem-solving. Insufficient or nonexistent resources make it impossible to conduct practical instruction. Studies suggest that in order to facilitate successful acquisition of scientific knowledge, it is crucial to have sufficient and pertinent resources at one's disposal, as they constitute a fundamental element (Dhurumraj 2013). According to Yara and Otieno (2010), the presence of instructional resources improves the efficiency of the learning process and can lead to better academic achievement in students.

Effective exploitation of learning resources is necessary to achieve desired outcomes. The chosen methodology must effectively engage the learner and maintain their active participation throughout the entire learning process. The majority of methodologies employed by scientific educators fail to optimally exploit the resources at their disposal. The 5E instructional strategy, a type of active learning, can optimize the use of learning materials.

2.4 The 5E instructional approach and learning

Dewey viewed education as a communal exchange between young individuals and grown-ups. He advocated for prioritizing the child, rather than the curriculum, as the focal point of the classroom. Twyman (2016) posited that knowledge cannot be passively transmitted to a child; rather, a pupil must actively engage with and experience something in order to learn. John Dewey advocated for a more comprehensive approach to students' learning experiences, emphasizing the importance of going beyond mere "hands-on" activities. Students ought to engage in science by following a procedure akin to the scientific method. Students are provided with the chance to identify and articulate a problem that needs to be resolved. Once an issue has been defined, it is important to formulate a hypothesis, carry out observations, assess the observations, and finally test the hypothesis. During this specific learning cycle, students are expected to adhere to the prescribed "hands-on" process. Once the students have finished the practical aspect of the activity, they should engage in a cognitive process known as "minds-on" to contemplate and analyze their experience (Brown & Abell, 2007).

In 1962, Atkin and Karplus proposed that effective learning cycles consist of three essential components: exploration, the introduction of terms, and the application of concepts (Tanner,2010). Atkin and Karplus (1962) state that the original learning cycle, which became widely acknowledged as an effective way of teaching inquiry-based science, was first developed by the Science Curriculum Improvement Study (SCIS). Johann Friedrich Herbart, J. Myron Atkin, John Dewey, and Robert Karplus were the primary thinkers whose work was included into the initial learning cycle model (Bybee et al., 2006). There is an investigational stage in the Science Curriculum Improvement Study's learning cycle model. During this stage, students might develop a genuine curiosity for the material, identify areas where they still need more clarity, and formulate questions to further their understanding (Tanner, 2010). Students have opportunities to engage in scientific activity at each level of the 5E Model, and each level has its own integrity. Following the steps in the correct order is critical to keeping the model running well (Bybee, 2014). The efficiency of the learning process was diminished when teachers tried to remove or alter the model (Tanner, 2010).

Conceptual comprehension and curiosity were the two pillars upon which Herbart built his pedagogical philosophy at the turn of the twentieth century. An early approach to education that resembled a learning cycle was Herbart's idea (Hanuscin & Lee, 2008).

According to Marek (2008), a "learning cycle" is a methodical process that is specifically created to help people learn and gain information. In this scenario, students could learn by doing, expanding upon what they already know. Teachers will enthusiastically promote student involvement in various activities in order to cultivate deeper relationships among them. By providing students with real-world examples and hands-on activities, educators help students understand the big picture and gain confidence in their ability to apply what they've learned. Herbart postulated that students would gain a deeper grasp and competence in scientific topics through independent research and inquiry (Bybee, et al., 2006). In 1987, the Biological Science Curriculum Studies created the 5E Instructional Model, which is also known as the 5E model. The five steps of learning are as follows: involvement, investigation, clarification, development, and evaluation. The constructivist perspective, upon which the 5E Model is based, views learning not as a passive act of acquiring information but as an interactive and contextualized process of creating new knowledge (Richards, 2015). Accumulating one's own experiences is the primary means by which one gains knowledge. Enhancing student-centered learning through the incorporation of phenomena into the 5E framework. Students can engage in scientific practice and acquire knowledge as they complete each level of the model (Bybee, et al., 2006). According to Hu, Gao, and Liu (2017), the 5E model has gained a lot of attention in the field of education and is used in a lot of science courses. The 5E method encourages both students and educators to actively participate in the learning and teaching process by drawing on and building upon each other's existing knowledge and experiences. It also stresses the significance of regularly testing one's own understanding of the material being taught (Ergin, 2012). In the engagement stage, the instructor makes an effort to draw on the students' prior knowledge. The primary objectives of the engagement phase are to stimulate curiosity and draw on students' existing knowledge in order to encourage them to investigate problems or disagreements. In order to come up with fresh ideas, students should take part in the exploration phase by asking questions and researching a topic. Students move on to the explain step after finishing the investigation phase.

Learners and teachers work together, with each group taking turns with certain tasks, throughout the explanation phase. The role of the teacher is to impart concepts and skills; the responsibility for expressing understanding of the subject lies with the students. During the elaboration phase, students get a deeper knowledge of the subject and improve their skills through exposure to new and unexpected material. Both the instructor and the student work together throughout the evaluation process. In this model, the instructor monitors the students' development toward learning objectives and the students are responsible for evaluating their own knowledge and skills (Hu, Gao, & Liu, 2017). Two to three weeks is the recommended amount of time to use the 5E instructional strategy, according to Bybee (2014). One or more classes can be built around each stage of the model. Because it limits the time and chances for actively engaging with and reconstructing knowledge to promote learning, using a single lesson model reduces the efficacy of the several stages (Bybee, 2014). If a whole program used this concept, each component would last longer and be of higher quality. The expected student experiences and outcomes of the stages may be less effective, nevertheless, if the model is not used comprehensively (Bybee, 2014). The BSCS 5E instructional model's principal goal was to raise students' scientific achievement. The initial iterations of this concept aimed to provide educators with a structured and goal-oriented curriculum. The idea has been included into state frameworks, national guidelines, and school curriculum due to its practical value, which has attracted attention from the science education community (Bybee, 2014).

Many students come to class with assumptions about how the world works, and some of those assumptions are misconceptions. These comprise misconceptions the learners carry that need to be addressed. This is their starting point for understanding; if they aren't fully engaged, they can have trouble moving on to more advanced topics. On the other hand, some students may learn what they need to know in order to pass a test, but they'll probably keep their biases and assumptions outside of class. Actively building one's own understanding of concepts is crucial, according to constructivists. Each individual learner is responsible for their own learning, which is a dynamic process. Several studies have shown that students' internal and external environments influence their academic performance. But what really matters when it comes to education, say the experts, are the classroom activities and events themselves (Orleans, 2007). This study sought to establish the kind of internal and external environments created when using the 5E approach.

Students' performance is greatly improved by active learning, making it the most effective method for teaching biology. According to Cater, Nobert, and Verella (2011), when compared to more conventional methods of instruction, active learning results in better knowledge acquisition, longer information retention, and overall class enjoyment. Enhancement of performance is a favorable outcome of active learning.

According to Weimer (2013), a learner-centered strategy is one that places more emphasis on the student than on the instructor. Biology students benefit greatly from active learning strategies when it comes to acquiring new information. Our classroom is unfortunately lacking in active learning opportunities.

The 5E pedagogical paradigm was developed by the Biological Science Curriculum Study (BSC5) in 1987 with the objective of promoting active and collaborative learning. The curriculum improvement study (SCIS) for elementary school programs followed the learning cycle developed by J. Myron Atkin and Robert Karplus in 1962. Significant learning can be achieved by following the model's outlined instructional sequence. The five stages that make up the paradigm are as follows: Investigate, Participate, Clarify, In the engagement phase, the instructor piques the students' interest, gets them to think critically, evaluates their background knowledge, and points out where they may be misunderstanding the material. Students' thinking is guided towards the desired learning goal through the use of brief, inquisitive exercises that help them make connections between what they already know and what they are learning.

Activities designed to aid exploration learners in recognizing and fostering conceptual change in their existing knowledge, abilities, and processes are provided to them. Critical thinking, strategy, structure, coordination, and information gathering are all given to students. To clarify, students analyze the results of their own investigations. Learners are guided to a particular part of their learning journey by this term, which also gives them an opportunity to demonstrate their competence in a variety of areas. The teacher facilitates a more profound knowledge by guiding learners through reflective exercises that are designed to elucidate and refine their understanding of a subject, all while learners articulate their comprehension. Explanation: Students are given the opportunity to strengthen and improve their understanding and skills. In order to improve their understanding, teachers give students difficult assignments. A fresh perspective is provided in order to foster a deeper and more thorough understanding. Students are provided with additional exercises to help them apply what they have learned. Evaluation: it is finished. Both the students and the teacher can use it to gauge how well they are learning and whether or not they are making progress towards learning goals.

Using the 5E Model in the classroom has been shown to improve student achievement in multiple studies. Bybee (1997) asserts that this approach allows students to rethink, organize, analyze, and change their current views by interacting with others and their environment. In an effort to promote collaborative and adaptable learning, the Biological Sciences Curriculum Study (BSCS) developed the 5E Model in 1987. It was created by Robert Bybee with the help of John Dewey and Jean Piaget as sources of inspiration. According to Duran (2004), the 5E learning model provides useful reform-based education and shows instructors how to use the structural list approach in processing courses. Furthermore, he stated that the method may make curriculum building easier.

According to Senan (2013), the technology-enriched 5E learning model is an effective instrument for students to develop 21st century abilities and for teachers to instruct on a specific idea. Prokes (2009) conducted a study on the 5E learning model and found that students in this model exhibited higher levels of activity and motivation compared to students in lecture-based classrooms. Additionally, these students were able to actively engage in sharing their knowledge and experiences, while also having their past knowledge recognized. The 5E model is significant for dispelling misunderstandings because it enables students to identify misconceptions, eradicate them through direct experience, and assess their own understanding (Acish and Turgut, 2011; Aksoy and Gurbuz, 2013; Aydin and Yilmaz, 2010).

Students must grasp the concepts and facts contained in a conceptual framework, have a solid foundation of factual information, and arrange their knowledge to make it easier to retrieve and apply it in order to become competent in the field of research. Extensive research indicates that teaching approaches based on learning cycles help students build a profound comprehension of scientific concepts. A cross-disciplinary comparison study found that using a teaching style based on the learning cycle led to significant improvements in subject matter learning (Ebraham, 2001). Additionally, he contended that this enhances student curiosity. Research indicates that the 5E model is more effective than other teaching strategies in facilitating students' achievement of significant learning outcomes in science. Various comparative studies have shown that the 5E strategy is superior to other methods in helping students achieve mastery in science disciplines (Akar, 2005; Coulson, 2002). Coulson found that kids whose instructors utilized the 5E model with moderate or high adherence received learning gains that were nearly double compared to teachers who did not use the model or used it with low adherence. Boddy (2003) found that the implementation of 5E had a positive effect on the development of scientific thinking. In addition, Akar (2005), Boddy (2003), and Tinnin (2001) discovered that the 5E model also had an impact on individuals' interest and attitude towards science. The ensuing research findings illustrate the advantageous impact of implementing the 5E paradigm in the classroom.

According to the teachings of biochemistry and molecular biology, the implementation of the 5E model led to a notable enhancement in comprehension of scientific topics when compared to conventional training. The acquisition and retrieval of scientific lectures were greatly improved. The study conducted by the International Journal on New Trends in Education and their repercussions found that the 5E model had a substantial impact on students' academic performance and their ability to retain knowledge. 5E enables education to facilitate a distinctive learning experience for students and assist them in establishing a solid knowledge base, hence promoting active engagement. Nevertheless, the 5E instructional model has not been implemented in secondary schools in Kenya to facilitate this distinctive experience.

Researchers conducted a study to determine whether the instructional approaches of novice instructors were enhanced by the implementation of the 5E model. The study included a group of forty novice teachers. Each participant was hand-picked from a pool of eligible Chinese citizens, hailing from Hubei, Henan, and Inner Mongolia, according to their chemistry scores. The 5E model of education was used in a series of instructional activities with the participants. Over the course of four months, with everyone's help, the operations were carefully tracked and recorded. Furthermore, surveys were filled out by the participants. The participants' examinations on the instructional process were collected by the researchers. These examinations focused on the participants' instructional design process at different phases according to the model. Before training, after instruction, and at the three-month mark, the tests were sorted into three groups. The researchers meticulously reviewed every test in order to glean the pertinent details and information. The instructional design was evaluated at each stage of the 5E model, and inexperienced teachers were also evaluated at each stage. Three participants were selected for further study from the initial pool of forty subjects. Despite their relative inexperience, the three instructors represented a wide range of educational paths, professional experiences, and present job situations. This research proved that the 5E model can enhance instructional design and have long-lasting effects on classroom practice. The researchers hypothesized that the 5E model's optimum framework for the construction of teaching methods was the primary cause for this improvement (Hu, Gao, & Liu, 2017).

According to Hu, Gao, and Liu (2017), the 5E model can help inexperienced teachers become more knowledgeable about various aspects of instructional design. The purpose of this research was to provide ethanol fermentation worksheets based on the 5E Instructional Model. The goal of the research was to use this paradigm to create effective workbooks. Using the 5E model, the researchers determined how much student achievement results from learning with worksheets and hands-on activities. The study's primary objective was to identify any correlation between the use of worksheets and improved academic performance in classrooms. Four professors who were considered "experts" in their fields were interviewed by the researchers. The Science Teaching Department at Bayburt University also administered exams to 28 second-year students. A group of twenty-eight students were assessed for their scholastic achievements. According to Toman et al. (2013), the assessment was made to fit in with the particular curricular goals and objectives. Researchers consulted with experienced educators about the results of the evaluation and incorporated the educators' feedback into the 5E Model into the curriculum's implementation as needed. As a follow-up to the first evaluation, the 28 students were given supplementary materials and another test to compare their results with. Students that participated in ethanol-related workbooks and practical exercises saw a rise of over 50% in their performance between the first and final assessments, according to the study. Students performed better in comprehending ethanol fermentation when worksheets with engaging activities, as opposed to conventional materials, were used.

Students are more engaged, have a deeper understanding of the material, and perform better academically when using 5E model constructivist approach worksheets, according to Toman et al. (2013). Turgut and Gurbuz (2011) looked at how using the 5E model affected student conduct and how teachers' ideas changed. The purpose of the research was to assess the extent to which eighth graders have false beliefs about heat and temperature. This research set out to compare how well eighth graders learned about heat and temperature using the 5E model with more conventional methods of instruction. For the eighth grade, 37 kids took part in the study. Over the course of the school year, the same instructor worked with both sets of participants separately. Using exercises developed according to the 5E paradigm, pupils in one randomly selected class were taught. Traditional teaching methods were used in the second class, which served as the control group (Turgut & Gurbuz, 2011). An attitude scale toward science and technology (ASST) and a three-part heat and temperature misconception test (HTMT) were used to collect the data. The data was analyzed using two types of t-tests: one for independent samples and one for paired samples. According to the results of the Heat and Temperature Concept Success Test, the 5E model is better at correcting misunderstandings.

According to Turgut and Gurbuz (2011), the 5E Model outperformed the conventionally structured training in terms of fostering a permanent conceptual change.

Turgut and Gurbuz (2011) found no statistically significant difference in students' perspectives on science and technology between the experimental and control groups. In this physics-related study, we looked at how teaching students to use the 5E model improved their grasp of magnetic hysteresis curves. Twelvety students from two Indian high schools in the Mardan area participated in the study, and the researchers looked at how the 5E Model helped them improve their conceptual understanding. Using the 5E model, an evaluation was carried out to contrast the standard teaching technique with the concept creation strategy. The test's goal was to find out how well the students had learned about magnetic hysteresis curves in their physics classes. To gather data, scientists administered a pretest and a posttest. The experimental group consisted of one randomly chosen class that used 5E model activities to teach its students. The other group of students was to serve as a control group, and they would have been taught using more traditional methods. Both the preliminary and final assessments indicated that the 5E model—a strategy for instruction that centers on the formation of concepts—was superior to more conventional approaches (Shah, Muhammad, Abubaka, Khalid, & Uzma, 2019). Students in the treatment group had a better grasp of the ideas surrounding magnetic hysteresis curves than in the control group. Tailored Instruction The 5E Instructional Model is grounded in scientifically-validated teaching methods, constructivist-learning theory, and cognitive psychology (Duran & Duran, 2004). Students improve their original ideas through self-evaluation, expansion, redefinition, and restructuring as part of a personalized learning process that makes use of the 5E Instructional Model (Bybee, 2009). Students are given the opportunity to take charge of their own learning through the 5E paradigm, which allows them to build their own interpretations based on what they understand conceptually. Schools in the United States in the 18th century typically consisted of a single classroom with a single teacher. It was believed that children of the same age might study at a uniform speed during the transition from one-room schoolhouses to graded schools (Gundlach, 2012). Teachers have known for a long time that students come to school with widely varying levels of background knowledge and experience. When dealing with pupils of the same age who demonstrate wildly varying degrees of academic competence, educators have turned to a wide variety of strategies (Josephson, Wolfgang, & Mehrenberg, 2018).

According to Herold (2017), personalized learning models aim to tailor the learning experience to each student by taking into account their own strengths, weaknesses, interests, and requirements. At its core, individualized learning encompasses a wide range of applications, from supplementary technological resources to comprehensive school reforms. The goal is for pupils to develop a sense of ownership over their own education. According to Easley (2017), one way for teachers to help their students succeed academically is through personalized learning which is advocated by the 5E instructional model.

Johns (2018) states that tailored education must have four main components. First, flexible materials and content; second, student accountability and self-reflection; third, data-driven decisions; and fourth, individualized lessons. Personalized learning encompasses a wide range of concepts, and Johns argues that teachers should see this continuum. It is recommended to develop each fundamental component independently, one at a time, so that you can completely maximize their efficiency. This approach will ensure that all four components are effectively and significantly integrated into the learning process. Teachers create adaptable content and tools by combining three distinct types of instructional resources to create personalized learning experiences. In order to meet the needs of their pupils and lay a solid groundwork for their education, teachers should make use of adaptable and diverse materials (Johns, 2018). Students are given opportunities to practice that are tailored to their unique level of difficulty through adaptive content. Instructors can create and organize their own one-of-a-kind curriculum with the help of customisable content, while students can work together and show what they've learned in creative ways. According to Johns (2018), all students are assured to have access to foundational knowledge, which provides a fundamental set of principles and activities. Incorporating tools for student ownership and reflection into the classroom can help students develop a habit of regularly thinking critically about and being accountable for their own learning (Johns, 2018). Teachers should make sure their pupils have plenty of chances to reflect on what they've learned and what they've accomplished. Establishing objectives, keeping tabs on development, and selecting course work are all part of this process. Personalized education relies on this crucial component, which encourages students to take more responsibility for their learning and achieve a better degree of mastery. Teacher decisions that are data-driven are those that are based on analysis of student work in contexts like tests, projects, and activities that measure performance. Teachers are able to make informed decisions about their kids' education and class placement with the help of systematic data collecting.

Students are also welcome to apply for this job, which will provide them the chance to assess their own data and make educated choices about their schooling (Johns, 2018). Students feel more invested in their education when they have a hand in making data-driven decisions. With the help of personalized learning plans, educators can divide their students into smaller groups according to their interests, needs, and current skill sets. It simplifies the group structure and gives priority to certain student groups or talents so that the requirements of students can be met more effectively. Using small groups in the classroom improves differentiation in a number of ways, including pairing students with similar levels of competence so that instructors can concentrate on individual topics and pairing students with different levels of competence so that they can work together more effectively (John, 2018). Teachers have made great efforts to cater to their pupils' unique requirements by incorporating their interests and preferences into the classroom curriculum. Personalized learning encompasses the integration of these principles throughout a whole school, spanning all grade levels and disciplines (Pane, 2018). Teachers therefore need to modify their methods to integrate the 5 stages of the 5E approach of instruction to achieve personalised learning for all learners.

According to Bray and McClaskey (2013), students are expected to take an active role in their own education in personalized learning settings. Each student has the opportunity to express his or her understanding of the course material in a way that is personally meaningful to him or her. In this type of learning, students work together to build their own knowledge and take ownership of their work. The educator acts as a guide and teacher throughout the learning process. Bray and McClaskey (2013) argue that students should be more accountable for their own education. Researchers in a qualitative study looked at how middle school students in individualized learning environments develop goals for themselves. In order to evaluate the methods used by eleven middle school teachers to establish goals, the researchers conducted semi-structured interviews that lasted thirty to sixty minutes. In its first year of operation, Vermont's state-wide comprehensive customized learning effort has just been established. The interviewers gave each participant a task sheet and told them to rank the importance of several factors that went into setting objectives. Additional course materials for goal-setting were contributed by a number of interviewees. The main source of data was the interview transcripts, with the task sheets and additional artefacts being used as supplementary sources. Goal setting is an essential part of individualized learning, and the researchers emphasized the critical need for more empirical studies in this field (DeMink, Carthew, Olofson, Leopros, Netcon, & Hennessey, 2017). Based on their analysis of educators' goal-setting practices, researchers have identified five distinct approaches: independent design, interest-driven co-design, skill-driven co-design, selection, and interest and skill-driven co-design. According to the results of the semi-structured interviews, individualized education can ensure that all children have equal access to quality learning opportunities. In order to cater to students' diverse interests, needs, and abilities, schools in the US are embracing personalized learning (DeMink, et al., 2017). The research looked at students who created their own "algebra stories" to see how situational interest affected tailored learning. Bernacki and Walkington (2018) used classroom and unit tests to look at how high school students' problem-solving abilities might change after four math units were modified. A total of 155 high school math students from a variety of backgrounds and taught by two separate instructors participated in the research. In order to determine whether some students showed more situational interest than their classmates who were given more conventional mathematics tasks, we gave them individualized problems to complete. Two groups of students participated in the study. One group included 77 students who finished all of the Algebra I content for the year, while the other group included 73 students who only covered half of the subject. Five students were removed from the program because there was no correlation between their data from the intelligent tutoring system logs and the data provided by their classroom teachers and administrators. Following the experiment, 150 high school students were surveyed. Those who performed normal algebra problems indicated less situational interest in algebra units than those who participated in the experiment. All four units' average level of activated situational interest was significantly affected by personalization, according to the data (β =.169, p =.025).

Bernacki and Walkington (2018) found that maintaining situational interest was indirectly affected by personalization, specifically in terms of enjoyment (β =.145, p =.026) and value (β =.098, p =.032). Students' mathematical proficiency improved when classroom learning activities included individualized instruction, which is tailored to each student's interests (Bernacki & Walkington, 2018). As a means of meeting the needs of their pupils, teachers have sought to incorporate students' interests and preferences into the classroom experience. When these ideas are fully implemented across all grade levels and subjects in a school, it is called personalized learning (Pane, 2018). The 5E paradigm, when used effectively, can stimulate student learning and lead to more individualized lessons.

According to Duran (2003), the 5E paradigm encourages students to work in groups to solve issues and explore new ideas by using the following steps: inquiry, observation, analysis, and inference. Through the five phases of the 5E instructional approach, teachers would stimulate learners, create personal interest in learners to ensure individual learning takes place.

2.5 The intervention: 5E Instructional Approach elaborated

The 5E instructional paradigm is an inquiry-based approach that is based on the notion that students are active cognitive processors who construct their own knowledge through interactions with phenomena, their environment, and other individuals. The concept involves categorizing instructional activities into five specific stages: Engage, Explore, Explain, Elaborate, and Evaluate. This enables students to actively construct their understanding of diverse disciplines. Every phase has a specific goal and helps the teacher deliver organized education, while also aiding the learners in developing a more thorough understanding of scientific and technological knowledge, attitudes, and skills (Bybee, 2006). The initial stage, known as Engagement, aims to inspire pupils by inducing cognitive dissonance or drawing upon relatable real-world scenarios. Students are led into the second phase, Exploration, by the interest generated. In this phase, they utilize direct concrete experiences to make observations, gather data, test predictions, and improve hypotheses. The obtained information allows them to start addressing questions that were raised during the Engagement phase. During the Exploration stage, the teacher fosters inquiry experiences and questions in a safe and guided manner, allowing students to identify their misconceptions about the idea. In the third step, known as Explanation, the teacher utilizes the students' observations and data to provide a scientific explanation for their findings. This is the point where suitable scientific language is presented and connected to the learners' personal experiences.

The fourth phase, Elaboration, aims to provide students with supplementary issues that enable them to use their newly acquired knowledge, offer solutions, make decisions, and draw logical conclusions. Typically, this takes the shape of an additional inquiry activity or an extension of the Exploration phase. The fifth phase, Evaluation, is crucial for assessing whether students have acquired a scientifically accurate comprehension of the topic and their ability to apply it in different settings. The 5Es are explained in detail as follows:

Engage

The initial phase of the lesson serves to establish the goals, prompt and link to existing information, stimulate curiosity, and develop interest in the learner. The stage offers a platform for educators to ascertain the existing knowledge or perceived knowledge of students. Learners are provided with the chance to reflect on their existing ideas and thoughts regarding the issue.

The teacher's primary responsibility is to stimulate pupils' curiosity and cultivate their interest in learning. The teacher facilitates students in generating their own inquiries, fosters their ability to juxtapose their own concepts, and so assess their present comprehension.

In the classroom, this technique is utilized during the introduction phase to pique curiosity, foster engagement, and provoke critical thinking in the student. The teacher serves as a facilitator, enabling learners to actively engage with each other in order to create an engaging introduction.

Explore

The stage entails engaging with inquiries through which the student encounters the fundamental principles, uncovers novel abilities, and establishes conceptual connections and comprehension of the important concepts. Students engage with the content and concepts by participating in classroom and small group conversations in order to develop a shared set of experiences. They engage in activities, make predictions, formulate generalizations, exchange ideas, and consider possible alternatives. The teacher's primary responsibility is to serve as a facilitator, overseeing and attentively observing pupils while they engage in interactive activities. Additionally, the teacher ensures that students have sufficient time for introspection and encourages collaborative learning.

Within the classroom setting, the instructor facilitates learning by offering learners opportunities to actively engage in activities that involve manipulating, discussing, and generating ideas within groups. In addition to the cultivation of ideas, the learner also fosters significant values such as respect, unity, and responsibility.

Explain

The objective of this stage is to establish a link between existing knowledge and background information with new findings, convey fresh comprehension and concepts, and establish a connection between informal language and formal language. This is accomplished by performing a scientific inquiry that allows the student to link past experiences with present learning and get a conceptual understanding of key ideas. During this phase, the student engages in active listening, utilizes prior observations and results, offers logical responses to inquiries, and engages in good interactions. The teacher furnishes definitions, unfamiliar vocabulary, and clarifications. In addition, he requests clarification and justification, fosters students' explanations of their discoveries, and attentively expands upon students' discussions. The student is required to articulate concepts and ideas using their own language, actively listen and compare explanations from others to their own, change their ideas as necessary, document their understanding in real-time, and employ accurate terminologies and formal language. During this stage, the students are guided to gain new knowledge, correct mistakes, and provide explanations for facts. The teacher ensures the accurate concepts are maintained and misunderstandings are clarified.

Elaborate

At this stage, the student must utilize newly acquired knowledge in unfamiliar or comparable scenarios. The objective is to expand and elucidate concepts under investigation, convey fresh insights using formal language, and establish connections between novel and formal experiences. The student is required to utilize newly acquired terminology and concepts, formulate logical conclusions and answers, document observations, explanations, and resolutions. The teacher's primary responsibility is to motivate students to use and expand upon the concepts and abilities they have learned. This includes encouraging students to utilize the words and definitions they have acquired, as well as using previously acquired knowledge to facilitate further learning.

In the classroom, the student is provided with the necessary support and guidance to effectively apply the knowledge they have received. Learners are given tasks to manage by using the concepts they have learnt. Actual scenarios are employed to elucidate concepts and comprehend the significance of the obtained knowledge.

Evaluate

The stage encompasses the evaluation of the student's knowledge and abilities. Illustration of novel idea and implementation of acquired knowledge. The learner assesses their own progress, offering logical reactions and explanations to events, expressing their present thoughts, and generating questions that delve more into a concept. The teacher evaluates the learners' knowledge and skills by monitoring their exploration and application of new concepts. He motivates pupils to evaluate their own learning. In addition, he poses open-ended questions in order to evaluate their answers.

The 5E instructional model aligns with the constructivist approach, which suggests that students should be given time to: articulate their thoughts, engage with objects to gain a variety of experiences to inform their thinking, reflect on their thoughts through writing and self-expression, compare their thoughts with others', and establish connections between their learning experiences and the real world. The 5E framework offers a built-in structure for establishing a constructivist classroom. Learning is thus centered around the student, allowing them to actively acquire knowledge.

The 5E educational style is highly compatible with the competency-based curriculum (CBC) that is now being implemented in the country. The CBC is structured based on a defined set of essential skills and principles. The competencies encompassed are as follows: (i) Communication and cooperation, (ii) Critical thinking and problem solving, (iii) Imagination and creativity, (iv) Citizenship, (v) Learning to learn, (vi) Self-efficacy, and (vii) Digital literacy. The values encompassed are love, responsibility, respect, unity, peace, patriotism, social justice, and integrity. The competences and values are centered around fulfilling the curriculum's goal of creating a "engaged, empowered, and ethical citizen" and the aim of "cultivating the potential of every learner". By following the five steps of the 5E educational paradigm, one can attain the specified competences and values, ultimately leading to the development of an engaged, empowered, and ethical citizen.

2.6 The conventional approach elaborated

In contrast to the 5E methodology described, the conventional method consists of three clear-cut stages: introduction, lesson development, and conclusion. The introduction primarily consists of the teacher's review of the preceding lesson. This is accomplished by a concise overview provided by the teacher or by the teacher posing questions that require the recollection of information. Consequently, the student is deprived of the opportunity to contemplate and evaluate their existing knowledge or beliefs. The lesson creation phase involves the teacher elucidating the concept to the learner through expository techniques such as lecturing, while the student attentively listens. During this stage, the learner's input may be minimal as the teacher guides the student to acquire new concepts through the process of memorizing and recitation. The teacher provides students with prepared notes. At the conclusion, the teacher may pose inquiries to recapitulate the lecture or provide a concise overview of the material discussed. Student participation is negligible and there is a complete absence of self-assessment.

The 5E instructional approach is an inquiry-based method in which students take charge of their own learning, while the teacher assumes the role of a guide. In contrast, the conventional approach places the teacher in a central position, with learners passively receiving knowledge. The 5E approach considers the unique characteristics of each student and facilitates their interaction with peers to attain a more profound comprehension of subjects. This issue is not resolved by conventional methods, as they only offer students the choice of memorizing things through repetition. By employing the 5E technique, the instructor can identify and address students' misconceptions regarding ideas, hence facilitating a deeper comprehension of the concepts. However, when employing the conventional approach, the teacher may struggle to comprehend the student's understanding and hence be unable to effectively address their misconceptions. The distinct disparities between the two methodologies are outlined in APPENDIX VIII.

2.7 Summary of Chapter Two and Gaps in the Literature

Biology serves as a foundation for instructing students in the application of scientific concepts and principles to solve practical problems encountered in daily life. This subject equips students with the necessary knowledge and skills to pursue further studies in practical fields such as agriculture, medicine, biotechnology, agrochemicals, and the food business. Biology has a high number of students enrolled in compared to other science subjects based on the understanding of its importance. Despite the high enrolment and willingness to excel in the subject, the rate of failure has remained very high. The subpar performance level is a cause for concern among all stakeholders and researchers. Literature review reveals a number of factors that contribute to the low achievement by learners the researcher focused to address.

Although science education is widely applied in economic growth, there is a persistent challenge of poor performance at local and international level. Okubuito (2004) asserts that despite biology being popular among students, there is still a significant rate of failure. Research reports have also shown that poor performance by students in science subjects is mainly caused by the teacher centered method of teaching in science classroom among other factors (Ukoh & Adewale, 2014). In Kenya, SMASSE that was introduced in Kenyan secondary schools sought to address methodology, availability of resources and learners' attitude. Despite the operationalization of the project for many years, low performance in biology still lingers on. This calls for research into innovative approaches. This study sought to determine whether the use of 5E instructional model would avert the situation.

Makgato and Mji (2006) contend that ineffective teaching approaches directly impacts students' performance in science disciplines. Student centered approaches have been found to encourage engagement, enjoyment and critical thinking critical to learning (Greitzep, 2002). According to wood (2009), majority of biology instructors employ the conventional teacher centered approaches that are dominated by the lecture method. Whether 5E would bring about learner engagement and critical thinking for improved performance was the researcher's concern.

Scientific skills refer to potentials, capacities and technical abilities that are acquired through experience and applicable in real life situations. Mastery of scientific skills equips learners for future acquisition of content knowledge and allows them conceptualise the content they know at a much deeper level (Sevilay, 2011). According to Brickman et al (2009), science literacy and skills development are enhanced by inquiry-based learning. Development of these skills would be reflected on student performance in practical examinations. However, students perform below average in practical biology examinations administered by the KNEC. This raises concern for the researcher to establish whether the 5E could avert the situation.

Attitude is one of the key factors that influence student performance in any subject in secondary school education. Attitude not only aid in the process of learning, but also affects the outcome of the students learning (smith et al., 2012). A study by (Nyaga, 2011) points out that negative attitude limits student performance because when motivation to learn is derailed then actual intake of concepts is inhibited. Student attitude determines their interest, ability and willingness to learn. In developed nations, the aspect of teaching and learning of science subjects is designed in such a way that it is purely interrogative, inquisitive and investigative with an aim of stimulating the learners" interest, enhancing the academic performance. This is not well adopted by the developing countries, Kenya being one of them. The researcher therefore postulated that the 5E could provide an enabling environment to create interest and motivate the learner through the five active phases.

According to Cater, Nobert, and Verella (2011), when compared to more conventional methods of instruction, active learning results in better knowledge acquisition, longer information retention, and overall class enjoyment. The constructivist perspective, upon which the 5E model is based, views learning not as a passive act of acquiring information but as an interactive contextualized process of creating new knowledge (Richards, 2015). Tinnin (2001) discovered that the 5E model also had an impact on individuals' interest and attitude towards science. There is limited research on the use of 5E instructional model in learning of cell biology Kenya. The researcher therefore sought to investigate the effect of the 5E model, being an active approach with an impact on attitude, on students' achievement in cell biology.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents research methodology under the following sub-headings: research design, the location of the study, target population and sample size, sampling procedure, research instruments, pilot study, reliability of instruments, validity of instruments, data collection procedure, data analysis and finally ethical considerations observed during the study.

3.2 Research Design

The study utilized a mixed methods research approach to gather both quantitative and qualitative data. Mixed method research design enables corroboration of data increasing the validity or trustworthiness of the research. Quasi- experimental design formed the main part for this study and it involved assignment of sampled intact classes into treatment and control groups in which quantitative data was collected using tests and questionnaires. The quasi-experimental design was ideal for this study because the researcher used intact classes which rendered random assignment of participants' impossible (Best & Kahn, 3003; Leech & Onwegbuzie, 2008). The selected schools provided either a treatment or control group but not both. The qualitative component entailed collecting qualitative data using focus group interviews in quick succession after collection of quantitative data collection. Qualitative component was utilized to provide deeper, clearer and detailed insight into the "why" and "how" as well as interrogate the wider and broader perspectives of issues under study (Denzel & Lincoln, 2008; Creswell & Plano, 2007). The focus group interviews were used to establish respondents' own perception and seek clarification in issues observed during the study. Mixed method research design was deemed suitable because the data from one method complements data from the other method leading to a better understanding of the research problem (Creswell & Plano-Clark, 2007; Johnson & Onwuegbuzie, 2004).

The research design process was schematized as shown in figure 3.1.

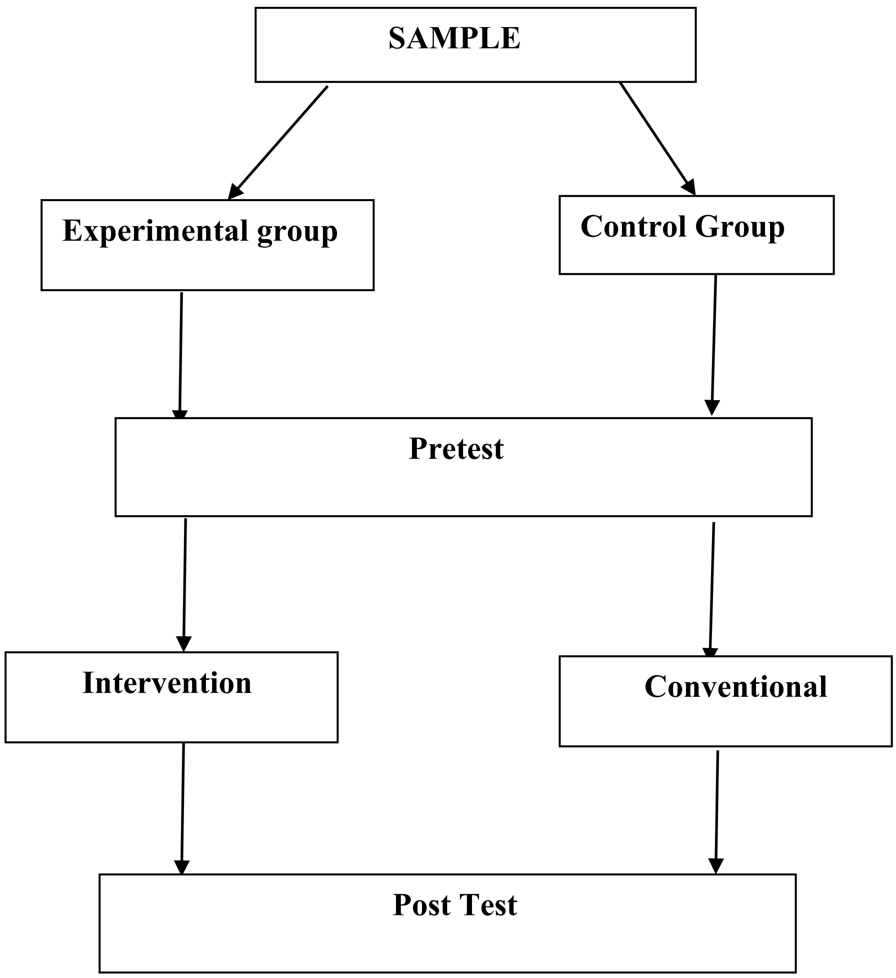

Figure 3.1: schematic representation of the quasi-experimental design.

As illustrated in Figure 3.1, the selected schools were divided into two groups, one group was assigned as experimental and the other group assigned as a control group. The pre-tests and pre-intervention questionnaire were administered to both groups to determine whether there was a distinction in their academic abilities and attitudes toward cell biology. The pre-test scores were documented were used to determine the entry behavior and, as a result, the homogeneity of the learner in both groups. A study is considered to lack internal validity if it does not meet these criteria (George and Mallery, 2003). Subsequently, the two groups were then given instruction on the concepts of cell biology under reproduction. The control group was instructed using the conventional method, whereas the experimental group was instructed using the 5E instruction model. Subsequently, post-tests were administered to the two groups were and their scores were recorded. The post-test scores were used to determine whether there was a difference in the academic achievement and scientific skills acquisition of learners when the 5E instructional model was implemented in comparison to the conventional approach. Any difference would be attributed to the treatment. Focus group interviews were implemented to accumulate qualitative data. Internal and external validity were jeopardized by the research design. The initial hazard was the potential for interaction among respondents. Maturity is a result of the cumulative impact of multiple treatments and the passage of time between interventions. The researcher, however, addressed the concerns in the following manner: (i) the utilization of control groups, which improved the internal validity of the study. (ii) the random assignment of the intact classes to the experimental and control groups. (iii) Employing distinct educational institutions as control and control groups. (iv) Minimizing the impact of maturation by reducing the time between interventions. This design enabled the researcher realize reliable data for constructive analysis.

3.3 Location of Study

The study was conducted in Vihiga County, Western region of Kenya. The county lies between 34 30' and 35 0' East of the equator and between 0 and 0 15' north of the equator. The county boarders Nandi County to the east, Kisumu County to the south, Siaya County to the west and Kakamega County to the north. Vihiga county is sub divided into five sub counties; Emuhaya, Vihiga, Sabatia, Lwanda and Hamisi. Vihiga county is dominated by the Luhya community with a fair mix of other Kenyan communities such as the Luo, Kalenjin and the Gikuyu. The county has 754 ECD schools, 392 primary schools, 155 secondary schools, 30 vocational training centres and 1 public university.

Vihiga County performance at KCSE has remained low as revealed in the table 3.1

Table 3.1: KCSE performance for past 4 years in Vihiga country

Year	**2020**	**2021**	**2022**	**2023**
M/Score	4.8379	4.4559	4.6988	4.6360
M .Grade	C-	D	C-	C-

Source: County Director of Education- Vihiga 2024

The performance indicate that most learners do not favorably compete for the limited chances in public universities. This possesses a disadvantage to the county in terms of professional empowerment.

Performance of students in individual science subjects is below the overall KCSE mean in the county as shown in Table 3.2.

Table 3.2: Science Subject Performance in KCSE for past 4 years in Vihiga country

	2020	2021	2022	2023
BIOLOGY	2.92582	3.0624	2.9836	3.5630
CHEMISTRY	2.36625	2.2557	2.5518	2.9180
PHYSICS	4.1931	3.4962	4.2073	3.9350

Source: County Director of Education- Vihiga 2024

From the table 3.2, the number of students from Vihiga who qualify to the prestigious science related professions like medicine and engineering is relatively low. Since resources are now being devolved to counties, locally produced professionals will be key to the advancement of each county. As a resident of Vihiga county, I felt indebted to use my research skills to seek answers to the dismal performance in key areas like biology. Being a science educator, i particularly thought of the critical area of teaching strategies with a view to make a personal contribution in an effort to improve learner performance in science education in the county,

Literature review has not revealed a study conducted in Vihiga county on classroom instruction and its effect on learners' performance. The researcher therefore sought to determine the effect of using the 5E instructional model in biology on learners' performance in the county. The low performance was the key motivator to researcher.

3.4 Target population and Sample Size

All 14,400 form three students taking biology in Secondary schools that have presented candidates for KCSE in biology for the previous four years formed the target population for this study. Form three students were targeted because they would have chosen biology as one of their KCSE subjects and were likely to opt for biology related careers.

According to Yamane (1967), a sample size is calculated using the following formular with 95% confidence assumed.

$n=\frac{N}{1+N(e)}2$ where n=sample size

N=population size

e=precision level

In this study; n= 390

$n = 14400/1+14400(0.05)^2$

=14400/37

=389.189 = 390 (rounded up)

According to Israel (1992) 10% of the sample is added to compensate non accessible respondents and a further 30% is added to compensate for non-response.

Compensated sample size = 390+ 39+117 = 546

The compensated sample size was therefore 546. With an average of 50 students per class, 12 intact classes in 12 schools were used in this study.

3.5 Sampling Procedure

Multistage sampling technique was used to select the required sample. Purposive sampling was used to select schools that had presented candidates for the previous four years. This was to use schools with an established foundation in the subject under study. Purposive sampling was again used to select schools that had an average mean of between 2.000 and 2.999 in biology. This provided sample schools with an almost similar entry behavior in terms of intellectual ability that ensured fair competition and minimized on the effect of student ability as an intervening variable. This formed the accessible population. Stratified sampling was then be used to select representative schools in each sub county apportioned based on the total number of schools in each sub-county. It involved the grouping the accessible schools into the respective sub-counties then each school was assigned a number. The numbers were written on pieces of paper, placed in separate containers based on sub-county. Pieces of papers equivalent to the required number of schools for each sub-county were randomly picked from each group as shown in Table 3.3

Table 3.2: Number of schools sampled in each sub-county

SUB COUNTY	Total Number of Schools	Number of Schools Selected	Percentage of total no of schools
EMUHAYA	18	2	11
VIHIGA	22	2	9
HAMISI	41	4	10
LWANDA	15	1	7
SABATIA	28	3	11
TOTAL	104	12	11

Stratified sampling of the schools ensured that the study covered all sub-counties in the county. Simple random sampling was then used to select the stated number of schools from each sub county. For the purpose of sampling, a list of targeted schools from each sub county was prepared and each school was assigned a code that comprised of a numeral and the first letter of the sub county randomly. The codes assigned to each school were then written on small separate pieces of paper then the papers were folded and placed in bags based on the sub county. A blindfolded learner was then asked to pick the required number for each sub county in succession. The schools represented by the codes picked formed the sample schools. Simple random sampling was also used to assign the schools into treatment and control groups. The schools in each subcounty were separately assigned consecutive numbers starting from one; all schools represented by odd numbers were assigned as treatment while those represented by even numbers were assigned as control groups. Since quasi experimental design was used the experimental group and the control group comprised of the entire selected classes. Simple random sampling was also used to select one stream in schools with more than one stream. The names of all streams in a school were written on separate pieces of paper and placed in a bag. One piece of paper was then picked from the bag by a blindfolded learner. The stream picked became the sample class. The biology subject teacher of the selected class automatically became part of the sample. These sampling techniques were used to ensure equitable distribution of opportunity to participate across the sub counties. A representative sample was therefore selected.

3.6 Research Instruments and methods of data collection

The researcher used six instruments to collect data, namely (1) cell biology achievement test I (CBAT1) -appendix I, (2) cell biology achievement test II (CBATII) -appendix III, (3) scientific skills achievement test -Appendix V (4) student attitude questionnaire I (SAQI) -appendix VI, (5) student attitude questionnaire II (SAQII)- Appendix VII, (6) Focus group interview guide Appendix VIII. Details of each instrument are discussed in the subsequent subsections.

3.6.1 Cell Biology Achievement Test 1 (CBAT1) - (Appendix 1)

Cell biology achievement test was used as pre-test to establish students' academic entry behavior based on cell biology concepts previously learnt. It was developed by the researcher after consultation with practicing teachers of biology and experts in science education from Masinde Muliro University. It was a one-hour test that was administered to all learners in in both groups before intervention. The achievement test had 12 items developed by the researcher in consultation with practicing experienced teachers of biology, based on KCSE past paper questions on the concepts of cell biology and in line with specific objectives outlined in the KICD syllabus. The items cut across all the six levels of Bloom's taxonomy. The test items consisted of short answer and structured questions. The test carried a minimum score of zero and a maximum score of fifty marks converted to 100% for the purpose of analysis. A score below 40% was considered poor; between 40% to 59% was considered fair while a score above 60% was deemed as good. The Cronbach's reliability was determined using the split-half method. Content and construct validity was established through consultation with experienced teachers and science educators. Pre-test scores were also utilized to establish the homogeneity of the two groups.

3.6.2 Cell Biology Achievement Test 1I (CBATII) -(Appendix III)

Cell biology achievement test II was used as post test to determine if there was a difference in academic achievement in cell biology when 5E instructional approach was used as compared to when the conventional approach was used. It was developed by the researcher based on KCSE past paper questions on the concepts of cell biology taught during the intervention and in line with specific objectives outlined in the KICD syllabus. It was a one-hour test that consisted of 12 items with a maximum score of 50 marks administered to all the learners in both groups after intervention. The items cut across all the six levels of Bloom's taxonomy. The test items consisted of short answer and structured questions. The test carried a minimum score of zero and a maximum score of fifty marks converted to 100% for the purpose of analysis. A score below 40% was considered poor; between 40% to 59% was considered fair while a score above 60% was deemed as good. Pool marking was used to mark and score the learners. Data obtained was used to address objective 1.

3.6.3 Student Attitude Questionnaire I - (Appendix VII)

The student attitude questionnaire I (Appendix VII) was a closed ended questionnaire administered to all learners before intervention. It sought to determine the students' attitude towards concept on cell biology before intervention.

The questionnaire had two sections;

Section A- consisted of items that required demographic data of the respondent. In addition, a random number designed by the researcher were given to each learner in confidence to be written on the questionnaire used. This number was written on the last page of the questionnaire before being handed over.

Section B- consisted of items that measure attitude towards concepts on cell biology and that required either True (T) or False (F) responses. Some of the statements were positive while others negative, however all statements sought information about the students' attitude towards concepts on cell biology concepts.

3.6.4 Student Attitude Questionnaire II - (Appendix VI)

The student attitude questionnaire II (Appendix VI) was a close ended questionnaire administered to all students in the sample after intervention. The questionnaire was used to measure students' attitude towards cell biology concepts after intervention. All students in the sample were required respond to the questionnaires

The questionnaire had two sections.

Section A- consisted of items that required demographic data of the respondent. In addition, the random number used on SAQ1 by the learner was written at the back of the questionnaire before handing over.

Section B- consisted of items that sought to determine the attitude of students towards cell biology concepts. It required either True (T) or False (F) responses. Some of the statements were positive while others negative, however all statements sought information about the students' attitude towards cell biology concepts. Data generated was used to address the objective 2, 3 and 4

3.6.5 Scientific Skills Acquisition Test (SSAT) - (Appendix v)

Scientific skills comprise of important skills necessary for effective learning of biology and other science subjects. Good science skills are believed to help students understand biology concepts easily and correctly. This tool therefore aimed at determining acquisition of scientific skills by the two groups after intervention.

Science skills achievement test (SSAT) (Appendix V) was prepared to assess science skills acquisition by the students. It comprised of five questions of practical orientation with a total of 25 marks done in 45 minutes. Scientific skills that were assessed consist of: observing, drawing, measuring, recording and analyzing. The test was administered to all students in the sample by the subject teachers with the help of research assistants after being trained by the researcher. Items in the test required use of the scientific skills mentioned above, and each was awarded a maximum of 5 marks. The cumulative score for each student was then converted to percentage for analysis. The data was used to address objectives 2, 3 and 4.

3.6.6 Focus Group Interviews (FGI) Guide – (Appendix VIII)

Twelve focus groups were the subject of a series of focus group interviews. Five randomly selected volunteer students from each sample school were interviewed, resulting in a total of sixty students. A set of guiding queries was established prior to the commencement of the study to provide the interviewers with guidance.

The guiding queries were centered on the learners' attitudes and experiences regarding the learning of cell biology concepts and the biology subject as a whole. The questions also addressed the student's perspective on the learning and teaching of biology, as well as their experience with the cell biology achievement test II. In order to assist the interviewer, probes were incorporated. The quantitative findings were further elucidated by the qualitative data collected by the instrument.

3.7 Pilot Study

A Pilot study was conducted in two schools in Vihiga County two weeks prior to the actual study for the purpose of improving the validity and reliability of the research instruments. To prevent the hallo effect in the actual research, the two schools were excluded from the sampling frame prior to the commencement of the study (Long-Crowell, 2015). The schools that were selected for the pilot study were randomly chosen from among the schools that had offered biology for the previous four years. Students in the selected schools kept their intact classes and were randomly assigned to control and treatment groups. All research instruments were employed during the pilot study, and the researcher collected information that was pertinent to the four research objectives. The results from pilot study were subsequently analysed and discussed with the supervisors. Consequently, any ambiguities, inappropriate level of difficulty or inaccuracies were expunged. This provided the researcher with the opportunity to enhance them. The research instruments' reliability and validity were computed using data from the pilot study.

3.8 Validity of instruments

Validity is the extent to which a study reflects or assesses the specific constructs that the researcher is attempting to measure (Thorndike, 1997). It answers the question: are the research findings true? (Mutai, 2001). An instrument is said to be valid if it measures what it is supposed to measure (pearl, 2015). Validity is a measure of how successful a scale is in determining what it sets out to measure so that the difference in individual scores can be taken as representing the true differences in the characteristics of the study (Mugenda & Mugenda, 2003; Kothari, 1990; Koul, 1992). All the research instruments were subjected to validity rating during the pilot study. The researcher focused on face and content validity. Face validity considers if an instrument appears to measure what it is intended to measure. According to De Vellis, 2003, content validity refers to the extent to which a specific set of items reflect the content domain. validity of the research instruments was determined through rating by experts in the fields of science education, measurement and evaluation and Kenya national examinations examiners using a rating scale of 1,2, 3,4 and 5, with 5 representing the highest score on relevance and 1 representing the lowest score on relevance. Modifications and relevant comments were also provided by the experts. The instruments were then amended accordingly before being used for the study.

The instruments were awarded the following average percentage score respectively; CBAT1 (78%), CBAT2 (76%), SAQ1 (80), SAQII (79), SSST (82%). All scores were above the minimum recommended score of 60% for educational researches (Kahn & Best, 1998). The instruments were therefore considered valid for the study.

3.9 Reliability of instruments

Reliability is the extent to which an instrument consistently measures the intended outcome. It is the degree to which an instrument generates consistent outcomes when employed under comparable circumstances (Joppe, 2000; Mugenda & Mugenda, 2003; Mutai, 2001). A research instrument is considered reliable if it can generate consistent results when administered to the same subjects on multiple occasions (Aziz, 2010). The Cronbach's alpha coefficients were calculated to ascertain the reliability of the research instruments. This enabled the researcher to ascertain the inter-item correlation of the instrument by analyzing a correlation matrix for all items in the instrument and the corrected item-total correlation. The elements that necessitated modification or removal would be identified (peters, 2014). The reliability of all instruments was verified through extensive consultation with experts prior to their implementation. This allowed the researcher to identify items that necessitated modification or elimination. The researcher employed this reliability assessment method due to its convenient time demands for the selected institutions, which necessitated only one test administration.

By the rule of thumb (George & Malley, 2003)

> *"A coefficient greater than 0.9 would be excellent, greater than 0.8 would be good, greater than 0.7 would be acceptable, while greater than 0.6 would be questionable, greater than 0.5 would be poor, and less then 0.5 would be unacceptable" (p231)*

Hence, an instrument with a determined alpha coefficient of 0.7 or above would be considered suitable for use in the investigation. The reliability analyses for the instruments used in the study surpassed the minimum acceptable reliability coefficient as follows; CBAT1: r=0.826, CBAT2: r=0.818, (SAQI: r= 0.785, SAQII: r=0.792, SSST: r=0.875. The instruments were therefore reliable and would yield similar results if given under the same conditions.

3.10 Data Collection Procedure

The study commenced in May 2021 after the approval of the research proposal by the school of graduate studies of Masinde Muliro University of Science and Technology. Following the university approval, the researcher obtained a research permit from the National Commission for Science, Technology and Innovation (NACOSTI). The sampled schools were pre-visited to meet with the administration, obtain their consent, and make any required arrangements. During the pre-visit the researcher met the subject teachers of sampled classed to discuss the finer details of the study. The researcher also trained twelve research assistants and the six teachers of biology for the experimental classes on the 5E instructional model. Research assistants were drawn from biology education graduates within Vihiga County. The training took two weeks during the month of May 2021 and it involved use of 5E pedagogy, lesson preparation, preparation of a tentative scheme of work for the selected concepts, peer teaching to ensure thorough teacher preparation and key areas were elaborated with special reference to teaching of cell biology using the 5E instructional model and administration of questionnaires. All the research assistants and trained teachers of biology were then appointed as research assistants at the end of the two weeks. The process of data collection encompassed the subsequent stages that took place during the month of June 2021 when schools were in session.

3.10.1 Administration of CBAT I and SAQ 1

The CBAT I was administered to all students in the sample before intervention by respective teachers of biology and research assistants during the first week of June

2021. The scripts were marked by all research assistant teachers at a central place. This allowed the researcher to co-ordinate the marking and ensure hallo effect was completely eliminated. This enabled the researcher establish the students' level of understanding of cell biology concepts previously learnt in biology. Marks scored were converted to percentage and recorded as pre-test score.

The student attitude questionnaire I (SAQI) was administered to all students in the sample by research assistants under supervision of subject teachers during the second week of June 2021. Each learner was given one questionnaire and allowed a period of three hours to respond to the items. The purpose of the questionnaire was outlined to the students and anonymity explained before they were administered. Maximum response was achieved. The responses from the questionnaires were recorded and used by the researcher to establish the student attitude towards cell biology concepts earlier covered in biology.

3.10.2 Instruction of Experimental Classes

Instruction of students in schools selected and assigned as experimental began during the third week of June 2021 and lasted for four weeks in their respective schools. The concepts of cell biology under the topic of reproduction selected and schemed were taught to the learners by the trained subject teachers using the 5E instructional model approach. The approach involved teachers facilitating of learner activities through the 5 stages of the approach; engage, explore, explain and evaluate. Research assistants and the researcher occasionally supervised the teaching learning process.

3.10.3 Instruction of control Classes

Instruction of students in schools selected and assigned as control began during third week of June 2021 and lasted for four weeks in their respective schools. The concepts of cell biology under the topic of reproduction selected and schemed were taught to the learners by their teachers using the conventional approach. The approach involved teachers teaching of learner using the traditional lecture-oriented methods. Research assistants and the researcher occasionally attended the classes.

3.10.4 Administration of Post-test, SSAT, SAQ.

Post-test was administered on the Wednesday of the third week of July 2021 after all sample classes had completed covering the selected concepts. It was a one-hour test that comprised of 12 structured questions on the work covered. All sample classes took the test on the same day and in their respective schools. The test was supervised by subject teachers of the sample classes with the assistance of research assistants. All the answer sheets were then collected and taken to a common marking Centre where they were coded before marking. Marking was centrally done by sample teachers and research assistants under the coordination of the researcher. Each examiner was allocated one question to mark for all the students to prevent the hallo effect and possible subjectivity. All papers were marked out of 50, then converted to percentage for analysis.

Scientific skills achievement test (SSAT) was also administered to students in the sample schools two days after the post-test. It had practical oriented test items that focused on acquisition of the five skills under study; observing, drawing, measuring, recording and analyzing. All sample students took the test in their school laboratories. It was supervised by the respective teachers, research assistants and laboratory technicians. The answer scripts were then collected coded and sent to a common marking. The five skills were each allocated a maximum of five marks totaling to twenty-five, which was then converted to percentage for analysis

Student Attitude Questionnaires II (SAQII) was also administered to all students in the sample after intervention at the beginning of the fourth week on July 2021. It was administered by the research assistants and subject teachers a day after the SSAT had been administered. To increase response rate, each learner was given one questionnaire and allowed three hours to make responses. The questionnaire enabled the researcher establish attitude of students towards cell biology when taught using conventional and when taught using the 5E instructional model.

3.11 Data Analysis

The research employed a mixed method approach which gave both quantitative and qualitative data. Data collected was sorted according to groups, coded and entered in the SPSS version 16 for descriptive and inferential analysis. Descriptive analysis generated percentages, mean, mode and standard deviation of pre-test and post-test scores. Inferential analysis involved the use of parametric tests which included; independent sample t-test, Pearson correlation coefficient, analysis of covariance (ANCOVA) and Standard Multiple Linear Regression all at 0.05 significant levels. These tests were used based on the assumptions that there is; normal distribution of data, homogeneity of variance, the data was continuous and the samples were independent.

Independent group t-test was used to establish if there is a significant difference in academic achievement, attitude and acquisition of scientific skills between the treatment group and control group as postulated in HO_1. Pearson product correlation coefficient was used to determine relationships between students' attitude, acquisition of scientific skills and academic achievement in biology as hypothesized in HO_2. ANCOVA was used to test interaction of students' attitude and acquisition of scientific skills to influence students' academic achievement in biology to address HO_3. The Standard Multiple Linear Regressions was used to test the HO_4 that students' scientific skills and attitude do not predict students' academic achievement in biology.

3.12 Ethical Consideration

The researcher keenly considered ethical issues that are important in research. These included; confidentiality, informed consent, anonymity and permission. On confidentiality, participants were asked to us availed codes on any response document and confidentiality of their responses was guaranteed throughout the study. With respect to permission, the researcher sought permission to carry out the research from the university after a successful defense of the research proposal first. The researcher then sought Research authorization from the NACOSTI before data collection. The researcher also sought and obtained consent from the sample schools' administrators and the sample teachers who were involved in the study. The participants were made aware of the intended use of the data and confidentiality of their responses assured. The participants were also requested to remain anonymous throughout the study to guarantee privacy of the information. The data collection tools did not require respondents to indicate their names to ensure anonymity. The researcher therefore ensured that there was informed consent from participants and that the confidentiality of respondents was assured. Teachers who teach the control groups were later guided on the 5E instructional model approach to use the researcher also made every effort to avoid plagiarism by acknowledging all sources used in the study.

CHAPTER FOUR

PRESENTATION, INTERPRETATION AND DISCUSSION OF FINDINGS

4.1 Introduction

The chapter provides an in-depth examination of primary data analysis, sample characteristics, the presentation of data analysis, and the interpretation and discussion of findings. The organization of data presentation in this study follows a structure from section 4.2 to 4.4, which is determined by the specific aims of the research. The data were analyzed and organized thematically according to the study's objectives, namely:

(i) to determine the effect of using the 5E instructional model approach and the conventional teaching approach on students' achievement in biology,

(ii) to determine if there is a correlation between students' scientific skills, attitude and academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach,

(iii)to determine the extent to which students' scientific skills and attitude interact to influence their academic achievement in biology when taught using 5E instructional approach and the conventional approach and

(iv) to establish the extent to which students' scientific skills and attitude could predict academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach.

Four hypotheses were postulated in reference to the objectives of the study as follows;

(i) **HO_1**: There is no significant difference in student's achievement in biology when taught using the 5E instructional approach and when taught using the conventional approach.

(ii) **HO_2**: There is no significant correlation between students' attitude, scientific skills and their academic achievement when taught using the 5Einstructional approach and when taught using the conventional approach.

(iii)**HO_3**: Students' attitude and scientific skills do not significantly interact to influence student's academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

(iv)**HO_4:** Students' scientific skills and attitude do not predict students' academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

4.2 Preliminary data analyses

Several exploratory studies were conducted to gather the necessary demographic information regarding the sample and respondents before the main data analyses could begin.

4.2.1 Response rate and characteristics of the respondents.

There were 104 secondary schools in Vihiga County as at the time this study was conducted out of which 12 school were chosen from which respondents were drawn. The study targeted 550 respondents being form three students taking biology in Secondary schools that have presented candidates for KCSE in biology for the previous four years preceding this study. Out of the 550 targeted, 505 respondents took part in the study. This gave the study a response rate of 91.81%. Creswell (2014) states that a response rate of 70% or higher is considered excellent for the purpose of generalizing findings from the sample to the complete population it was taken from.

Table 4. 1: Distribution of Respondents by Gender

Group	Male	Female	Total	Percentage
Experimental	121	130	251	49.70
Control	112	142	254	50.29
Total	**233**	**272**	**505**	**100**
Percentage	**46.13**	**53.86**	**100**	

From Table 4.1, the respondents of the study comprised of 233 (46.13%) boys and 272 (53.86%) girls. The girls were therefore slightly more than the boys in the analysed data. Of the 233 boys, 121 were in the experimental group while 112 were part of the control group. There were therefore more boys in the experimental group compared to the control group. However, the differences were minimal. Of the 272 girls, 130 were part of the experimental group while 142 were part of the control group. There were therefore more girls in the control group as compared to the number in the experimental group. However, the difference was minimal.

With regard to school type, 192 (38.01%) were from mixed schools, 171 (33.86%) from boys schools while 142 (28.12%) were from girls schools. Respondents were asked about the marks they scored in KCPE before admission to secondary school and findings revealed that 86 (17.03%) had scored below 200 in KCPE, 222 (43.96%) had scored between 200 and 299 in KCPE while 197 (39.01%) had scored more than 300 marks in KCPE. This revealed that most respondents had fairly good entry behaviour to secondary school.

Return rate for all research instruments was also established to determine whether there was any wastage of research instruments used. The results were as presented in appendix 11, indicating that all instruments used for research were collected for the analysis exercise. All the 505 questionnaires and test item tools were collected. The return rate was therefore 100%. This achievement was attributed to the trained, competent research assistants and prior sensitization of respondents by the researcher.

The completion rate for administered research instruments was also calculated as a percentage. This was achieved by calculating the percentage of items that were fully responded to in each instrument. This was done by dividing the number of fully responded items by the total number of items in each instrument and then multiplying by 100. The results, as shown in appendix 12, indicate a high completion rate, with all figures over 10%. This suggests that a minuscule and therefore inconsequential quantity of data was lost throughout the data collection process.

4.2.2 Adequacy of data

To assess the suitability of the acquired data for this research, the Kayser-Meyer-Olkin (KMO) measure of sampling adequacy was utilized. This measure provides a value that indicates the extent to which the sample is adequate for the study. According to Field (2009), as cited by Hutcheson & Sofroniou (1999), values that are higher than 0.9 are considered excellent, values between 0.8 and 0.9 are considered very good, values between 0.7 and 0.8 are considered good, and values between 0.5 and 0.7 are considered average. The study yielded a value of 0.803, indicating that the data collected for the investigation were highly satisfactory (Table 4.2).

To determine whether the correlation matrix contained any meaningful correlations or if it was an identity matrix—where all correlation coefficients would be zero—the

Bartlett's Test of Sphericity was run. Barlett's Test produced a p-value of less than 0.05 based on the given data, indicating that the data was very relevant and suitable for this specific statistical investigation.

Table 4. 2: Test for Sampling Adequacy and Data Sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	**.837**	
Bartlett's Test of Sphericity	Approx. Chi-Square	31353.495
	Df	1855
	Sig.	.000

Source: Field Data, 2021

4.3 Statistical assumptions

Requisite statistical assumptions were ascertained prior to using parametric tests herein. This was done because violation of the assumption would lead to commission of Type I or Type II errors (Field, 2009). Statistical assumptions used during inferential data analysis were assessed to avoid committing either of the errors mentioned. The study employed four parametric tests for namely: independent sample t-test, Pearson product moment correlation coefficient, ANCOVA and standard multiple linear regression. These parametric tests are predicated on several common statistical assumptions, such as homogeneity and normality. In general, there are two methods for evaluating normality. In order to identify any discrepancies, graphical tests are employed to plot empirical observations and their distribution in comparison to a theoretical distribution.

Furthermore, numerical testing may be implemented to compute the skewness and kurtosis statistics. Although numerical tests are perceived as more objective, graphical tests may be more intuitive and simpler to interpret (Namusonge, 2009). Therefore, the numerical procedure was implemented in this investigation. The Shapiro-Wilk D statistic was applied to the total factor scores in order to analyze univariate normality (Table 4.3). The responses of the study participants were combined. The statistical process evaluated whether the distribution exhibited a general deviation from the normal distribution.

Table 4. 3: Test for Normality in data distribution for the study

	Shapiro-Wilk		
Variables	**Statistic**	**Df**	**Sig.**
Cell biology achievement test II score	.893	45	.301
Student attitude questionnaire II score	.872	45	.089
Scientific skills acquisition score	.896	45	.132

a. Test statistic is normal

b. Test statistic is uniform

N =550 listwise

Source: Field Data, 2021.

The test yielded p-values that were not statistically significant, suggesting that the data followed a normal and uniform distribution. This is indicated by all significant values for variables in the test being greater than 0.05. The researcher was able to apply statistical procedures, including regression analysis, that presume normality and uniformity in data distribution due to the presence of such a normal and uniform distribution. Field (2009) argues that while examining the connections between variables, especially those involving numerous variables, it is crucial to ensure that the study data meets the criteria of normality and uniformity. This is due to the fact that one of the fundamental assumptions of regression analysis is that the data being studied follows a normal distribution.

The assumption of independence was also ascertained by the study design. Independence assumes that selection of one case should not influence the selection of another case and that behavior of one respondent does not influence the behavior of another (Field, 2009). In this study it was assumed that the data from the respondents was independent and that the behavior of one each respondent was independent from other participants' behavior. This was achieved through use of intact classes and different schools for the treatment groups, that is a school was either assigned as experimental or control group school. Therefore, none of the schools hosted both the control and treatment groups presenting no chance of particular participant belonging to both the control and experimental groups.

Homogeneity of variance within the population was also an assumption that was established before data analysis was done. Levene's test is usually used to test for the homogeneity of the variance; however according to Field, 3013, levene's test is not necessarily the best test for homogeneity of the variance. Determining the variance ratio, which is obtained by dividing the largest variance by the smallest is more reliable. The ratio should be less than 2 to indicate homogeneity. The variance ratio obtained was 1.024 which was less than 2 hence homogeneity was assumed to have been attained. With normality, independence and homogeneity established, unique assumptions for each parametric test were also determined as outlined in sections 4.3.1 to 4.3.4

4.3.1 Assumptions for independent sample t-test

Independent sample t test was used to test the first hypothesis that: there is no significant difference in student's achievement in biology when taught using the 5E instructional approach and when taught using the conventional approach. Variables used were CBAT I scores, CBATII scores, SSAT scores, SAQI and SAQII. The assumptions for the test and which were ascertained were as follows;

The dependent variable, which is the variable being studied, must be measured on a continuous scale. The data which comprised of scores in all the variables was converted to percentages making it continuous. The assumption was therefore met based on the data in use.

The independent variable must consist of two distinct groups, each having two levels. The sample comprised of 550 learners who were divided into two groups; the treatment and the control group. Each group was pretested and post tested yielding two levels of data. This assumption was therefore met.

The data must possess independence of observations. The treatment and control groups were in different schools known to the researcher and the research assistants only. Close supervision was provided by the research assistants during administration of the research data collection instruments to ensure that students in the same school gave independent responses. Each group should have a dependent variable that follows a normal or nearly normal distribution. The validity of this assumption was assessed by employing Levene's test for homogeneity of variances as earlier reported in preliminary findings. The test relies on the following assumptions: the data is continuous, the data is randomly selected from a population, and there is uniformity of variance (i.e., the variability of the data in each group is similar), the distribution is approximately normal, and the data consists of independent observations. The indicated instruments collected data that was translated into percentages, resulting in a continuous format. Therefore, the first assumption was satisfied. By implementing sampling strategies in the research design, a random sample was acquired, hence fulfilling the need of obtaining a random sample from the population. Homogeneity and linearity was ascertained through scatter diagrams. Normality was assessed by performing the Shapiro – Wilk test in preliminaries the test showed as ear lier reported. Independence of observations were realized in administration of the research tools where close supervision by research assistants was ensured.

4.3.2 Assumptions for Pearson Correlation Coefficient

There are five key assumptions for Pearson product moment correlation coefficient. These include level of measurement, related pairs, normality of variables, linearity and homoscedasticity. Reference to the first variable, each variable should be continuous. This parametric test was used to test the second hypothesis, where variables used were; cell biology achievement test II (CBAT II) as posttest, scientific skills achievement test (SSAT) and the student attitude (SAQ) assessment questionnaire II (SAAQ II). CBAT II and SSAT scores were both on continuous scale. However, scores from SAQ which were on ordinal scale were converted to percentages to yield continuous data. The assumption of related pairs is met if each participant or observation has a pair of values (Nikolic, 2012). In this study, each participant had scores for CBAT I, CBAT II, SSAT, SAQI and SAQII meeting this assumption. The assumption of related pairs was therefore met. For linearity and homoscedasticity, a scatter plot with posttest academic achievement on the y-axis and posttest student attitude questionnaire score on the x-axis was drawn. The scatter plot revealed a tube-like shape with dots on a straight line hence the assumptions of homoscedasticity and linearity were met.

4.3.3 Assumptions for analysis of covariance (ANCOVA)

ANCOVA was employed to evaluate the third hypothesis, which posits that the academic performance of students in cell biology is not substantially influenced by their scientific skills and attitude. The following instruments were employed to collect data: SSAT, CBAT II, and SAQ II. Continuous data is required for the analysis in the test (Miller & Chapman, 2011). A scale of 0 to 50 was employed to score the instruments. Consequently, the assumption was satisfied, as the data was on a quantitative ratio interval, which is continuous. Other assumptions for ANCOVA analysis include normality and linearity. The Shapiro-Wilk test was conducted to evaluate normality in the preliminary phase, and the results were consistent with those previously reported. Scatter diagrams were constructed to evaluate linearity, with posttest academic achievement plotted against posttest scientific skills and posttest attitude on distinct axis. The linear relationship between the variables was indicated by both graphs, and homogeneity was also established. Consequently, the test was conducted and the assumptions were satisfied.

4.3.4 Assumptions for standard multiple linear regression (SMLR)

SMLR was used to test the fourth hypothesis that student's scientific skills and attitude do not predict student's academic achievement in cell biology. The assumptions checked out in order to use SMLR were variable types, linearity, non-zero variance, homoscedasticity and non-perfect multicollinearity. On variable types, all predictor variables should be quantitative or categorical and the outcome variables be quantitative and continuous. This was the case for the data in use. Preliminary data screening revealed that for the data in use, normality and linearity were met. ANOVA test gave results that confirmed the fitness of regression, $F(505) = 29.596$, $p < 0.001$which was significant at 99% confidence level. (Appendix 10). Consequently, regression analysis could proceed. Non-zero variance was also met as the predictors did not have a variance of zero as confirmed by the Levene's test. Multi-collinearity was measured by variance inflation factor (VIF) and tolerance statistics (Appendix XI). According to Field (2009), a correlation statistic above 0.80 between two predictor variables indicates possible multicollinearity. He further suggests that VIF values above 10 and tolerance below 0.10 should be of concern. Variance inflation factor obtained in the study were far below 10 (0.124 and 0.058) while the

tolerance statistics were below 0.1 (0.548 and 0.3960 indicating non- perfect multicollinearity.

4.4. Descriptive Statistics

The researcher employed a pre-test post-test equivalent group design, a type of experimental research strategy that guarantees reliable results and minimizes the impact of errors. The researcher administered a pre-test to assess students' prior knowledge of cell biology concepts, and a post test to determine if there was a disparity in academic performance when students were instructed using the 5E instructional approach compared to the conventional method.

The experimental group was exposed to the 5Es educational paradigm, whereas the control group received the usual teaching style. The duration of the intervention's treatment period was six weeks. Both groups underwent six weeks of instruction using two different teaching methods: the 5Es instructional model and a conventional teaching approach. There were no interruptions during this period. After the instruction, both groups were tested to evaluate the impact of the experimental instructional model on the academic achievement of secondary school students in the subject of Biology. The findings are summarized in the following parts.

A number of descriptive measures were computed on the data obtained before and after intervention to establish trends and patterns that would help elaborate findings of quantitative data. The results were as presented in table 4.4

Table 4. 4: Means and Standard Deviations of Pretest Data

Parameter of Learning	Group	N	Mean	SD
Scientific skills	Exp	251	15.73	4.21
	Cont	254	15.18	3.88
Attitude	Exp	251	11.06	4.04
	Cont	254	11.17	5.16
Academic Achievement	Exp	251	18.96	4.79
	Cont	254	18.59	4.58

Table 4.4 indicates that the experimental and control groups had mean scores that were comparatively similar in terms of academic achievement: (experimental) 18.96, S.D.=4.79; (control) 18.59, S.D.=4.58. In the same vein, the pretest scores were analyzed with regard to attitude, and the results indicated a similarity in the scores [mean (experimental = 11.06, S.D = 4.04; mean (control) = 11.17, S.D = 5.16]. Additionally, the table indicated that the scientific skills scores followed a comparable pattern [mean (experimental) = 15.73, S.D =4.21; mean (control) = 15.18, S.D = 3.88;] The pretest scores of the experimental and control groups were similar, as indicated by the means and standard deviations in the table. It is also evident that the centers for

both groups in the three variables were low. The means did not reach the average result, which suggests that all areas under investigation performed poorly.

Table 4. 5: Means and Standard Deviations on scientific skills areas observed before intervention

Parameter of Learning	Group	N	Mean	SD
Observing	Exp	251	15.07	3.12
	Cont	254	14.55	3.16
Drawing	Exp	251	13.73	2.74
	Cont	254	13.79	3.09
Measuring	Exp	251	9.11	2.45
	Cont	254	9.02	2.33
Recording	Exp	251	10.47	2.77
	Cont	254	10.64	2.24

The experimental and control groups exhibited comparable means and standard deviations for the scientific skills that were the subject of the study, as indicated by table 4.4.2. In the case of observing, the experimental group had a mean of 15.07, S.D. =3.12, while the control group had a mean of 14.55, S.D. =3.16. Similarly, in the case of drawing, the experimental group had a mean of 13.73, S.D. =2.74, while the control group had a mean of 13.79, S.D. =3.09. Similarly, the experimental mean was 9.11 with a standard deviation of 2.45, while the control mean was 9.02 with a standard deviation of 2.33. The table also demonstrates that the mean (experimental) is 10.47 with a standard deviation of 2.77, while the mean (control) is 10.64 with a standard deviation of 2.24. This information is relevant to the recording process.

The experimental and control groups exhibited comparable performance, as indicated by the descriptive analysis of pretest data. Furthermore, the overall performance was subpar, as all of the scores were below the average.

Table 4. 6: Means and Standard Deviations of Posttest Data

Parameter of Learning	Group	N	Mean	SD
Scientific skills	Exp	251	21.57	7.11
	Cont	254	15.91	5.86
Attitude	Exp	251	18.98	4.53
	Cont	254	12.69	4.61
Academic Achievement	Exp	251	23..40	3.73
	Cont	254	18.63	3.80

Table 4.6 indicates that the experimental and control groups exhibited significant differences in their academic performance scores, with the experimental group achieving a mean of 23.40 and a standard deviation of 3.73, and the control group achieving a mean of 18.63 and a standard deviation of 3.80. In the same vein, the pretest scores were analyzed with regard to attitude, and the results indicated a similarity in the scores [mean (experimental = 18.98, S.D = 4.53; mean (control) = 12.69, S.D = 4.61]. Furthermore, the table indicated that the scientific skills scores followed a comparable pattern [mean (experimental) = 21.57, S.D = 7.11; mean (control) = 15.91, S.D = 5.86]. The pretest scores of the experimental and control groups exhibit a startling disparity, as indicated by the means and standard deviations in the table. It is also evident that the experimental group's scores were high, whereas the control group's scores were low.

From a critical analysis of tables 4.2 and 4.4, it is evident that the experimental group experienced a substantial improvement in all three dependent variables as a result of the intervention. Specifically, the mean gain for academic achievement in the experimental group was +4.44, while the mean gain for scientific skills was +5.84 and the mean gain for attitude was +0.73. It was observed that both groups exhibited a positive deviation in all areas that were measured; however, the experimental group achieved a greater "gain" than the control group in all areas.

4.5 inferential statistics

The significance of the differences observed in the descriptive analysis was determined using inferential statistics. Multiple parametric tests were conducted at a statistical significance threshold of 0.05 alpha to examine the null hypotheses generated from the study goals.

4.5.1 Results for Objective One

The first objective of this study was to determine the effect of using the 5E instructional model approach and the conventional teaching approach on students' achievement in biology. Data collected with respect to this objective involved use of cell biology achievement test I (CBAT I) as pretest, cell biology achievement test II (CBAT II) as posttest, scientific skills achievement test (SSAT) and the student attitude assessment questionnaires (SAAQ). The null hypothesis that was formulated to address this objective was:

> *HO_1: There is no significant difference in student's achievement in biology when taught using the 5E instructional approach and when taught using the conventional approach.*

Independent sample t tests were carried out to determine whether the differences in students' achievement in terms of scientific skills, attitude and academic achievement in biology was significant for the treatment and control groups. The results were as presented in tables 4.7, and 4.8

Table 4. 7: T-test results on pretest scores

Parameter of Learning	Group	N	Mean	S	SD	T	P
Scientific skills	Exp	251	15.73	1.02	4.21	1.59	0.83
	Cont	254	15.18	1.08	3.88		
Attitude	Exp	251	11.06	1.17	4.04	1.63	0.41
	Cont	254	11.17	1.12	5.16		
Academic	Exp	251	18.96	0.96	4.79	14.84	0.519
Achievement	Cont	254	18.59	1.00	4.58		

Critical t at 0.05=1.96, df = 50

Table 4.5 indicates that in the pretest scores, there was no significant difference in the academic achievement of learners with respect to cell biology concepts between the experimental and control groups; t (1.00) =14.84, p>0.05 at p<0.05. In the same vein, the table indicated that there was no statistically significant difference in the attitude of learners toward cell biology concepts between the experimental and control groups (t (1.12) =1.63, p>0.05 at p<0.05). The analysis also demonstrated that there was no significant difference in the acquisition of scientific skills between the experimental and control groups; t (1.08) = 1.59, p>0.05 at p<0.05. Nevertheless, the posttest results analysis disclosed contradictory information for all variables, as illustrated in Table 4.7.

Table 4. 8: T-test results on posttest scores

Parameter of Learning	Group	N	Mean	S	SD	T	P
Scientific skills	Exp	251	21.57	1.20	7.11	4.99	0.000
	Cont	254	15.91	1.05	5.86		
Attitude	Exp	251	18.98	1.14	4.53	4.65	0.000
	Cont	254	12.69	1.09	4.61		
Academic	Exp	251	23.40	1.03	3.73	5.37	0.000
Achievement	Cont	254	18.63	1.08	3.80		

Critical t at 0.05=1.96, df = 50

Table 4.7 reveals that there was a significant difference in posttest achievement scores in all the variables under study. With respect to academic achievement, t (1.08) = 5.37, $p < 0.05$; p value is less than the stipulated alpha indicating a significant difference; with respect to attitude, t (1.09) = 4.65, $p < 0.05$ reveals a significant difference and similarly with respect to scientific skills, t (1.05) = 4.99, $p < 0.05$.

Based on the data from tables 4.6 and 4.7, the postulated null hypothesis was rejected as the empirical evidence that arose from the data collected suggested a contrary assertion. The data therefore affirms the contrary that, there is a significant difference in student's achievement in biology when taught using the 5E instructional approach and when taught using the conventional approach.

4.5.2 Discussion of findings from the first objective

The results indicated that the 5E instructional model approach had a substantial positive impact on the academic performance of students in the field of biology. This was relevant to the acquisition of scientific abilities, the development of a positive attitude, and academic achievement. The experimental group, which was instructed using the 5E instructional model, achieved substantially higher scores on the achievement test than the control group, which was instructed using the conventional method. This is in direct opposition to the findings of the pre-test score analysis, which indicated that the two groups were statistically equivalent in terms of their academic performance. In the same vein, the experimental group demonstrated a more favourable view of cell biology concepts and achieved statistically higher scores in the scientific skills acquisition test than the control group. The researcher therefore ascribed the discrepancy in post-test test performance to the treatment administered to the experimental group.

The results are consistent with those of prior biological research. According to Akubuito (2004), the methodology of the teacher has a substantial impact on the performance of students in biology. Students who are taught effectively are more likely to achieve high levels of success, while those who are not taught well will perform inadequately. Research on teaching behavior suggests that certain teaching methods have a more positive impact on students' academic performance than others (Wenglinsky, 2000). There is a significant correlation between the academic success of students and the classroom practices of the teacher, who must establish environments in which learners are encouraged to ask questions, conduct experiments, and uncover facts and relationships (Nyongesa, 2011). Therefore, the development of scientifically literate citizens and the enhancement of performance for sustainable development are highly dependent on the quality of biology education. It provides learners with a profound conceptual comprehension.

Nevertheless, the manner in which biology and other sciences are taught in institutions presents a significant challenge. Traditional learning methods have not resulted in the anticipated level of engagement among learners in laboratory inquiry. The majority of learners are unsuccessfully served by this approach, as instructors are the sole source of information, and learners remain passive. Wood (2009) elucidates that the majority of biology instructors implement conventional cookbook laboratories that are commonly found in numerous extensive introductory lecture courses. Less comprehension of biological concepts is achieved by learners in comparison to scientific inquiry. According to Wood (2009), conventional methods are ineffective for the majority of students, who perceive biology as a collection of disconnected facts that are of little relevance to their lives and are likely to be forgotten. Learners should be involved in meaningful learning assignments that allow them to develop their own knowledge.

The study is also consistent with previous research that has demonstrated that academic achievement in science subjects is influenced by one's attitude toward a subject. Gbadamosi (2014) defines attitude as an idea or thought that is contingent upon a situation and that influences an individual's preference for or against an object. Abudu and Gbadamosi (2014) have observed that students' performance and perceptions of the subject are significantly influenced by their attitude toward the subject. Better performance in science education is contingent upon maintaining a positive attitude. Interest in the subject is stimulated by a positive attitude, which in turn leads to a sense of commitment. Academic achievement is facilitated by commitment (Osbourne, Simon & Collins, 2003). Mart (2003) and Osborne et al. (2003) contend that a positive attitude and commitment from the teacher are the only factors that can foster a positive attitude in the learner. They are enthusiastic, confident, and possess a positive attitude toward the science subject, and they teach in a variety of methods. According to research, students' academic performance is adversely affected by instructors who fail to implement the appropriate methodology and exhibit a negative attitude toward science. (Abudu & Gbadamosi, 2014). Anand (2004) demonstrated that instructors also influence student attitudes through motivation, a critical factor that impacts performance. Motivation pertains to cognitive, affective, and behavioral indicators of the learner's investment in an attachment to education. Herman Tucker and Zyco (2007) determined that science instructors are the most critical factor in enhancing student performance in educational institutions. The student's motivation and attitude are influenced by the teacher's professional skills, teaching methodology, and approach.

The majority of educators employ teacher-centered methodologies that fail to inspire students. Consequently, students have developed a negative attitude toward science subjects, which has contributed to their subpar performance. The 5E instructional approach has been shown to have a positive effect on learners' attitude toward science subjects. (Lebata, 2014). This suggests that students who were instructed using the 5E model exhibited a more optimistic perspective toward the biology subject than those who were instructed using the traditional method. The results of this study were compared to those from studies that examined the extent to which students' scientific skills and attitude interact to influence their academic achievement in biology when educated using the 5E instructional approach and the conventional approach. There was substantial corroboration. Wood (2009) posited that the development of scientifically literate citizens and the enhancement of performance for sustainable development are both contingent upon the quality of biology instruction. It provides learners with a profound conceptual comprehension. Wood (2009) elucidates that the majority of biology instructors implement conventional cookbook laboratories that are commonly found in numerous extensive introductory lecture courses. Less comprehension of biological concepts is achieved by learners in comparison to scientific inquiry.

According to Wood (2009), conventional methods are ineffective for the majority of students, who perceive biology as a collection of disconnected facts that are of little relevance to their lives and are likely to be forgottenAkiri and Nkechi (2009) argue that the reason for the decline in education standards and low performance can be ascribed to instructors' inefficient contact with students in the classroom. Senan (2013) asserts that the technology-enhanced 5E learning paradigm is a highly successful tool for students and teachers to develop 21st century abilities and teach specific concepts. During his examination of the 5E learning model. In a distinct study, Prokes (2009) noted that the students in this particular model had higher levels of activity and motivation compared to those in a classroom that relied on lectures. Moreover, these students demonstrated the ability to recognize and seize opportunities to disseminate their expertise and personal experiences. The research undertaken by Acish and Turgut (2011) and Aksoy and Gurbuz (2013) demonstrates that 5E is an essential framework for dispelling myths. It allows students to recognize misunderstandings, eliminate them through direct experience, and evaluate themselves.

4.5.3 Results for objective two

The second objective of the study sought to determine if there was a correlation between students' scientific skills, attitude and academic achievement in biology when taught using 5E instructional approach as compared to when taught using the conventional approach. Data collected with respect to this objective involved use of cell biology achievement test II (CBAT II) as posttest, scientific skills achievement test (SSAT) and the student attitude assessment questionnaire II (SAAQ II).

The null hypothesis that was formulated to address this objective was:

> $HO_{2:}$ *there is no significant correlation between student's attitude, scientific skills and their academic achievement when taught using the 5E instructional approach and when taught using the conventional approach*

To address this hypothesis, Pearson's product moment correlation coefficients were determined. The correlations were used to determine the relationships between the dependent and the independent variables. Correlations are further used to determine the direction and strength of the relationship (LeBreton et al., 2004). Analysis of student's **scientific skills and academic achievement realized the data shown in Table 4.9.**

Table 4. 9: Pearson Correlations for students' scientific skills and academic achievement in biology

		Scientific Skills	**Academic Achievement**
Scientific Skills	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	504	
Academic Achievement	Pearson Correlation	.624**	1
	Sig. (2-tailed)	.000	
	N	504	504

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Research Data (2022)

A correlation coefficient statistic that describes the degree of linear association between scientific skills and academic achievement was computed. Study findings revealed that scientific skills had a strong positive correlation with academic achievement for students in biology subject (r=0.624; P<0.05). The positive corelation implies that high scientific skills score translates to a high achievement score and vice-versa.

Table 4. 10: Pearson Correlations for Students Attitudes and academic achievement in biology

		Attitude	Academic Achievement
Attitude	Pearson Correlation	1	
	Sig. (2-tailed)		
	N	505	
Academic Achievement	Pearson Correlation	.563**	1
	Sig. (2-tailed)	.000	
	N	505	505

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Research Data (2022)

A correlation coefficient statistic that describes the degree of linear association between students' attitude and academic achievement was computed. Study findings revealed that students' attitude had a positive correlation with academic achievement for students in cell biology concepts (r=0.563; P<0.05). this implied that a student with a positive attitude had higher achievement in academic achievement in cell biology. Findings from both tables a contrary assertion to the second null hypothesis. The second hypothesis was therefore rejected because the empirical evidence from data collected data suggested otherwise. It can therefore be asserted that there is a strong positive association between students' acquisition of scientific skills and academic achievement in biology Similarly, there is a positive association between students' attitude and academic achievement in biology.

4.5.4 Discussion of findings of objective two

It was determined that the academic achievement of cell biology concepts among secondary school students in Vihiga County was significantly positively correlated with the acquisition of scientific skills. Also, the learners discovered that their attitude was positively correlated with their academic performance in cell biology concepts. Contrary to the second null hypothesis, the associations were statistically significant at the 0.05 alpha level in both instances. The association's direction suggested that the acquisition of scientific skills and a positive attitude would result in high achievement in cell biology and, as a result, in biology as a subject.

The results of this study are consistent with those of prior research on the relationship between academic achievement and the acquisition of scientific abilities. Abudu and Gbadamosi (2014) discovered that the acquisition of scientific skills is a critical factor that influences students' performance and ideas regarding the subject. In the field of science education, only a positive attitude leads to improved performance. Interest in the subject is stimulated by a positive attitude, which in turn leads to a sense of commitment. Academic achievement is facilitated by commitment (Osbourne, Simon & Collins, 2003).

This result is further corroborated by the findings of the study conducted by Mart (2003) and Osborne et al. (2003), which established that only a teacher with a positive attitude and commitment can help foster a positive attitude in the learner. They are enthusiastic, confident, and possess a positive attitude toward the science subject, and they teach in a variety of methods. Research has shown that students' academic performance is negatively impacted by instructors who do not employ the appropriate approach and have a negative attitude toward science (Abudu & Gbadamosi, 2014).

Teachers also have an impact on student attitudes by teaching them the skills necessary to acquire science, which is a critical factor that affects performance. Technologists also provide motivation regarding cognitive, emotional, and behavioral indicators of learners' investment in an attachment to education (Anand, 2004). It is imperative that learners are inspired to achieve success. For certain researchers, motivation is the sole factor that directly influences academic achievement; all other factors only influence achievement through the influence of motivation (Herman Tucker & Zyco 2007). Science teachers have been identified as the most critical factor in enhancing student achievement in institutions, according to Ballore Dura (Zerniak and Haney (2005). The student's motivation and attitude are influenced by the teacher's professional skills, teaching methodology, and approach. The majority of educators employ teacher-centered methodologies that fail to inspire students. Consequently, students have developed a negative attitude toward science subjects, which has contributed to their subpar performance. It is anticipated that the 5E instructional approach will reverse this trend.

4.5.5 Results for objective three

The third objective sought to investigate the Extent to which students' scientific skills and attitude interact to influence their academic achievement in biology when taught using 5E instructional approach or the conventional approach.

The null hypothesis formulated to explore this objective was:

> *$HO_{3:}$ students' attitude and scientific skills do not significantly interact to influence student's academic achievement in biology when taught using either the 5E instructional model approach or the conventional approach*

Student Scientific skills and student attitude were measured using scientific skills acquisition test (SSAT) and the students attitude questionnaire II (SAQII) respectively. In order to use analysis of covariance (ANCOVA), achievement in the two constructs was set at three arbitrary levels; “good”, “fair” and “poor”. This generated ordinal data applicable for ANCOVA. The levels of student academic achievement constituted the dependent variable while the levels of student scientific skills acquisition and level of student attitude constituted the independent variables. Academic achievement score from the cell biology achievement test I (CBATI) was used as a covariate. ANCOVA was then used to evaluate the interactive effect of the two constructs on the level of academic achievement.

An ANCOVA test was run to explore the interactive effects of the two constructs; to assess the main effects of the levels of scientific skills and attitude to affect academic achievement. The results were as presented in the table 4.11

Table 4. 11: Interactive effects of student scientific skills and attitude

Source	DF	F.	p
Pretest achievement	**1**	**0.013**	**0.874**
Posttest SSSAL	**2**	**3.050**	**0.035**
Posttest SAL	**2**	**2.726**	**0.049**
SSSL*SAL	**3**	**0.928**	**0.345**

R^2=.302 (Adjusted R^2 = .276), * interaction

From table 4.17, an ANCOVA (between subjects factor: posttest achievement, covariate: pretest achievement) revealed the main effects of level of student scientific skills was significant (F(2, 505)=3.050 , P = .035) while the level of student attitude was marginally significant ($F(2, 505) = 2.726$, $P = .049$). This implied that students with high levels of scientific skills may perform well in cell biology concepts regardless of their attitude. Interaction between levels of scientific skills and attitude gave ($F(3, 505) = .928$, $p = .345$) which was non-significant. The results suggested that the two constructs do not interact to influence academic achievement. Students may therefore perform well regardless of their attitude provided the scientific skills are acquired. The null hypothesis was therefore affirmed; scientific skills and attitude do not interact to influence academic achievement in cell biology concepts.

4.5.6 Discussion of findings for the third hypothesis

The data collected for the third hypothesis indicated that the academic achievement of students in biology is not influenced by the interaction between their attitude and the level of scientific skills acquisition. This was demonstrated by the p-value for the interaction exceeding the predetermined alpha level of 0.05.

The findings of this study are consistent with those of previous research on the impact of instructional methods on students' academic performance. Duran (2004) posits that the 5E learning model is beneficial and advantageous to educators because it offers an illustration of the structural list approach's implementation in course processing and offers effective reform-based instruction. Additionally, he asserted that the paradigm could be beneficial in the curriculum's development. Senan's (2013) study found that the technology-enhanced 5E learning model is a valuable tool for students and teachers to acquire 21st century abilities and effectively teach a specific idea. Prokes (2009) found that students in classrooms utilizing the 5E learning paradigm had higher levels of engagement and motivation compared to students in lecture-based classrooms. In addition, these students were able to establish connections between their existing knowledge and experiences and those of others. The 5E model is an important approach for addressing misunderstandings in education. It allows students to recognize misconceptions, eliminate them through hands-on experience, and evaluate their own understanding (Aksoy & Gurbuz, 2013; Acish & Turgut, 2011).

The study conducted by Akubuito (2004) also established that the methodology of the teacher has a substantial impact on the performance of students in biology. Students who are taught effectively are more likely to achieve excellent results, while those who are not taught well will perform poorly. Research on teaching behavior suggests that certain teaching methods have a more positive impact on students' academic performance than others (Wenglinsky, 2000). Students' attitudes toward a subject are significantly correlated with the methodologies of instruction. The teacher's classroom practices must establish an environment in which students are encouraged to pose questions, conduct experiments, and uncover facts and relationships (Nyongesa, 2011). Therefore, it is imperative to provide quality instruction in Biology in order to cultivate the appropriate attitude and mentality among students, thereby enhancing their performance in the context of sustainable development.

4.5.7 Results for objective four

The fourth objective of the study sought to investigate the extent to which students' scientific skills and attitude could predict academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach. From this objective a null hypothesis was formulated as follows:

HO_4: *student's scientific skills and attitude do not predict student's academic achievement in biology when taught using the 5E instructional model approach and the conventional approach*

To address this objective and test the hypothesis, study data was subjected to Standard Multiple Linear Regression (SMLR) analysis. Data used to test this objective were collected by use of cell biology achievement test II (CBATII), student's attitude questionnaire II (SAQII) and scientific skills achievement teas (SSSAT).

A standard multiple linear regression (SMLR) was performed on the data collected to determine whether students' acquisition of scientific skills and attitude could predict their achievement in cell biology.

The 'enter' method was utilized to 'forces' the predictors in the regression model all at once. The results were as presented in table 4.12

Table 4. 12: Model I: Standard multiple linear Regression analysis

Model	R	R^2	Adjusted R^2	R^2 change	F Change	Sig. (2-tailed)	Durbin-Watson
1	.323	.279	.264	.279	39.742	.000	1.771

Dependent variable: Academic achievement

Predictors: student scientific skills, student attitude

The results presented in model 1 reveal a coefficient of determination (adjusted R^2) of o.264; which indicates the proportion of variance in the dependent variable that can be explained by the independent variables. The implication was that the independent variables accounted for 26.4 % of the variance in academic achievement in cell biology. The model further showed that the independent variables (student scientific skills and student attitude) are statistically significant predictors of the level of academic achievement, [F (2, 550) = 39.742, p < 0.05]. The model therefore revealed that 73.6 % of the variance in cell biology academic achievement could be predicted by factors other than scientific skills acquisition and students attitude.

In subsequent analysis, one of the predictors was removed from the model to assess the effect on the regression model. The eventual analysis results for the regression coefficient were as presented in table 4.13.

Table 4. 13: Model II: Standard Multiple Linear Regression Analysis

Model	B	T	P
Constant	32.01	8.420	0.000
Scientific skills	.368	2.024	0.000
attitude	0.242	3.486	0.001

Table 4.13 reveals that student scientific skills significantly predicted their achievement score in cell biology [ß = 0.368, t (505) = 2.024, p<0.05]. Similarly, student attitude score significantly predicted their academic achievement [ß =0.242, t (505) = 3.486, p < .05]. Further analysis of the regression model coefficients shows that there is a positive beta co-efficient of 0.368 for student's scientific skills with a p-value = 0.000 which is less than 0.05 and a positive beta co-efficient of 0.242 for students' attitude with a p value less than 0.05. Therefore, students' scientific skills and attitude had a significant contribution to the model for student academic achievement in cell biology concepts among form three students in secondary schools in Vihiga County. Considering the constant term, the model revealed that it scientific skills and student attitude explained

a significant amount of the variance in the values of the posttest achievement score obtained [ß = 32.01, t (505) = 8.420, p < .05]. from the SMLR analysis a regression equation was formulated as follows:

Achievement score = 32.01 + 0.368 (scientific skills score) + 0.242(student attitude score)

The findings therefore contradict the fourth null hypothesis as earlier stated. The fourth hypothesis was therefore rejected and the alternative hypothesis affirmed. Student's scientific skills and attitude do predict student's academic achievement in biology

4.5.8 Discussion of findings from objective 4

The regression analysis results indicated that the student attitude score and the student scientific abilities score are substantial predictors of academic achievement. The equation that was developed can be represented as follows:

SAA = 32.01 + 0.368(SSS) + 0.242(SAS) where SAA denotes the student academic achievement score, SSS denotes the student scientific abilities score, and SAS denotes the student attitude score. In the model, the student scientific score predicted up to 36.8% of the variance in student academic score, while the student attitude score predicted up to 24.2%.

The findings regarding the function of students' scientific skills in academic achievement in biology were compared to those from previous studies on the same subject area, and significant similarities were identified. Classroom administration and instructional practices are among the primary factors that contribute to subpar performance in science subjects, as per Njuguna (2003). According to Akubuito (2004), the methodology of the teacher has a substantial impact on the performance of students in biology. Students who possess effective scientific skills are more likely to achieve positive results, while those who lack these skills will perform inadequately. Ineffective pedagogy that is teacher-centered, a lack of motivation, a poor attitude, inadequate infrastructural facilities, the attitude of students, a lack of scientific skills by students, a lack of competences by science teachers, and a lack of professional development for science teachers are among the numerous factors that have been identified as contributing to poor performance in science subjects (Braimoh & Okadey, 2001; Olaleye, 2002). The results of this study are consistent with those of prior research on the influence of students' attitudes on academic performance. One example is the results of a study conducted by Abudu and Gbadamosi (2014). Therefore, who established that students' performance and perceptions of the subject are significantly influenced by their attitude toward science? The only way to achieve superior performance in science education was to maintain a positive attitude. This argument is also supported by the results of a study conducted by Osbourne, Simon, and Collins (2003), that a positive attitude fosters interest in the subject matter, which in turn leads to commitment. In turn, academic achievement is the result of commitment to learning. The learner's positive attitude is significantly influenced by the teacher.

Mart 2003, Osborne et al. (2003) contend that a positive attitude and commitment from the teacher are the only factors that can facilitate the development of a positive attitude in the learner, as evidenced by the results of their study. They are enthusiastic, confident, and possess a positive attitude toward the science subject, and they teach in a variety of methods. Research suggests that students' academic performance is negatively impacted by instructors who fail to employ the appropriate methodology and maintain a negative attitude toward science.

4.6 Qualitative Findings

Focus group interviews were conducted immediately after the administration of the SAQII to collaborate the findings from quantitative data. Some students in the experimental group interviewed expresses high levels of attitude and confidence to excel in the test. Transcripts from three randomly picked participants supported this as they had the following scores: ETQIS 1 had 45/50, ETQIS 2 had 41/50 while ETQIS had 37/50. Their attitude scores were respectively 94, 91 and 88 expressed as percentages. The students also had this to say;

ETQIS 1 *"I understood the topic much better than topics earlier taught. All students even those who never talk in class were active. Am sure I will score all the test items well because the questions were set directly from what we. Learned."*

ETQIS 2 *"our teacher taught us reproduction differently and we all enjoyed the lessons. He gave us time to think on our own in groups and that enabled us understand the content well. Most learners were active and happy. I will score highly in the test. The questions were ok. I hope our teacher will continue teaching us in the same way."*

ETQIS 3 "*Reproduction lessons were enjoyable. We were all engaged and interacted with one another well as we learned. The teacher was mainly guiding us and we took the active role through discussions. We were able to relate all aspects in the lessons with real life experiences. The method the teacher used made everything to be realistic unlike when we keep on listening as the* *teacher teaches. I understood and I know that I have passed the test. Our teacher should continue using this method to enable all students to participate."*

The interview responses and score of sampled students from the experimental group clearly indicated that the 5E instructional model is an active, learner centered method that allowed learners to be active recipients of knowledge. The responses also indicated a positive attitude by the students who considered the lessons as enjoyable with teachers considered as facilitators of learning. The approach gave students confidence on test performance.

A similar number of students in the control group interviewed expressed doubt in handling the test items. Transcripts from three randomly picked participants supported this as they had the following scores: CTQIS 1 had 18/50, CTQIS 2 had 19/50 while CTQIS had 21/50. Their attitude scores were respectively 40, 36and 42expressed as percentages. The students also had this to say;

CTQIS 1 *"Reproduction is the topic I was eager to learn though it became complicated with the cell division parts. There was a lot of confusion between types and stages. The teacher was very fast in teaching tough he gave us all the notes. I did not understand the difference well. The questions in the test were also confusing though I will not fail all of them. "*

CTQIS 2 *"The topic of reproduction was complicated by the cell division part. It was confusing especially when it came to the stages of mitosis and meiosis. The teacher was also confused! The test was* *normal; however, biology exams are unpredictable. Sometimes marking is so strict."*

CTQIS 3 *"Reproduction lessons were boring especially the parts of cell division. The teacher was very fast and most of the students were sleeping. The exam was a bit challenging with most questions concentrated on cell division. We were also not given enough time to prepare for the exam because some questions required cramming. Some questions were difficult."*

The interview responses and score of sampled students from the control group clearly indicated that the conventional approach is teacher centered with most students being passive recipients of knowledge. The responses also indicated a negative attitude by the students towards cell concepts and biology as a subject. they considered the lessons as boring, abstract and therefore not easy to understand. Teachers were considered as owners of knowledge. The approach left students with little confidence on test performance.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of major findings of the study, conclusions and recommendations based on the findings regarding the effect of the 5E instructional model approach of learning on students' achievement in cell biology concepts among secondary school biology students in Vihiga County. Implications and suggestions for further research are also highlighted.

5.2 Summary of the Study

This study was compelled by the concerns about the observed decline in student achievement in science education specifically biology globally and in Kenya. The desire to bring about a positive change in students' performance through novel instruction approaches drove the researcher into the study. The purpose of the study was to determine whether the 5E instructional model approach of learning was more effective on students' achievement in cell biology concepts than the conventional approach among secondary school biology students in Vihiga County, Kenya. Three learning constructs were studied, namely, academic achievement, scientific skills, and attitude. Four scientific skills were observed in the study; observing, drawing, recording and measuring.

Four objectives were developed to guide the study. these were; (i) to determine the effect of using the 5E instructional model approach on students' achievement in biology, (ii) to determine if there is a correlation between students' scientific skills, attitude and academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach, (iii) to determine the extent to which students' scientific skills and attitude interact to influence their academic achievement in biology when taught using 5E instructional approach and the conventional approach and (iv) to establish the extent to which students' scientific skills and attitude could predict academic achievement in biology when taught using 5E instructional approach and when taught using the conventional approach.

From the aforementioned objectives, four null hypotheses were formulated and tested at $\alpha = 0.05$ level of statistical significance. The hypotheses were:

HO_1: There is no significant difference in student's achievement in biology when taught using the 5E instructional approach or when taught using the conventional approach.

HO_2: There is no significant correlation between students' attitude, scientific skills and their academic achievement when taught using the 5Einstructional approach and when taught using the conventional approach.

HO_3: Students' attitude and scientific skills do not significantly interact to influence student's academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

HO_4: Students' scientific skills and attitude do not predict students' academic achievement in biology when taught using the 5E instructional model approach and the conventional approach.

The study was anchored on constructivist theory to learning, which suggests that people construct knowledge and meaning from experience. The theory advocates for inquiry learning that supports teachers to facilitate students in reconstructing their own knowledge through a process of interacting with objects in the environment and engaging in higher thinking and problem solving

Constructivism has its roots in the works of three psychologists; Jean Piaget and John Dewey, on childhood development and education, and Lev Vygotsky's work on social aspects of learning through experience. The study employed a mixed methods research design to collect quantitative and qualitative data. Quasi experimental design forming the main part of the design and yielded quantitative data while focus group interview was used to provide qualitative data that was used to compliment the quantitative data. a sample of 550 students and 12 teachers was selected by multistage sampling technique that involved Purposive sampling, Stratified sampling and simple random sampling. research instruments used for data collection were; Cell Biology Achievement Test 1 (CBAT1), Cell Biology Achievement Test 1I (CBAT II), Student Attitude Questionnaire I (SAQ I), Student Attitude Questionnaire II (SAQII), Scientific Skills Acquisition Test (SSAT) and Focus Group Interviews (FGI) Guide. The independent variables consist of instructional approaches used in teaching of the selected biology concepts. They include the conventional approach and the 5E instructional model approach. The dependent variables consist of academic achievement, attitude and acquisition of scientific skills. The intervening variables comprise of gender and sshool type.

The study was piloted in two schools within vihiga county two weeks to the actual study. Data from the pilot study was used to assess validity and reliability of the research instruments. The reliability of the research instruments was determined using Cronbach's alpha coefficients. The reliability analyses for the instruments used in the study surpassed the minimum acceptable reliability coefficient as follows; CBAT1: r=0.826, CBAT2: r=0.818, (SAQI: r= 0.785, SAQII: r=0.792, SSST: r=0.875. The validity of the research instruments was determined through rating. The instruments were awarded the following average percentage score respectively; CBAT1 (78%), CBAT2 (76%), SAQ1 (80), SAQII (79), SSST (82%). All scores were above the minimum recommended score of 60% for educational researches (Kahn & Best, 1998).

Descriptive and inferential analyses were carried out. Independent sample t test, Pearson Product Moment Correlation Coefficient, ANCOVA and multiple linear regression analyses were conducted to test the null hypotheses.

5.3 Summary of Findings

Four main findings of the study based on the objectives that guided the study were:

1) There was a statistically significant difference in student's achievement in all learning outcomes in cell biology when taught using the 5E instructional approach as compared to when taught using the conventional approach.

2) There is a strong positive association between students' acquisition of scientific skills and academic achievement in cell biology. Similarly, there is a positive association between students' attitude and academic achievement in cell biology

3) Scientific skills and attitude do not interact to influence academic achievement in cell biology concepts.

4) student's scientific skills and attitude do predict student's academic achievement in cell biology

5.4 Conclusions from the main research findings

Based on the empirical evidence arising the data collected, four main conclusions were made as follows:

1) The 5E instructional model approach is more effective in teaching of cell biology concepts. It enables students to attain higher scores in achievement tests, acquire important scientific skills to higher levels and develop a positive attitude towards learning of cell biology concepts.

2) Students' acquisition of scientific skills has a strong positive correlation with academic achievement in cell biology. A student who acquires a high level of basic scientific skills is likely to perform better in academic achievement in cell biology concepts. Similarly, there is a positive association between students' attitude and academic achievement in cell biology. A student with a positive attitude towards cell biology concepts would score higher in cell biology achievement test.

3) Students' scientific skills and attitude do not interact to influence their academic achievement in cell biology. Each variable associates with academic achievement independently.

4) Students' scientific skills and attitude are statistically significant predictors of academic achievement in cell biology

5.5 Overall Conclusion of the Study

From the research findings herein, it can be concluded that use the 5E instructional model approach of learning results in increased students' achievement in cell biology concepts among secondary school biology students as compared to the conventional teaching and learning approaches. Additionally, acquisition of scientific skills and development of a positive attitude significantly improves academic achievement of students.

The model for students' excellent academic achievement in of biology would therefore involve use of 5Einstructional model approach, acquisition if scientific skills and development of a positive attitude as presented in figure 5.1.

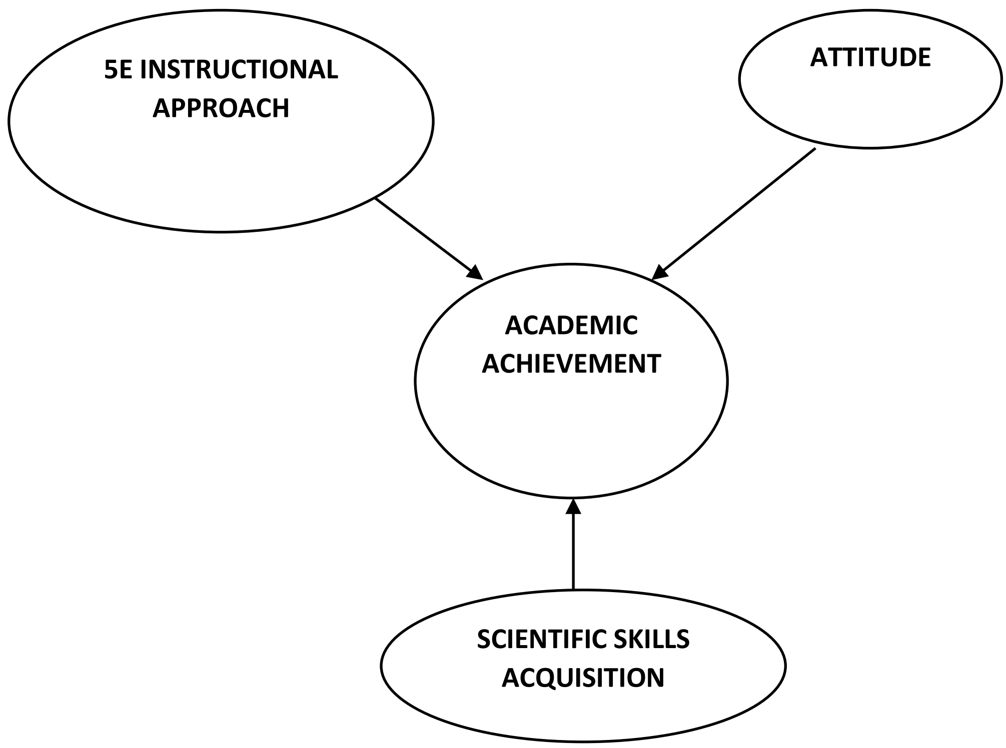

Fig. 5.1 Model: ***excellence in academic achievement***

5.6 Recommendations

According to the study's findings and conclusions, the following recommendations are made:

Biology teachers seeking to enhance their students' learning achievement need to employ innovative active teaching approaches, such as the 5E instructional model, which has been acclaimed for its positive impact on students' learning outcomes. 5E is effective compared to the traditional lecture method because it allows students to be actively involved, motivates them and is sensitive to differentiated learning typical of Kenyan classes. This is especially applicable in the competency-based curriculum that demand learners' discovery of knowledge with teacher facilitation.

Teacher educator institutions need to adopt the use of 5E model and infuse it in the teacher education curriculum as a learning strategy under active learning. Teachers leaving such institutions would be competent in use of the model to facilitate learning as required by the competency-based curriculum. This would improve interest, create a positive attitude in the learner leading to improved performance.

Policy makers should embrace and facilitate adoption of 5E instructional model approach for quality learning. 5E is an activity oriented instructional model that may require resources of all categories; improvised, commercial and locally available. These may require additional cost by learning institutions however utilization of these resources would ensure active engagement that may lead to development of scientific skills. Development of scientific skills would enhance academic achievement leading to experts in key fields of development.

5.7 Suggestions for Further Research

The present study sought to investigate the effect of the 5E instructional model approach of learning on students' achievement in cell biology concepts among secondary school biology students.

i. Another study may be conducted on the effect of 5E instructional model approach of learning on students' achievement in other subjects and findings compared to those of this study. This will create more knowledge and widen the scope of understanding of the application of 5E instructional model and its effect on learning outcomes generally.
ii. This study was conducted in Vihiga County within the Republic of Kenya. A similar study may be conducted in other counties to examine the effect of the 5E instructional model on learning outcomes. This will facilitate generalization of findings beyond the study area.
iii. This study found that the 5E instructional model was superior to the conventional learning approach for Biology students. Another study needs to be conducted to investigate the flaws in the conventional instructional approach that cause challenges to students' learning outcomes and corrective measures implemented.

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APPENDICES

APPENDIX 1: CELL BIOLOGY ACHIEVEMENT TEST I (CBAT I)

FORM 3.

TOPIC: THE CELL AND CELL PHYSIOLOGY (50 Marks)

Time: 1hour **Date…………………**

PART A: STUDENT BIODATA

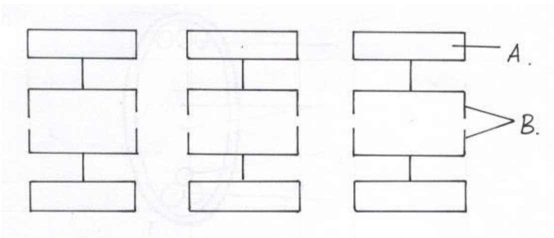
Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

PART B: THE QUESTIONS

Answer all the questions in this section in the spaces provided

1. The diagram below represents an organelle of a cell



a) Identify the organell (1mk)

………………………………………………………………………………………

b) Name the parts labeled A and B (2 mks)

A…………………………………………..B…………………………………………

c) State **two** functions of the above structure (2 mks)

…………………………………………………………………………………………

…………………………………………………………………………………………

……

2. Give an appropriate term or phrase to the following descriptions of cell structures:

a) A structure within a cell, bound by a membrane and having a particular function in the cell

(1 mk)

……………………………………………………………………………………

b) A folding of the inner membrane of a mitochondrion (1 mk)

…………………………………………………………………………………………

……………………………………………………

c) Modification of a cell structure to perform a particular function (1 mk)

....

.....

3. The diameter of a diagram of a cell was found to be 5cm. The magnification of the eye piece lens of the microscope used to view the cell was X10 while that of its objective lens was X40. What was the actual size of the cell in microns? Show your working

(4 mks)

4. What is a cell?

……………………………………………………………………………(1mk)

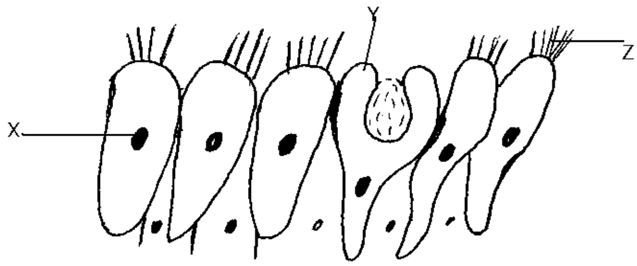
5. Differentiate between diffusion and active transport

(2mks)

……………………………………………………………………………………………

…………………………………………………………………….

6a) The diagram below represents specialized cells of a certain tissue



i) Identify the cells (1 mk)

……………………………………………………………………………………………

ii) Name **two** structures in the human body where the cells are found (2 mks)

i)…………………………………..ii)……………………………………………

b) How are the following cells modified to their function (4mks)

i) Sperm cells

…………………………………………………………………………………………

…………………………………………………………………………………………

……

ii) Palisade cells

…………………………………………………………………………………………

…………………………………………………………………………………………

……

7a) Name **two** structures that are found in plant cells but absent in animal cells

(2mks)

i)……………………………………………….

ii)………………………………………………

b) Explain what happens to an animal cell placed in distilled water

(3mks)

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………..

8. In the space provided below, draw a large and well-labeled diagram of a typical plant cell as seen under a light microscope

(5 mks)

9. a) Name the organelles that perform the following functions:

i) Synthesis of RNA (1mk)

………………………………………………………………………………………….

ii) Formation of spindle fibres (1mk)

…………………………………………………………………………………………

iii) Synthesis of lysosomes (1mk)

………………………………………………………………………………………….

iv) Packaging of synthesized glycoproteins (1mk)

……………………………………………………………………………………………
.

10. a) What is the name given to the circular space in a light microscope in which the image of the specimen is observed? (1 mk)

……………………………………………………………………………………………
………

b) Briefly describe how you would estimate the diameter of the space

(3mks)

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11.Why are lysosomes sometimes referred to as ‘suicide bags’? (2 mks)

…………………………………………………………………………………………

…………………………………………………………………………………………

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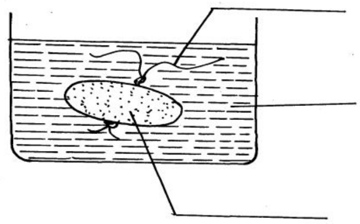
12. In an investigation, raw banana was pealed, mashed into a paste and was treated as shown below



Name the physiological process being investigated (1 mk)

…………………………………………………………………………………………

b) State the expected colour of the iodine solution inside and outside the visking tubing after 30 minutes (2 mks)

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
…………

c) Explain the observation made in (b) above (3 mks)

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
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……………

d) State three factors that affect that process named in (a) above

(3mks)

…………………………………………………………………………………………………

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APPENDIX 2: MARKING SCHEME: (CBAT I)

FORM 3.

TOPIC: THE CELL AND CELL PHYSIOLOGY (50 Marks)

Time: 1hour **Date…………………**

PART A: STUDENT BIODATA

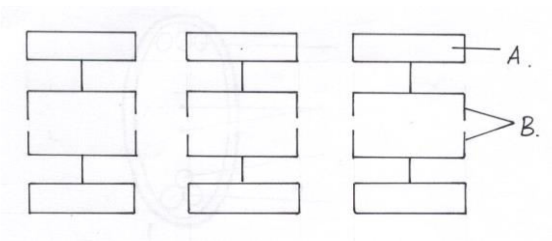
Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

PART B: THE QUESTIONS

Answer all the questions in this section in the spaces provided

1. The diagram below represents an organelle of a cell



a) Identify the organelle (1 mk)

cell membrane

b) Name the parts labeled A and B (2 mks)

A protein layer B phospholipid layer

c) State **two** functions of the above structure (2 mks)

- Allow selective movement of substances into and out of the cell
- Encloses cell organelles

2. Give an appropriate term or phrase to the following descriptions of cell structures:

a) A structure within a cell, bound by a membrane and having a particular function in the cell (1 mk)

Organelle

b) A folding of the inner membrane of a mitochondrion (1 mk)

Cristae

c) Modification of a cell structure to perform a particular function (1 mk)

Cell specialization

3. The diameter of the field of view of a microscope was estimated to be 50 mm under a certain magnification. four cells were observed along the diameter of the field of view. What was the **actual** diameter of one cell in microns (μm) if the total magnification of the microscope was X500? Show your working (4 mks)

i) Diameter of field of view = 50 mm X 1000 = 50000µm;

Size of one cell = Diameter of field of view / Number of cells;

= 50000 µm / 4 = 12500 µm;

Actual diameter = diameter of image/magnification

= 12500/500 = 25 µm

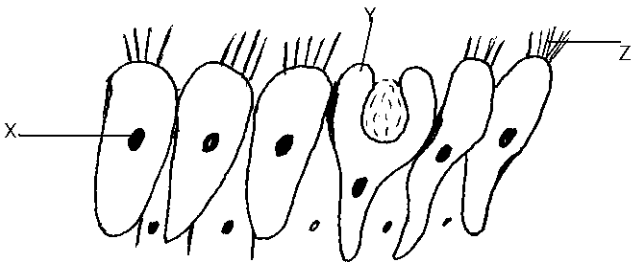
4. What is a cell? (1mk)

The basic structural and functional unit of a living organism

5. Differentiate between diffusion and active transport (2mks)

Diffusion	Active transport
Molecules/particals move along a concentration gradient	Molecules/particals move against a concentration gradient
Energy is not required	Energy is required

6. The diagram below represents specialized cells of a certain tissue



i) Identify the cells

(1 mk)

Ciliated epithelial cells

ii) Name **two** structures in the human body where the cells are found (2 mks)

i) Nasal cavity, ii) Trachea, also accept oviduct

b) How are the following cells modified to their function

(4mks)

i) Sperm cells

Head has a large nucleus to carry genetic material

Head has an acrosome with lytic enzymes to digest ovum wall

Long tail that propels it forward

Many mitochondria in neck region to provide energy for movement

ii) Palisade cells

Numerous chloroplasts to trap maximum amount of light for photosynthesis

Elongated to increase surface area for packaging of more chloroplasts

Located beneath upper epidermis to trap light directly from the sun

7. Name **two** structures that are found in plant cells but absent in animal cells (2 mks)

i) Chloroplasts ii) cell wall, also accept tonoplast

b) Explain what happens to an animal cell placed in distilled water (3mks)

The cell draws in water through the semi permeable membrane by osmosis;

It then swells due to increased content; and eventually burst, a process called lysis;

8. In the space provided below, draw a large and well-labeled diagram of a typical plant cell as seen under a light microscope (5 mks)

9. a) Name the organelles that perform the following functions:

i) Synthesis of RNA…………………………………………….Nucleolus (1 mk)

ii) Formation of spindle fibres……………………………..Centrioles (1 mk)

iii) Synthesis of lysosomes………………………………… Golgi bodies/apparatus (1 mk)

iv) Packaging of synthesized glycoproteins………..Golgi apparatus (1 mk)

10. What is the name given to the circular space in a light microscope in which the image of the specimen is observed? (1 mk)

Field of View

b) Briefly describe how you would estimate the diameter of the space (3mks)

Place a transparent ruler on the stage such that the mm marks run across the diameter;

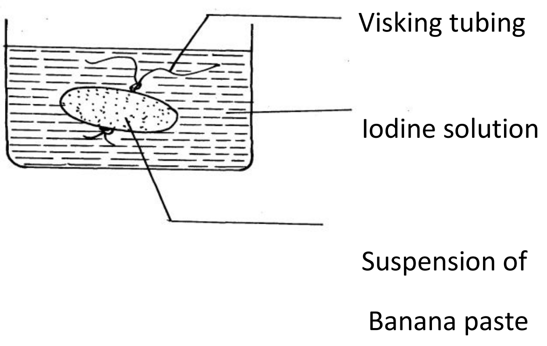
Count the spaces between the mm marks observed across the spaces/field of view;

Convert the number of spaces to micrometers by multiplying by 1000 to get the diameter in micrometers;

11. Briefly explain why lysosomes are sometimes referred to as 'suicide bags' (2 mks)

They contain lytic enzymes capable of destroying the cell that contains them

12. In an investigation, raw banana was pealed, mashed into a paste and was treated as shown below



a) Name the physiological process being investigated (1 mk)

Diffusion

b) State the expected colour of the content inside and outside the visking tubing after 30 minutes (2 mks)

Inside Colour turns blue black

Outside Brown colour of iodine is retained

c) Explain the observation made in (b) above (3 mks

Iodine molecules moved into the visking tubing reacted with the starch in the banana suspension to form the blue black colour; The starch molecules in the banana suspension were large; and could not pass through the visking tubing thus the colour of the iodine solution remained brown outside the visking tubing;

d) State three factors that affect that process named in (a)above (3mks)

Temperature; size of particles;

APPENDIX 3: CELL BIOLOGY ACHIEVEMENT TEST II (CBAT II)

FORM 3.

TOPIC: REPRODUCTION (50 Marks)

Time: 1hour **Date…………………**

PART A: STUDENT BIODATA

Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

PART B: THE QUESTIONS

Answer all the questions in this section in the spaces provided

1. State the role of the following structures in a cell

a) Centrioles

(2mks)

…………………………………………………………………………………

…………...

....

b) Chromosomes

(1mk)

…………………………………………………………………………………

…………..

2. Explain the meaning of the following terms

a) chiasmata

(1mk)

…………………………………………………………………………………

…………..

b) Synapsis

(1mk)

………………………………………………………………………………………..

3. Identify **three** events that occur in the interphase as a prerequisite for cell division (3mks)

…………………………………………………………………………………

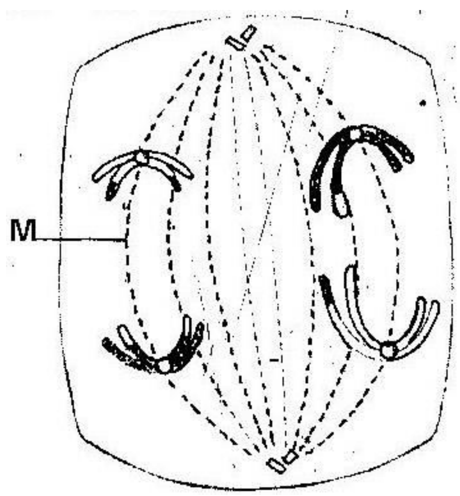
…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

4. The diagram below represents a stage during cell division



(a) (i) Identify the stage of cell division

(1mk)

……………………………………………………………………………………

…………

(ii) Give three reasons for your answer (a) (i) above

(3mks)

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

………………………………

(b) Name the structure labeled M

(1mk)

……………………………………………………………………………………

………

5. Describe briefly the activities that occur at the following stages

a) Metaphase II

(3mks)

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

………………………………

b) Telophase

(3mks)

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

………………………………

6. a) Distinguish between mitosis and meiosis

(3mks)

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

………………………………

c) state two structures in plants where meiosis occurs

(2mks)

………………………………………………………………………………

…………..

d) State the significance of mitosis

(2mks)

………………………………………………………………………………

………………………………………………………………………………

……………………

7.) Draw a well labeled diagram of a plant cell whose diploid number is 8 undergoing Prophase

(5mks)

8. A certain species of a flowering plant relies entirely on sexual reproduction for propagation. The number of chromosomes of the cell in the ovary wall is 16. State the number of chromosomes in:

a) The pollen tube nucleus (1 mk)

……………………………………………………………………………………………
……

b) A cell of the endosperm (1 mk)

……………………………………………………………………………………………
………

9. What name is used to describe the following?

a) Division of the nucleus (1mk)

……………………………………………………………………………………………
……..

b) Division of the cytoplasm (1 mk)

……………………………………………………………………………………………
…….

c) A Flower without a stalk (1 mk)

……………………………………………………………………………………………
………

d) Transfer of pollen grains to the stigma of another flower of the same species (1 mk)

………………………………………………………………………………………
……….

10. a) Briefly describe the process of binary fission in amoeba (3 mks)

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………

b) State the type of asexual reproduction exhibited by the *Rhizopus* spp (1mk)

………………………………………………………………………………………
…

11. describe fertilization in flowering plants (5mks)

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

……………………………………………………………………………………

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……………………………………………………………………………………

……………………

12. briefly explain the development of an ovary after fertilization

(4mks)

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

………………………………

APPENDIX 4: MARKING SCHEME (CBAT II)

FORM 3 BIOLOGY TEST. **TOPIC: REPRODUCTION (50 Marks)**

Time: 1hour **Date…………………**

PART A: STUDENT BIODATA

Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

PART B: THE QUESTIONS

Answer all the questions in this section in the spaces provided

3. State the role of the following structures in a cell.
   c) Centrioles

      (2mks)

      Form cilia and flagella

      Form spindle fibres during cell division

   d) Chromosomes

      (1mk)

      Carry genetic information

4. Explain the meaning of the following terms
   c) chiasmata

      (1mk)

      Point of attachment of chromatids of homologous chromosomes during crossing over

d) Synapsis

(1mk)

Pairing of homologous chromosomes during prophase I of meiosis

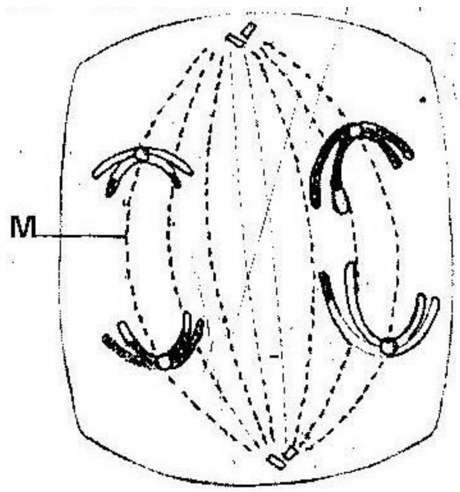
3. Identify **three** events that occur during interphase as a prerequisite for cell division (3mks)

Replication of chromosomes

Duplication of cell organelles

Build up of energy in form of ATP

5. The diagram below represents a stage during cell division



(a) (i) Identify the stage of cell division

(1mk) Anaphase I

(ii) Give three reasons for your answer (a) (i) above

(3mks)

Centrioles are at the poles

Homologous chromosomes are moving to opposite poles

Spindle fibres shorten pulling the homologous chromosomes to opposite poles

(b) Name the structure labeled M

(1mk) Spindle fiber

5. Describe briefly the activities that occur at the following stages

e) Metaphase II

(3mks)

Centrioles replicate and move to opposite poles

A new spindle fibres formed are fully developed

Chromosomes line up singly at the equator with centromere attached to the spindle fibres

f) Telophase

(3mks)

The cell constricts along the middle to form four new cells

Nuclear membrane and nucleoli reform

Chromatids become chromosomes

7. a) Distinguish between mitosis and meiosis

(3mks)

Mitosis	Meiosis
Two daughter cells formed	Four daughter cells formed
Daughter cells identical to parent cell	Daughter cells not identical to parent

	cell
Number of chromosomes retained	Number of chromosomes halved
Homologous chromosomes do not pair up	Homologous chromosomes do pair up

g) state two structures in plants where meiosis occurs (2mks)

Anthers, Ovary

h) state the significance of mitosis (2mks)

Growth, Repair of worn out tissues, asexual reproduction

7.) Draw a well labeled diagram of a plant cell whose diploid number is 8 undergoing Prophase (5mks)

8. A certain species of a flowering plant relies entirely on sexual reproduction for propagation. The number of chromosomes of the cell in the ovary wall is 16. State the number of chromosomes in:

a) The pollen tube nucleus (1 mk)

8

b) A cell of the endosperm (1 mk)

24

9. What name is used to describe the following?

a) Division of the nucleus (1mk)

Karyokinesis

b) Division of the cytoplasm (1 mk)

Cytokinesis

c) A Flower without a stalk (1 mk)

Sessile

d) Transfer of pollen grains to the stigma of another flower of the same species (1 mk)

Cross pollination

10. a) Briefly describe the process of binary fission in amoeba (3 mks)

Binary fission is a form of asexual reproduction in which a cell divides to form two cells

It starts with division of the nucleus; followed by division of cytoplasm and the entire cell components. Each cell then becomes a separate organism capable of existing on its own.

b) State the type of asexual reproduction exhibited by the *Rhizopus* spp

(1mk)

Sporulation/spore formation

13. describe fertilization in flowering plants

(5mks)

the pollen grain lands onto the sticky stigma and germinates; a pollen tube develops and grows down the style to the ovary; the tube nucleus is located at the tip of the tube and it directs and controls the growth of the tube nucleus; the generative nucleus is located just behind the tube nucleus, it divides by mitosis to form two male nuclei. In the ovary the pollen tube enters the ovule through the micropyle; the tube nucleus disintegrates, tip of the pollen tube bursts open releasing the two male nuclei into the embryo sac. One male nucleus fuses with nucleus of egg cell to form a zygote while the other male nucleus fuses with the two polar nuclei to form a triploid primary endosperm nucleus; the process is known as double fertilization.

14. briefly explain the development of an ovary after fertilization

(4mks)

the zygote grows by mitosis to form an embryo consisting of plumule radical and cotyledons; the triploid primary endosperm nucleus undergoes mitosis to form many nuclei that become separated to form cells called endosperm cells these form the endosperm that surround the embryo . the ovule thus develop into seeds while the ovary develops into fruit.

APPENDIX 5: SCIENTIFIC SKILLS ACHIEVEMENT TEST

ADM. NO…………………..……GENDER………………………..

TOPIC: REPRODUCTION

TIME: 45 MIN

PART A: STUDENT BIODATA

Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

PART B: PRACTICAL TEST

INSTRUCTIONS

Answer all questions in the spaces provided.

1) Observe the clip of a process in a living organism and answer the questions below

   a) Identify the process in the clip (1mk)

   ……………………………………………………………………………….

   b) With a reason, state the organism from which the clip was obtained (2mks)

   Organism ……………………………………………………………….

   Reason ………………………………………………………………….

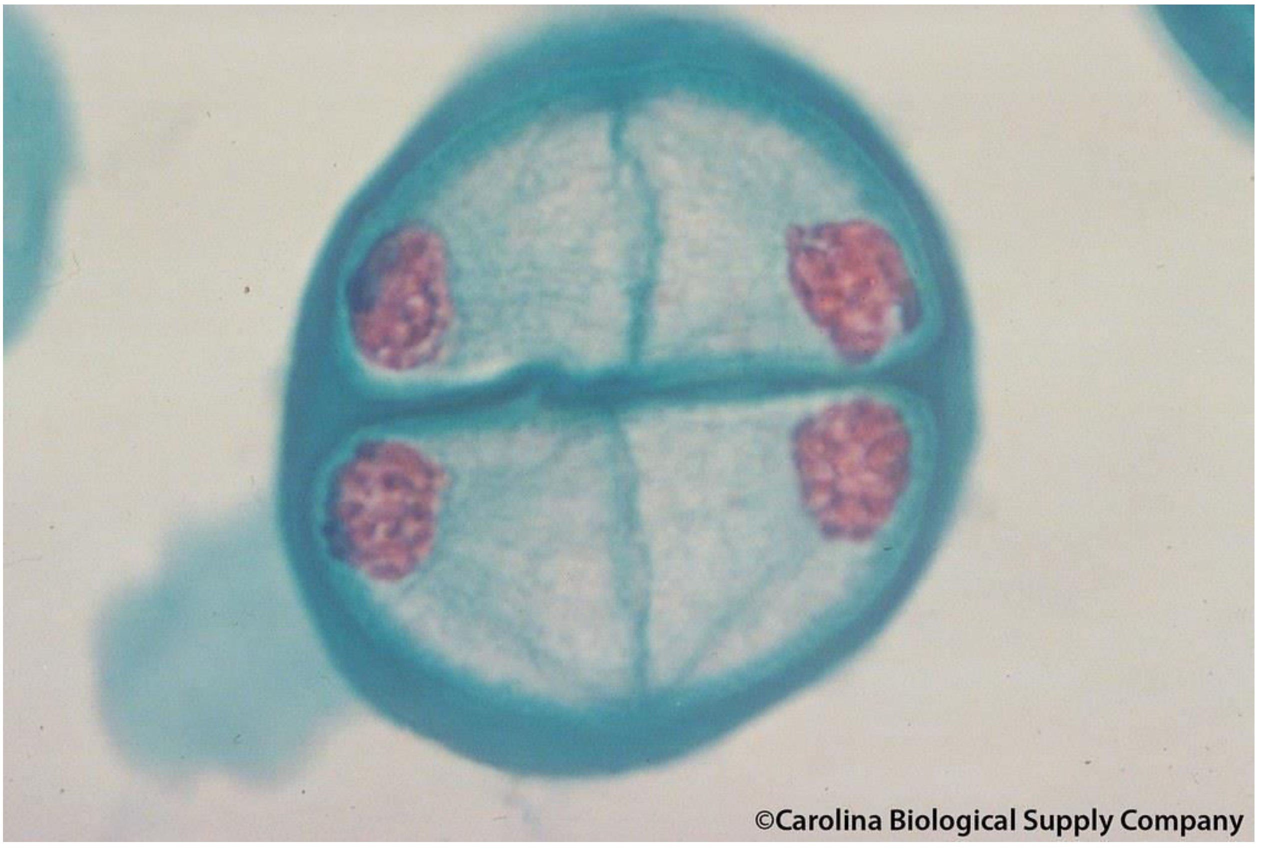
   c) Outline the stages observed in the clip and briefly describe them using diagrams

(12m

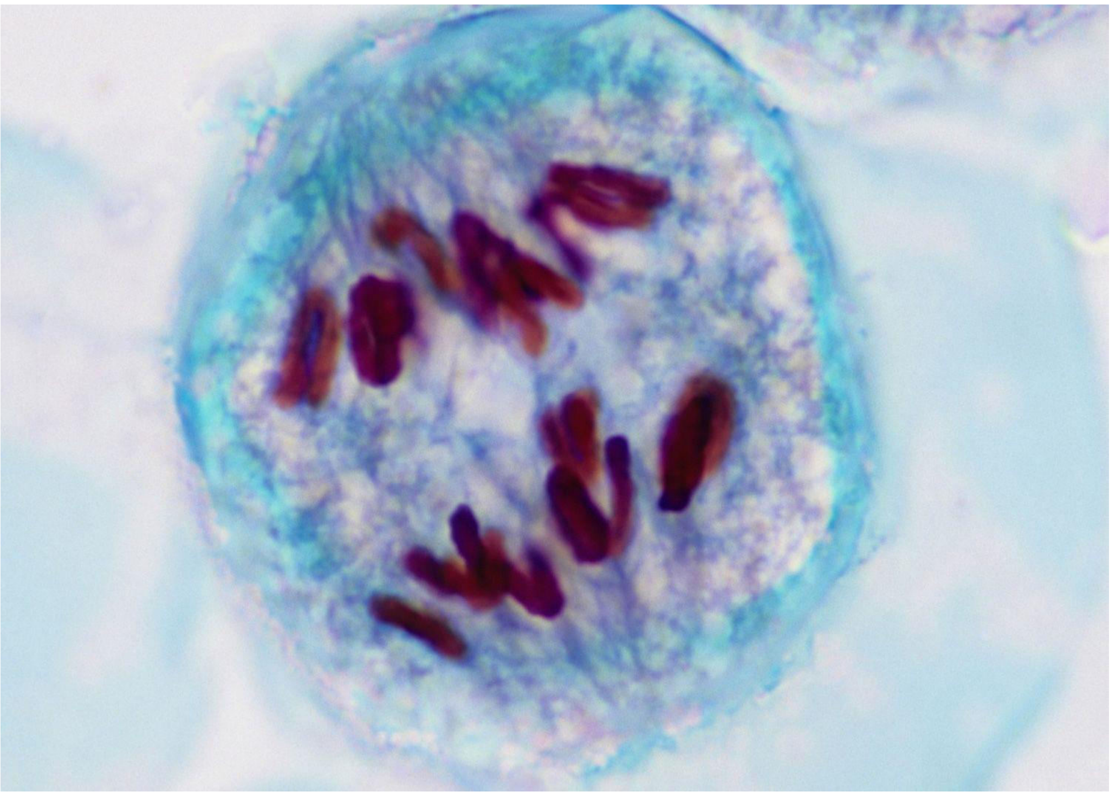
ks)

2. You are provided with photomicrographs labeled X and Y

X:



Y:



a) Identify the stage of cell division shown by each photomicrograph

(2mks)

X…………………………………………………………………………….

Y…………………………………………………………………………….

b) using observable features only support your answer in (a) above

X

(3mks)

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

……………………………..

Y

(3mks)

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

………………………………

3. You are provided with specimen labeled J.

a) (i) Measure the length of the filaments in the specimen and find the average length. Record the results below.

(3mks)

(ii) Measure the style and record the length.

(iii) Based on your values in (i) and (ii) above, suggest the agent of pollination for this specimen.

(1mk)

(iv) Give a reason for your answer.

(1mk)

c) Carefully cut the specimen J longitudinally to get two identical halves.

(i) Draw and label one half of the flower.

(4mks)

(ii) Calculate the magnification.

(2mks)

APPENDIX 6: STUDENTS' ATTTITUDE QUESTIONNAIRE (SAQ I)

To be filled all students in the sample before intervention

This is not a test. There is no correct or wrong answer. The purpose of this questionnaire is to seek your honest view and opinion about the teaching and learning of cell biology concepts in secondary schools in Vihiga County. All the information that you shall provide will be used only for research purpose and will be treated with utmost confidentiality.

Your cooperation is highly appreciated.

SECTION A: PERSONALDETAILS.

Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

SECTION B: CELL BIOLOGY CONCEPTS (CELL, CELL SPECIALIZATION, CELL PHYSIOLOGY)

INSTRUCTIONS

1. This is **NOT** a test and there is no **RIGHT** or **WRONG** answer
2. Provide an honest answer as much as possible
3. Tick (√) only one of the responses provided
4. The letter choices given denote the following responses;

T -True **F –False**

QUESTIONS	RESPONSES	
	T	**F**
1. I enjoy learning the cell biology concepts		
2. I find learning of cell biology concepts boring		
3. cell biology concepts are difficult for me to understand		
4. cell biology concepts are easy to understand		
5. I like the topic of cell biology		
6. I like cell biology experiments		
7. cell biology knowledge improves the biology grade		
8. cell biology is of little importance in our lives		
9. cell biology is quite useful in our society		
10. cell biology is not applicable after school		
11. cell biology is an interesting topic		
12. I find cell biology boring to learn		
13. I am not good at cell biology		
14. I am good in cell biology		
15.I find cell biology concepts very interesting		
16. I don’t understand cell biology concepts		
17. I wouldn’t wish to attend any more cell biology lessons		
18. I would like to have cell biology questions more often		
19. I will pursue cell biology related careers		
20. I cannot pursue cell biology related careers		

APPENDIX 7: STUDENTS' ATTTITUDE QUESTIONNAIRE II

To be filled all students in the sample before intervention

This is not a test. There is no correct or wrong answer. The purpose of this questionnaire is to seek your honest view and opinion about the teaching and learning of cell biology concepts in secondary schools in Vihiga County. All the information that you shall provide will be used only for research purpose and will be treated with utmost confidentiality.

Your cooperation is highly appreciated.

SECTION A: PERSONALDETAILS.

Tick (√) where applicable

Gender:	Male ( )	Female ( )	
School type:	Mixed ( )	Girls ( )	Boys ( )
KCPE Marks:	below 200 ( )	200-299 ( )	above 300 ( )

SECTION B: CELL BIOLOGY CONCEPTS (CELL, CELL SPECIALIZATION, CELL PHYSIOLOGY)

INSTRUCTIONS

1. This is **NOT** a test and there is no **RIGHT** or **WRONG** answer
2. Provide an honest answer as much as possible
3. Tick (√) only one of the responses provided
4. The letter choices given denote the following responses;

T -True **F –False**

QUESTIONS	RESPONSES	
	T	F
1. I enjoy learning the reproduction concepts		
2. I find learning of reproduction concepts boring		
3. reproduction concepts are difficult for me to understand		
4. reproduction concepts are easy to understand		
5. I like the topic of reproduction		
6. I like reproduction experiments		
7. reproduction knowledge improves the biology grade		
8. reproduction is of little importance in our lives		
9. reproduction is quite useful in our society		
10. reproduction is not applicable after school		
11. reproduction is an interesting topic		
12. I find reproduction boring to learn		
13. I am not good at reproduction		
14. I am good in reproduction		
15.I find reproduction concepts very interesting		
16. I don't understand reproduction concepts		
17. I wouldn't wish to attend any more reproduction lessons		
18. I would like to have reproduction questions more often		
19. I will pursue reproduction related careers		
20. I cannot pursue reproduction related careers		

APPENDIX 8: Focus Group Interview Guide

(FOR THE EXPERIMENTAL GROUP)

DATE--

FOCUS GROUP ID---

INTERVIEW MODERATED BY---

Preamble

The researcher is conducting an investigation on the effects of 5E instructional model approach on students' performance in cell biology concepts. This focus group will help the researcher understand your attitudes, experience and feelings about cell biology concepts you just learned and the test that you just did. Your insights will help your teacher improve on the way they teach you. You have been selected from among the students who attended lessons taught using the 5E instructional model and completed the test and questionnaires. The interview will take only 20 minutes.

[*may I begin or we schedule a convenient time for you]*

Everything you tell me is confidential. The information you give will not be attributed to you in any report that will be made. Anonymity will be upheld. there are no wrong or wright answers. Your opinion will be highly valued. Feel free to share your views and opinion even if they differ from others' views. Be informed that I am interested in both positive and negative comments for improvement purposes.

You could have probably noticed a voice recorder in my cell phone. I will be recording this session so that I can understand your thoughts later as I make my report. However, the recorded message goes no further than the interview room and anything said will remain confidential. During a presentation or response, start with your name so that as I listen to the tape, I will be able to relate comments you made at different times or on different issues. Be assured of complete confidentiality. Your participation is voluntary.

Do you have any questions before we begin?

INTERVIEW QUESTIONS

1. Kindly tell me about your experience in biology classe?

   Probe: how often do you use the laboratory for biology classes?

2. What was your experience during the lessons of the topic of reproduction you just completed?

   Probes: did you participate in the lesson? What of other students? What was different in these lessons as compared to other lessons previously attended? What did you like or dislike about the lessons on the topic of reproduction?

3. What was your during the test on reproduction?

   Probes: did you experience challenges? Did the questions make sense? Do you think the teacher prepared you appropriately? Comment on the teachers approach in relation to the test

4. Do you think you will do well in the test?

   Probes: what challenges do you normally experience during biology tests? How do you think you can address them?

5. Do you have any comment about the learning of cell biology and biology in general?

Thank you so much for accepting to be interviewed and sparing your time for this session. I promise to use the information you have provided to help teachers improve teaching of cell biology concepts and biology in general.

APPENDIX 9: Focus Group Interview Guide

(FOR THE CONTROL GROUP)

DATE---

FOCUS GROUP ID---

INTERVIEW MODERATED BY---

Preamble

The researcher is conducting an investigation on the effects of teaching approach on students' performance in cell biology concepts. This focus group will help the researcher understand your attitudes, experience and feelings about cell biology concepts you just learned and the test that you just did. Your insights will help your teacher improve on the way they teach you. You have been selected from among the students who attended lessons taught using the 5E instructional model and completed the test and questionnaires. The interview will take only 20 minutes.

[*may I begin or we schedule a convenient time for you]*

Everything you tell me is confidential. The information you give will not be attributed to you in any report that will be made. Anonymity will be upheld. there are no wrong or wright answers. Your opinion will be highly valued. Feel free to share your views and opinion even if they differ from others' views. Be informed that I am interested in both positive and negative comments for improvement purposes.

You could have probably noticed a voice recorder in my cell phone. I will be recording this session so that I can understand your thoughts later as I make my report. However, the recorded message goes no further than the interview room and anything said will remain confidential. During a presentation or response, start with your name so that as I listen to the tape, I will be able to relate comments you made at different times or on different issues. Be assured of complete confidentiality. Your participation is voluntary.

Do you have any questions before we begin?

INTERVIEW QUESTIONS

1. Kindly tell me about your experience in biology classes?

   Probe: how often do you use the laboratory for biology classes? How do you study biology?

2. What was your experience during the lessons on the topic of reproduction you just completed?

   Probes: did you participate in the lesson? What of other students? What was your role as a student? What did you like or dislike about the lessons on the topic of reproduction?

3. What was your during the test on reproduction?

   Probes: did you experience challenges? Did the questions make sense? Do you think the teacher prepared you appropriately? Comment on the teachers approach in relation to the test.

4. Do you think you will do well in the test?

   Probes: what challenges do you normally experience during biology tests? How do you think you can address them?

5. Do you have any comment about the learning of cell biology and biology in general?

Thank you so much for accepting to be interviewed and sparing your time for this session. I promise to use the information you have provided to help teachers improve teaching of cell biology concepts and biology in general.

APPENDIX 10: Differences between use of 5E instructional approach and the conventional approach:

When using the 5E Instructional Model, as a teacher, you engage in practices that are different from those of a traditional teacher. Similarly, the students learn in ways that are different from those they experience in a traditional classroom as discussed in tables (a) and (b).

a) **Teachers' practices**

5E Instructional Model Approach	Conventional Instructional Approach
Engage • arouses students' curiosity and generates interest in the learner • Determines students' current understanding (prior knowledge) of a concept or idea • Invites students to express what they think and raise their own questions	**Introduction** • Review previous lesson by a briefly summary of key points or asking questions that demand recall of knowledge • Neglects students' current understanding and prior information about the concepts being taught.
Explore • Encourages student-to student interaction, observes and listens to the students as they interact	**Lesson development** • Leads the students step by-step to through the new concept

<table>
<tr>
<td>• Asks probing questions to help students make sense of their experiences
• Provides time for students to puzzle through problems</td>
<td rowspan="2">• Gives information and facts that solve the problem
• Introduces vocabulary and explains concepts
• Provides definitions and definitive answers
• Discourages students' ideas and Questions
• Proceeds too rapidly for students to make sense of their experiences
• Provides closure
• Accepts explanations that are not supported by evidence
• Introduces unrelated concepts or skills
• Neglects to help students connect new and former experiences</td>
</tr>
<tr>
<td>Explain
• Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations
• Asks questions that help students express understanding and explanations
• Requests justification (evidence) for students' explanations
• Provides time for students to compare their ideas with those of others and perhaps to revise their thinking
• Introduces terminology and alternative explanations after students express their ideas</td>
</tr>
</table>

Elaborate • Focuses students' attention on conceptual connections between new and former experiences • Encourages students to use what they have learned to explain a new event or idea • Reinforces students' use of scientific terms and descriptions previously introduced • Asks questions that help students draw reasonable conclusions from evidence and data	
Evaluate • Observes and records as students demonstrate their understanding of the concepts and performance of skills • Provides time for students to compare their ideas with those of others and perhaps to revise their thinking • Interviews students as a	**Conclusion** • Tests vocabulary words, terms, and isolated facts • Introduces new ideas or Concepts thus creates ambiguity • Promotes open-ended discussion unrelated to the concept or skill • Accepts explanations that

means of assessing their developing understanding • Encourages students to assess their own progress	are not supported by evidence

b) Learners' experience

5E Instructional Model Approach	Conventional Instructional Approach
Engage • Become interested in and curious about the concept or topic • Express current understanding of a concept or idea • Raise questions such as, What do I already know about this? What do I want to know about this? How could I find out?	**Introduction** • Ask for the "right" answer • Offer the "right" answer as gained through rote memorization. • Listens to the teachers preview
Explore • "Manipulate materials and Ideas as they conduct investigations in which they observe, describe, and record data with others.	**Lesson development** • Get passively involved in concept development • Accept explanations

• Try different ways to solve a problem or answer a question • Acquire a common set of experiences so they can compare results and ideas with those of others	without justification • Work with little or no interaction with others • Propose explanations from "thin air" with no relationship to previous experiences • Propose explanations without evidence to support their ideas • Do not link previous information or evidence to new concept • Use terminology inappropriately and without understanding
Explain • Explain concepts and ideas in their own words based on evidence acquired during previous investigations • Record their ideas and current understanding • Reflect on and compare their ideas with what scientists know and perhaps revise their ideas • Express their ideas using appropriate scientific language	
Elaborate • Make conceptual connections between new and former experiences • explain a new object,	

event, organism, or idea using scientific terms and descriptions • Draw reasonable conclusions from evidence and data and scientifically communicate their understanding to others	
Evaluate • Demonstrate what they understand about the concept(s) and how well they can implement a skill • Compare their current thinking with that of others and perhaps revise their ideas • Assess their own progress by comparing their current understanding with their prior knowledge • Ask new questions that take them deeper into a concept or topic area	**Conclusion** • Draw conclusions with no regard to evidence or previously accepted explanations • Offer only yes-or-no answers or memorized definitions or explanations as answers • Do not express satisfactory explanations in their own words or use irrelevant terminologies

APPENDIX 11: APPROVAL FROM MMUST

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

Tel: 056-30870
Fax: 056-30153
E-mail: directordps@mmust.ac.ke
Website: www.mmust.ac.ke

P.O Box 190
Kakamega – 50100
Kenya

Directorate of Postgraduate Studies

Ref: MMU/COR: 509099

Date: 24th May, 2021

Nabie Alice,
EDS/H/01-56602/2016,
P.O. Box 190-50100,
KAKAMEGA.

Dear Ms. Nabie,

RE: APPROVAL OF PROPOSAL

I am pleased to inform you that the Directorate of Postgraduate Studies has considered and approved your Ph.D proposal entitled: ***"Effects of Teacher's use of 5E Instructional Model on Secondary School School Student's Achievement in Biology in Vihiga County, Kenya"*** and appointed the following as supervisors:

1. Prof. Toili William - SEDU
2. Dr. Ongunya Raphael - SEDU

You are required to submit through your supervisor(s) progress reports every three months to the Director Postgraduate Studies. Such reports should be copied to the following: Chairman, School of Graduate Studies Committee and Chairman, Science and Mathematics Education Department. Kindly adhere to research ethics consideration in conducting research.

It is the policy and regulations of the University that you observe a deadline of three years from the date of registration to complete your PhD thesis. Do not hesitate to consult this office in case of any problem encountered in the course of your work.

We wish you the best in your research and hope the study will make original contribution to knowledge.

Yours Sincerely,

DEAN
SCHOOL OF GRADUATE STUDIES
MASINDE MULIRO UNIVERSITY
OF SCIENCE & TECHNOLOGY

Dr. Consolata Ngala
DEPUTY DIRECTOR, DIRECTORATE OF POSTGRADUATE STUDIES

APPENDIX 12: NACOSTI APPROVAL FOR RESEARCH

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 347572

Date of Issue: 25/April/2023

RESEARCH LICENSE

This is to Certify that Ms.. ALICE NABIE of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Vihiga on the topic: EFFECTS OF TEACHER'S USE OF 5E INSTRUCTIONAL MODEL ON SECONDARY SCHOOL STUDENT'S ACHIEVEMENT IN BIOLOGY IN VIHIGA COUNTY, KENYA for the period ending : 25/April/2024.

License No: **NACOSTI/P/23/25377**

347572

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013 (Rev. 2014)
Legal Notice No. 108: The Science, Technology and Innovation (Research Licensing) Regulations, 2014

The National Commission for Science, Technology and Innovation, hereafter referred to as the Commission, was the established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

CONDITIONS OF THE RESEARCH LICENSE

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
    i. Endanger national security
    ii. Adversely affect the lives of Kenyans
    iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
    iv. Result in exploitation of intellectual property rights of communities in Kenya
    v. Adversely affect the environment
    vi. Adversely affect the rights of communities
    vii. Endanger public safety and national cohesion
    viii. Plagiarize someone else's work
3. The License is valid for the proposed research, location and specified period.
4. The license any rights thereunder are non-transferable
5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
7. Excavation, filming, movement, and collection of specimens are subject to further necessary clearance from relevant Government Agencies.
8. The License does not give authority to transfer research materials.
9. The Commission may monitor and evaluate the licensed research project for the purpose of assessing and evaluating compliance with the conditions of the License.
10. The Licensee shall submit one hard copy, and upload a soft copy of their final report (thesis) onto a platform designated by the Commission within one year of completion of the research.
11. The Commission reserves the right to modify the conditions of the License including cancellation without prior notice.
12. Research, findings and information regarding research systems shall be stored or disseminated, utilized or applied in such a manner as may be prescribed by the Commission from time to time.
13. The Licensee shall disclose to the Commission, the relevant Institutional Scientific and Ethical Review Committee, and the relevant national agencies any inventions and discoveries that are of National strategic importance.
14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and Innovation(NACOSTI),
Off Waiyaki Way, Upper Kabete,
P. O. Box 30623 - 00100 Nairobi, KENYA
Telephone: 020 4007000, 0713788787, 0735404245
E-mail: dg@nacosti.go.ke
Website: www.nacosti.go.ke

APPENDIX 13: MAP OF VIHIGA COUNTY