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THE EFFECT OF 5E INSTRUCTIONAL MODEL ON STUDENTS' ACHIEVEMENT IN SELECTED CONCEPTS IN GENETICS

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DECLARATION

STUDENT'S DECLARATION

I, Lydia Awortwe, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE : ….……………………………...........

DATE : ………………………….................................

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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DATE : ………………………………......................................

DEDICATION

This work is dedicated to my parents Mr Samuel and Mrs Peggy Awortwe and my siblings Freda, Victoria, Martha, Roberta and also to Sampson Nyaw.

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ABSTRACT

This study was conducted purposely to determine the effect of 5E instructional model on students' achievement in genetics. The study was guided by four research questions and three null hypotheses, which were tested at 0.05 level of significance. Pretest-posttest nonequivalent control group quasi-experimental research design was employed in this study. The study sample comprised 84 third year students from five intact classes at Uncle Rich Senior High School, Winneba. The intact classes were randomly assigned to experimental and control groups. The experimental and control groups were taught selected genetics topics using 5E instructional model and expository instruction respectively over a period of six weeks. Two instruments, namely Genetics Achievement Test (GAT) with a reliability coefficient of 0.67 and 5E Instructional Model Evaluation Questionnaire with a reliability of 0.71 were used for data collection. Data obtained from the research instruments were analysed using percentages, descriptive statistics such as mean and standard deviation, and student's t-test. The findings of the study showed that students in the experimental group exposed to the 5E instructional model had a higher mean achievement scores in genetics than those in the control group exposed to the expository method of instruction. On the issue of gender differences, the study revealed that there was no statistically significant difference between the mean achievement scores of male and female students in the experimental group exposed to the 5E instructional model. Based on the findings, the study recommended that the 5E instructional model should be employed in the teaching of science especially genetics.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter comprises the background to the study, statement of the problem, purpose of the study, research objectives, research questions and hypotheses, significance of the study, delimitations, limitations and organization of the study.

1.1 Background to the Study

Students' achievement in science is an important measure of their learning progress. Over the years, research has established that effective instruction is an indispensable tool in promoting students' achievement in science (Ajaja & Eravwoke, 2012).

Effective instruction goes beyond mere presentation of content, processes and skills, it encompasses a range of activities that are designed to cater for the individual learning needs of students and promote meaningful, life-long learning (McLeod, 2017). Meaningful learning occurs only when students are able to consciously link new knowledge to relevant concepts they already possess (Dogru-Atay & Tekkaya, 2008). Contrary to meaningful learning is rote learning.

Rote learning involves the memorization of isolated facts without proper integration of new concepts with prior knowledge to form a coherent framework (Novak, 2002). Research has established that rote learning impedes students' comprehension and achievement in science topics such as respiration and photosynthesis in plants, cell concept, human circulatory system and genetics (Sukola, 2015).

According to Dogru-Atay and Tekkaya (2008), genetics is regarded by many teachers and researchers as one of the most important topics in the science curriculum. The recognition of genetics as important stems from the fact that in recent times, most of the popular and controversial scientific and technological innovations that have gained worldwide preeminence are related to genetics.

Some examples of these innovations include the human genome project, genetically modified organisms, cloning of organisms, gene testing and gene therapy (Kılıç & Sağlam, 2014). The knowledge of genetics has been found to play a very important role in the understanding of other areas of biology such as the concept of evolution (Sukola, 2015).

The fields of molecular genetics and genomics have also become increasingly important in the everyday lives of people (Yu-Chien, 2008). This is evidenced by the growing interests in stem cell research, genetic engineering, the use of DNA fingerprinting in criminal investigations coupled with the worldwide controversies generated on the acceptance and use of genetically modified foods and cloning of organisms (Yu-Chien, 2008).

In view of this, Tsui and Treagust (2004) stressed on the importance of having contemporary knowledge on DNA, genes and their relations to human affairs in order to make informed decisions about ethically and socially controversial genetics-related issues.

Genetics forms an integral part of the science curriculum used in almost all second cycle institutions in Ghana. But despite its apparent importance, most students consider genetics to be a difficult topic and this in many ways affect their achievement in the topic (Dogru-Atay & Tekkaya, 2008).

A lot of studies have been conducted globally over the past decade by researchers and teachers to investigate the sources and possible causes of students' learning difficulties in genetics. The findings from some of these studies have been outlined in subsequent paragraphs.

Knippels, Waarlo and Boersma (2005) in a study indicated that students' difficulties in genetics could be attributed to its abstract and complex nature, the use of domain-specific vocabularies and terminologies, cytological processes and the mathematical content of Mendelian genetics. Probabilistic reasoning in relation to genotypic and phenotypic frequencies in offspring from genetic crosses was noted as challenge to students (Banet & Ayuso, 2000).

Banet and Ayuso (2000) found that a high level of formal theoretical reasoning was required for the meaningful understanding of genetics concepts like monohybrid and dihybrid inheritance, genetics crosses and linkages and sex determination. The comprehension of these abstract concepts was noted to be a source of challenge among students, especially those with low formal reasoning ability.

Bahar, Johnstone and Hansell (1999) in a study reported that students were often not very confident about the definitions of genetics terminologies like alleles, genes and homologous chromosomes. This accounted for the students' poor usage of such terminologies. In a similar study, Cassels and Johnstone (1978) had earlier noted that genetics terms such as homologous and homozygous, mitosis and meiosis, and chromosome and chromatid, looked and sounded similar to students, and this was a source of confusion among students.

Albaladejo and Lucas (1988) found that students do not fully understand the nature of structures like the chromosomes, genes and alleles which are involved in the transfer of genetic information. Finally, Stewart *et al*. (1990) noted that some students have alternative views of processes such as mitosis and meiosis.

In addition to the above findings, observations made of final year students from two successive batches 2017/2018 and 2018/2019 respectively by the researcher in the course of her teaching practice revealed that students had considerable difficulties in comprehending genetics-related concepts like codominance, sex-linkages and inheritance of sex-linked traits. These concepts were predominantly abstract.

The students also had difficulties applying Mendel's first and second laws of inheritance in solving problems on monohybrid and dihybrid inheritance, and in using the Punnett square to determine the genotypic and phenotypic ratios of offspring in dihybrid crosses. In almost all their classroom tests and exercises, the researcher observed that the students easily answered knowledge questions on genetics as compared to the comprehension and application questions.

Students' difficulties in genetics have also been noted to have a culminating negative effect on their academic achievements and this is evidenced by the West African Examinations Council (WAEC) Chief Examiner's reports from 2008 to 2014, which noted the decline in students' performances in biology examinations, especially in the area of genetics (WAEC, 2008; WAEC, 2010; WAEC, 2012; WAEC, 2014).

Students' poor performances in genetics were attributed to their lack of understanding of genetics concepts and their poor usage of genetics terminologies and symbols. The reports also indicated that only few candidates attempted solving questions on genetics because they found it to be difficult (Umeh, 2006).

Analyses of the findings from the empirical studies cited above together with the researcher's personal observations and the WAEC reports further highlighted the need for the implementation of more effective and innovative instructional strategies that could promote students' achievement in genetics other than the conventional teacher-directed expository instructional methods used in most science classrooms.

Expository instruction is primarily teacher-centred and thus has been noted to have little impact on students' acquisition of meaningful understanding of genetics concepts (Banet & Ayuso, 1995). The lack of meaningful understanding of genetics in turn leads to students' underachievement in the topic.

In a research on teaching genetics at secondary schools: a strategy for teaching about the location of inheritance information, Banet and Ayuso (2000) criticized the 'traditional' teaching approach as inadequate in addressing students' misconceptions about the concept of inheritance. They therefore suggested the implementation of more effective alternatives. The 5E instructional model is one of such alternatives (Dogru-Atay &Tekkaya, 2008).

The 5E instructional model is generally regarded as an effective hands-on inquiry approach to science with a strong constructivist foundation (Dogru-Atay & Tekkaya, 2008). The 5E instructional model comprise five main phases namely**:** engagement phase, exploration phase, explanation phase, elaboration phase and evaluation phase. Each phase of the 5E instructional model is characterized by unique set of activities that are designed to stimulate and sustain students' interests, and also to address their diverse learning needs.

In reviewing literature related to the study, the researcher noted that the 5E model had been studied extensively by researchers in different parts of the world. Most of the studies reported findings on the effect of the 5E model in promoting students understanding of science topics such as acids and bases (Bilgin, 2009); photosynthesis and respiration in plants (Balcı, Çakıroglu &Tekkaya, 2006); cell concepts (Kaynar, 2007); movement and force (Açışlı, Altun &Yalçın, 2011) and heat and temperature concepts (Turgut & Gurbuz, 2011).

Only one of the studies focused on the 5E model and its impact on students' achievement in genetics. This study was carried out by Sukola (2015) and it was conducted to investigate the impact of 5E teaching cycle on the attitude, retention and performance in genetics among pre-NCE students with varied abilities in Nigeria.

Since the researcher found insufficient literature on the 5E model and its effect on students' achievement in genetics, the researcher therefore decided to conduct this study which was aimed at investigating the effect of 5E instructional model on students' achievement in some selected concepts in genetics.

1.2 Statement of the Problem

The researcher in the course of her teaching practice observed that students had considerable difficulties in correctly applying Mendel's first and second laws of inheritance in solving problems of monohybrid and dihybrid crosses and explaining concepts such as codominance, sex-linkages and inheritance of sex-linked traits. These difficulties caused the students to perform poorly in class exercises on genetics.

The researcher found that expository instruction was ineffective in adequately addressing students' difficulties in genetics and consequently promoting their achievement in topic. In order to remedy this situation, there was the need for the implementation of more effective student-centered instructional strategies other than the expository instructional method which is primarily teacher-centered.

Many studies have documented the effectiveness of the 5E instructional model in promoting students achievement in different science topics. This study was therefore carried out at purposely to investigate the effect of the 5E instructional model on students' achievement in selected concepts in genetics

1.3 Purpose of the Study

The purpose of this study was to investigate the effect of 5E instructional model on students' achievement in selected concepts in genetics.

1.4 Research Objectives

The objectives of this study were to**:**

1. Determine the effectiveness of 5E instructional model on students' achievement in genetics.
2. Determine the differences in the mean genetics achievement test scores of the experimental and control groups taught using the 5E instructional model and expository instruction respectively.
3. Determine the differential impact of the 5E instructional model on male and female students' achievement in genetics.

4. Evaluate the effect of the 5E instructional model on the teaching and learning of genetics from the students' perspectives.

1.5 Research Questions

The study sought to address the following questions:

1. To what extent does the use of 5E instructional model affect students' achievement in genetics?
2. What are the differences in the mean genetics achievement test scores of the experimental and control groups taught using 5E instructional model and expository instruction respectively?
3. What is the differential impact of 5E instructional model on male and female students' achievement in genetics?
4. From the students' perspectives, to what extent does the use of the 5E instructional model affect the teaching and learning of genetics?

1.6 Research Hypotheses

The following null hypotheses guided the study and were tested at 0.05 confidence level of significance:

H_O 1: There is no significant difference between the mean genetics achievement pretest and posttest scores of the experimental group.

H_O 2: There is no significant difference between the mean genetics achievement pretest and posttest scores of the experimental group and the control group taught using the 5E instructional model and expository instruction respectively.

H$_O$ 3: There is no significant difference between the mean genetics achievement pretest and posttest scores of male and female students taught using the 5E instructional model.

1.7 Significance of the Study

The findings of the study could serve as a useful guide to science teachers who would want to adopt and implement the 5E instructional model in their teaching practice.

The study could serve as a useful reference material to researchers who would want to carry out future studies on the effectiveness of the 5E instructional model in different subject areas.

Finally, the study would add to the existing body of science literature knowledge on the effectiveness of the 5E instructional model in promoting students' understanding of genetics.

1.8 Delimitations of the Study

Since the syllabus specifies that genetics should be taught in the year of the senior high level, study was delimited to only form three students in Uncle Rich Senior High School.

Out of the many students-centered instructional strategies, the researcher selected and implemented only the 5E instructional model because many studies have reported findings on the effectiveness of the 5E instructional model in promoting students' achievement in science.

Finally, the study only focused on students' achievement in genetics even though there are many other science topics students consider to be difficult.

1.9 Limitations to the Study

Best and Khan (1993) defined limitation as a condition beyond the control of the researcher that places a restriction on the validity of the study. Some of the students were observed by the researcher to be repeatedly absent either during the administration of the tests or the treatment. Students' absenteeism posed a significant challenge to the study.

1.10 Organization of the Study

The study was organized into five chapters. Chapter One comprised the background to the study, statement of the problem, purpose of the study, research objectives, research questions and hypotheses, significance of the study, delimitations and limitations of the study, the organization of the study and operational definitions of terminologies.

Chapter Two comprised the review of related literature under the following sub-headings: Theoretical framework of the study, Expository science instruction, Inquiry-based science approaches, Differences between inquiry-based science instruction and expository science instruction, 5E instructional model as a major scientific pedagogy, Academic achievement in science, Cognitive variables that influence students' achievement in science, Factors that hinder students' achievement in genetics, 5E instructional model and Students' achievement in science, Students' attitudes and achievement in science, and Gender and students' achievement in science.

Chapter Three is concerned with the methodology employed in the study. It includes the research design, population, sample and sampling techniques and instrumentation.

Chapter Four includes data presentation, analysis and discussions. Chapter Five contains a summary of the research findings, conclusions, recommendations and suggestions for further studies.

Operational Definition of Terms

Academic Achievements: It refers to the scores that students obtain after being subjected to tests or examinations at the end of a program or instruction.

Perspectives: It refers to students' opinions or views regarding the effectiveness of a particular instructional method.

Expository Instruction: It is a teacher-centered method of instruction mainly characterized by the use of lecture and classroom discussion methods

5E instructional model: It is an instructional model that comprise five distinct phases**:** Engagement, Exploration, Explanation, Elaboration and Evaluation. Each phase of the model is dependent on the preceding phase.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

Literature relevant to the subject under study is reviewed in this chapter. This chapter begins with an elucidation of the theoretical framework underpinning the 5E instructional model and its implications to science teaching and learning. This is followed by an in-depth discussion of expository science instruction and inquiry-based science instruction. The concluding part of the discussion highlighted key differences between the two instructional methods.

This chapter further examines the 5E instructional model as a major scientific pedagogy, academic achievement in science, cognitive variables that influence students' achievement in science, factors that hinder students' achievement in genetics, 5E instructional model and students' achievement in science, students' attitude and achievement in science and the role of gender on students' achievement in science.

The concluding part of this chapter presents an overview of empirical studies relevant to the present study and its implications to the present study.

2.1 Theoretical Framework

The 5E instructional model hinges on both the constructivist theory of learning and Kolb's experiential theory of learning. These theories together form the theoretical framework of the study. The underlining principle of the 5E instructional model is that learners actively construct their own understandings during the teaching and learning process based on their prior knowledge and experience with the concept or topic under study (Beaudin & Quick, 1995).

Constructivism is based on the idea that all learning is constructed and that new knowledge is built upon the prior experiences of the learner (Kruckeberg, 2006). This learning theory emphasizes the importance of students' prior knowledge and learning experiences in the construction of new knowledge (Gogus, 2012).

Kolb's experiential theory of learning, however, describes learning as a four-part process where learners first engage themselves in a new experience, actively reflect on that experience, conceptualize that experience and integrate it with past experiences (Beaudin & Quick, 1995).

Experiential learning requires learners to have an active interaction or encounter with the phenomenon under study rather than just memorizing abstract concepts, thus it is termed learning-by-doing (Kumar & Bhandarker, 2017). Learners also reflect on the activities they engaged in during the teaching and learning process in order assimilate the new knowledge they received (McLeod, 2017).

Experiential learning is sometimes referred to as a "hands-on" approach to learning. Both the constructivist and experiential theories of learning recognize the fact that learners play an important role in the learning process by actively constructing their understandings of a concept or phenomenon based on prior knowledge and experiences (McLeod, 2017). Thus, both theories are essentially learner-centered.

The constructivist and experiential theories of learning highlight the role of the teacher as a facilitator or guide in the teaching and learning process. This is contrary to the traditional view of teachers as "dispensers of knowledge" (Bradley & Habeshaw, 1991). Both theories also emphasize the need for teachers to provide students with multiple modes of representations or perspectives on the subject matter under study, create new understandings through coaching, pose problems of emerging relevance to the students and design learning activities that emphasize hands-on, real-world experiences (Christie, 2005).

Detailed explanations of Kolb's experiential theory of learning and constructivism, and their implications to science teaching and learning are presented as follows:

2.2 Kolb's Experiential Theory of Learning

Experiential theory of learning was developed by David Kolb in 1984 (McLeod, 2017). The theory is grounded on the humanistic and constructivist perspectives of learning, which emphasize that learners have inherent abilities to learn and that experience plays a critical role in knowledge construction and acquisition (Beaudin & Quick, 1995). According to Kolb (1984), learning occurs when someone creates knowledge though experiential transformations.

Experiential learning theory posits that learning involves the acquisition of abstract concepts that can be flexibly applied in a range of situations. The theory holds that effective learning occurs when a learner progresses through a cycle of four stages**:** concrete experience, reflective observation, abstract conceptualization and active experimentation (McLeod, 2017)

According to the experiential theory, the learning cycle begins when learners first have a concrete experience with the topic or concept to be learnt. Learners at the first stage of the learning cycle may either encounter new experiences or engage in a reinterpretation process of an existing experience.

This is followed by a reflective observation of the learning experience. The learner in the second stage of the cycle reviews and reflects on the new experiences gained and identifies any inconsistencies between the experience and understanding.

Through the reflective process, the learner may either create new ideas or modify existing abstract concepts. Learners analyse the concepts acquired in order to form conclusions and generalizations in what is termed abstract conceptualization.

The final stage of the cycle involves active experimentation. The learner plans and tries out what was learned and is able to apply the new knowledge to other situations. The conclusions and generalizations made this time around are used to test hypotheses. The learner thus engages in new experiences.

Kolb (1984) views learning as an integrated process with each stage being mutually supportive of and feeding into the next, thus it is possible for the learner to enter at any of the four stages of the learning cycle and follow through its logical sequence to acquire new knowledge.

According to McLeod (2017), Kolb identified four distinct learning styles based on the four-stage learning cycle. The learning styles include diverging learning style, assimilating learning style, converging learning style and accommodating learning style.

Each of the learning styles maybe influenced by factors such social environment, educational experiences or the basic cognitive structure of an individual. Preference for any of the learning styles is influenced by two variables**:** students' approach in performing a given task and their perception about learning as explained below (McLeod, 2017)**:**

Diverging learning style require learners to be able to look at things from different perspectives. Learners with diverging learning style prefer to watch how a task is performed rather than perform it themselves. They tend to gather information and use their imagination to solve problems. They are best at viewing concrete situations from several different viewpoints and work better in group settings. Divergent learners have broad cultural interests and perform better in situations that require ideas-generation, for example, brainstorming.

Assimilating learning style involves a concise and logical approach to learning. Ideas and concepts are essentially important to learners with assimilating leaning style. Learners are more interested in the explanations of ideas and abstract concepts than practical activities. They are attracted to logically sound theories more than approaches based on practical value. They excel at understanding wide-ranges of information and also in organizing information received in a clear, logical format. Learners with assimilating learning style prefer readings, lectures and exploring analytical models.

People with a converging learning style are very good at finding practical uses for ideas and theories. They prefer to perform tasks or solve problems that are very technical in nature. They prefer to experiment with new ideas, to simulate and to work with practical applications.

Accommodating learning style is 'hands-on,' and relies on intuition rather than logic. People with accommodating learning style often prefer a practical and experiential approach in solving problems or executing tasks. They are usually attracted to new challenges and experiences. They commonly act on 'gut' instinct rather than logical analysis. People with an accommodating learning style tend to rely on others for information rather than carry out their own analysis.

2.2.1 Implications of Kolb's experiential theory of learning to the teaching and learning of science

Experiential learning traditionally applies to three areas of educational endeavour: field-based experiences, prior learning assessment, and experiential classroom-based learning (Lewis & Williams, 1994).

Experiential learning requires learners to engage in activity-based science rather than rote memorization of abstract scientific concepts. Learners are able to meaningfully construct new knowledge when they are actively engaged in more hands-on practical science activities that allow them to interact with concrete materials relating to abstract concepts.

According to Burnard (1989), experiential knowledge is gained through direct encounter with a subject, person or thing. Thus, experiential classroom-based learning focuses more on the implementation of instructional techniques like case studies and simulations that are based on real life experiences (Beaudin & Quick, 1995).

In experiential learning, there is an integration of the cognitive learning processes and emotional experiences that promote understanding of the material being covered (Beaudin & Quick, 1995). Experiential learning stresses on humanistic values by emphasizing that feelings are part of the learning process and are as equally important as cognition. Teachers therefore ought to consider students' learning style preferences and interests when designing science curriculum materials.

Experiential learning is predominantly learner-centered with the teacher only acting as a facilitator or a guide. The role of the teacher as a facilitator is to design activities that account for students' previous learning experiences and also stimulate students' curiosity, interests and desire to learn.

2.3 Constructivism

Constructivism is a learning theory found in psychology that attempts to explain how people construct knowledge and meaning from their experiences. According Elliott *et al*. (2000), constructivism is "an approach to learning that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner" (p. 256).

Constructivism is based on the principle that knowledge is constructed, rather than innate, or passively absorbed. Constructivism's central idea is that human learning is constructed and that learners build new knowledge upon the foundation of previous learning. This prior knowledge influences what new or modified knowledge an individual will construct to form new learning experiences (Phillips, 1995).

During the learning process, leaners analyse new knowledge gained in the light of their previous knowledge. If there are inconsistencies, leaners may modify existing knowledge to accommodate the new knowledge. Constructivism dispels the idea that new knowledge is etched on a '*tabula rasa*' and presupposes that learners have prior experiences and knowledge that is useful in constructing new knowledge (Olusegun, 2015).

The second principle underlying constructivism is that learning is an active process and not passive. Learners remain active throughout the learning process**;** they apply current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge, and based on that judgment they can modify knowledge (Phillips, 1995).

Constructivists argue that learners construct meaning only when actively engaged in the learning process (Olusegun, 2015). According to McLeod (2019), the third principle underlying constructivism is that all knowledge is socially constructed. In similar vein, Dewey posited that learning is regarded as a social activity; it is something we do together, in interaction with each other, rather than an abstract concept (McLeod, 2019).

According to McLeod (2019), cognitive development stems from social interactions through guided learning within the zone of proximal development as children and their partner's co-construct knowledge. He stressed that the nature of the environment in which children grow influence how they think and what they think about.

Accommodation and assimilation are two key concepts in constructivism associated with the construction of new knowledge. Accommodation involves the restructuring or modification of existing knowledge in order to fit with the new knowledge received whereas assimilation involves the incorporation of new experiences into old experiences. Both processes are important in knowledge construction as they help to integrate new knowledge and experiences in existing schemas and ensure that there is consistency (McLeod, 2019).

John Dewey, Jean Piaget, Jerome Bruner and Lev Vygotsky have been credited for their significant contributions to the foundation of the constructivist theory (GSI Teaching and Resource Center, 2015). John Dewey (1998) is often cited as the philosophical founder of constructivist approach. Dewey posited that children learn best when they interact with their environments and are actively involved with the school curriculum (McLeod, 2019).

Jean Piaget founded the cognitive-constructivist theory which posits that knowledge is something that is actively constructed by learners based on their existing cognitive structures. Therefore, learning is relative to the learner's stage of cognitive development (McLeod, 2019).

The social constructivist theory was developed by Lev Vygotsky. The theory posits that every function in the child's cultural development appears twice: first, on the social level and, later on, on the individual level; thus first, between people (interpsychological) and then inside the child (interpsychological). Social constructivist theory views learning as a collaborative process where knowledge develops from the learner's interactions with culture and society (McLeod, 2019).

The development of radical constructivism is credited to the work of Ernst von Glasersfeld (Mcleod, 2019). The theory posits that all knowledge is constructed on the foundations of existing knowledge rather than perceived through the senses. Thus, knowledge is invented and not discovered (McLeod, 2019). Many students-centered instructional methods like the learning cycle, collaborative learning and cooperative approach are founded on constructivism (Bernard, Borokhovski, Schmid, Waddington & Pickup, 2019)

Constructivism enables students to take full responsibility of their own learning whilst the teacher acts as a facilitator or a guide. This promotes a sense of agency among students. During the learning process, the immediate learning environment together with the prior knowledge has collaborative effect on the construction of knowledge.

2.3.1 Implications of constructivism in the teaching and learning of science

Constructivism is founded on the idea that students' actively construct their own understandings based on prior experiences. This is in sharp contrast to the traditional teaching methods where the teacher is regarded as the sole reservoir of knowledge. Constructivism's profound and unique recognition of human learning has brought about significant transformation to the traditional perspective of teaching (Yanchun, 2002).

Constructivists recognize that without students' initiative and active participation, learning becomes meaningless. Constructivism appreciates teachers' facilitative role which is useful in enabling students learn knowledge effectively.

Constructivism emphasizes on cooperation and communication, and trains students' cooperative consciousness. In traditional teaching, the cooperation between teachers and students, and also among students is neglected (Darling-Hammond et al., 2019). Constructivists hold that knowledge is the social construction of individuals and others by negotiation. Therefore, in the process of constructing knowledge, students must cooperate and communicate with others (McLeod, 2019).

In a collaborative learning environment, students are able to enlarge their views, instead of receiving knowledge passively. It also helps them build up their own knowledge system, cultivate their innovative spirit and problem-solving ability.

Constructivists hold the view that students' previous knowledge, experiences, thinking mode, learning habits and methods are important foundations in the construction of new knowledge. Modern cognitive psychologists argue that learning is an interactive process of new knowledge and old knowledge. The former knowledge and techniques stored in the memory system are important internal conditions for generating study activities.

Learning is an initiative process based on students' previous knowledge and experiences. Therefore, students ought to be guided to produce new knowledge and experience from original ones, achieving the mutual connection of new and old knowledge.

Constructivist theory of learning requires teaching and learning to be organized in real or semi-real environment, emphasizing either on non-structural knowledge or students' previous experiences. Traditional teaching, however, focuses on structural knowledge and not on non-structural knowledge and students' life experiences.

Constructivism focuses on creating an interactive learning environment for students, helping students to explore and discover new knowledge. It also builds a bridge between new knowledge and students' previous knowledge which is useful in promoting students' problem-solving ability.

2.4 Expository Science Instruction

Expository instruction is a conventional teaching method used in most science classrooms. It is basically considered as a direct instruction with one-way flow of information from teachers to students (Long-Crowell, 2012). Expository science instruction is a teacher-directed instructional strategy characterized by teachers providing students with information on science topics under study through lecture whiles students take notes of key points (Maheshwari, 2013). Teacher-led classroom discussions, demonstrations and lecture are types of expository instruction.

Expository science instruction is sometimes referred to as deductive teaching because the teacher often begins with a definition of concepts to be learnt, illustrates them with examples and outlines their implications (Maheshwari, 2013).

Students are not allowed to make any independent discoveries in expository instruction since the teacher presents them with the entire content of what is to be learnt. Teachers play the dominant role in expository instruction whiles learners are passive participants (Long-Crowell, 2012).

Expository instruction can be particularly useful in instances where students have no prior knowledge on the topic or concepts to be learnt and therefore teachers can save time by giving them the needed information (Maheshwari, 2013).

Expository instruction can be purposeful in situations where teachers develop innovative means of delivering content to students. The inclusion of videos, power point presentations and computer simulations in expository instruction are some of the ways in which teachers can diffuse boredom and stimulate student's interests in the content being delivered. The resultant effect will be an increase in students' participation in the teaching and learning process.

2.5 Inquiry Approach to Science Teaching and Learning

The term inquiry generally signifies the process of acquiring or obtaining information by investigation, often personally and voluntarily carried out by the person who is eager to know the phenomenon in question (Shamsudina, Abdullah & Yaamat, 2013).

Inquiry refers to the process of understanding the characteristics of science through scientific experiments (Millar, 1998). Hiang's (2005) elaboration of inquiry includes investigation of a problem; finding truth or knowledge that requires thinking critically, making observations, asking questions, doing experiments and stating conclusions; and thinking creatively and using intuition. There are essentially three levels of inquiry namely structured, guided and open inquiry (Pappas, 2014).

The structured inquiry requires that the teacher direct the inquiry by providing the question to be investigated, which is followed by a step-by-step instruction to help the students arrive at the answer to the question. This kind of inquiry is important because it enables students to gradually develop their ability to conduct more open-ended inquiry.

At the guided inquiry level, the teacher chooses the question whilst the students take on the role of establishing the direction and methods of the inquiry. The teacher plays an important role in the guided inquiry either by providing feedback or by posing further questions to lead the students in the right direction.

Open inquiry allows students to take the lead in establishing the questions and methods whiles the teacher takes on a supportive role. Thus, having students to ask questions is an essential component of open inquiry and requires high order thinking.

It can be garnered from the foregoing that inquiry approach to the teaching and learning of science provide students with opportunities to investigate science-related problems, search for possible solutions, make observations, ask questions, test out ideas, think creatively and use their intuition.

The implementation of inquiry-based teaching methods in science classrooms is recommended to be effective in improving students' analytical and critical-thinking skills through discovery and scientific investigations organized in authentic settings (Hwang & Chang, 2011).

Through critical thinking, students can draw upon many different resources in order to explain events and predict outcomes (DiPasquale, Mason, & Kolkhorst, 2003). The inquiry approach to science teaching prioritizes students' questions, ideas and analyses. It focuses on moving students beyond general curiosity into the realms of critical thinking and understanding (Guido, 2017).

Inquiry-based learning involves a systematic investigation into a topic, idea, problem, or issue with a focus on students constructing their own learning and meanings. Inquiry-based learning enables students to learn through curiosity, discovery, and collaboration rather than being presented with facts through direct instruction (Friesen *et al*., 2015).

Parim (2009) sees inquiry-based learning is a way of asking questions, seeking information and finding new ideas relating to an event. Students learn by using cause and effect, relational and critical thinking, and combining both scientific knowledge and operations. It requires students to conduct scientific reasoning and use critical thinking when combining scientific knowledge and processes to generate a perception of science (Bianchini & Colburn, 2000).

Varma, Volkmann and Hanuscin (2009) opine that science should be taught and learned through inquiry. Activities in science classrooms should involve observations, questioning, reading books and other sources of information, investigating, gathering, and analyzing, predicting, explaining and communicating results (Chin & Osborne, 2008).

Inquiry method of teaching have been found to have several positive implications on the teaching and learning of science (Duran & Dökme, 2016). The use of inquiry method of teaching enables teachers to design and implement unique set of activities that seeks to provide students with opportunities to explore possible solutions to science problems, develop explanations for the science phenomena under investigation, and elaborate on science concepts and processes.

The feedback provided to students by teachers during the implementation of inquiry instruction is critically important in helping students assess their learning progress and the extent to which they have understood lesson being taught. It is no wonder that it is argued that inquiry-based teaching methods are the best path to achieving scientific literacy because they provide students with the opportunity to discuss and debate scientific ideas (Gormally, Brickman, Hallar & Armstrong, 2009).

2.6 Expository Science Instruction versus Inquiry-based Science Instruction

The teacher-directed, expository science instruction has long been criticized for causing students to dislike science. This is largely attributed to boring presentations, too much writing, too little practical activities and too much whole class teaching where students are simply recipients of information (McLeod, 2019).

Many researchers have acknowledged inquiry-based science instructional methods as effective in promoting students' interests and attitude towards science, enhancing students' science process skills and critical thinking skills, and promoting mastery of science curriculum (Irwanto *et al*., 2019).

Inquiry-based science instruction focuses on student-constructed learning as opposed to teacher-transmitted information. Inquiry-based science instruction encourages students to connect their prior knowledge to observations, and to use their observations as evidence to increase personal scientific knowledge (Shields, 2006).

In inquiry-based science instruction, students are engaged in activities that allows them to formulate their own hypotheses, conduct experiments to test their hypotheses and justify the results obtained based on evidence (Seok-oh, 2010).

In contrast with inquiry-based science instruction, expository instruction follows the assumption that there is a fixed body of knowledge that students must come to know (Stofflet, 1999). Students are therefore expected to accept knowledge from their teachers without questioning them (Stofflet, 1999).

Expository instruction is primarily teacher-centered as it seeks to transfer thoughts and meanings from the teacher to the passive students leaving little opportunity for student-initiated questions, independent thinking or communication between students.

The distinctions between inquiry-based instruction and expository instruction have been summarized in the table below:

Table 1: A Comparison of Inquiry-based Instruction with Expository Instruction.

Characteristics	Inquiry-based Instruction	Expository Instruction
Principle Learning Theory	Constructivism	Behaviourism
Student Participation	Active	Passive
Student Involvement in Outcomes	Increased Responsibility	Decreased Responsibility
Student Role	Problem solver	Direction follower
Curriculum Goals	Process oriented	Product oriented
Teachers Role	Guide/facilitator	Director/ transmitter

Source: Shamsudin, Abdullah & Yaamat (2013). p.584.

2.7 Learning Cycle

Learning cycle model is a widely recognized model for teaching inquiry-based science. Learning cycle is regarded as one of the effective, hands-on inquiry-based scientific pedagogy; especially for enhancing understanding (Stamp & O'Brien, 2005). The inception of this model can be traced back to an elementary school science curriculum project during the late 1950s by the Science Curriculum Improvement Study (SCIS) in America ((Bybee et al., 2006).

In general, the learning cycle is considered to be a guided inquiry approach to science where the teacher provides only the materials and problems required for scientific investigations and the students execute their own procedures to solve problems under the guidance of teachers (Martin-Hauser, 2002; Windschitl, 2003).

Numerous studies have shown that the learning cycle as a model of instruction is far superior to transmission models in which students are passive receivers of knowledge from their teachers (Bybee, 1997). As an instructional model, the learning cycle provides active learning experiences.

The effectiveness of the learning cycle model is evidenced by its positive influence on students' achievement in science and also in enhancing students' critical thinking skills and attitudes towards science (Dogru-Atay & Tekkaya, 2008).

According to Quarareh (2012), the learning cycle model has made great strides in the educational field as an effective instructional strategy that harmonizes with the nature of science and attaches great importance to the learner.

Cavallo (2003) in a study examined the effect of the learning cycle on students' interpretation of chemical reactions and found that students understanding and interpretation of chemical reactions improved significantly in comparison with their colleagues taught using the traditional approach. Kevin (2003) also found that the learning cycle had significant effect on students' comprehension of the laws of mechanics.

The learning cycle, as first developed by Robert Karplus, constituted only of three phases**:** exploration, concept introduction, and concept application (Dogru-Atay &Tekkaya, 2008). The exploration phase marked the beginning of the cycle. During this phase, the teacher provides learners with concrete experiences related to the content to be learned. This allows students to mentally examine ideas by brainstorming to recollect what they already know.

After the exploration phase, the teacher introduces the concepts to the learners more explicitly. The teacher promotes a discussion period in which students share their observations with their peers. The teacher then links learner experiences to the relevant scientific concept. After the introduction of the scientific concepts, learners engage in additional activities in which they apply their newly developed knowledge to new situations (Colburn & Clough, 1997; Settlage, 2000).

According to Abraham and Renner (1986), there is a direct correspondence among the elements of Piaget's mental function model and the phases of the learning cycle. For example, the exploration phase allows students to assimilate the essence of the science concept through direct experience.

When students investigate a new concept through exploration, their new experiences cause them to re-evaluate their past experiences. This process produces disequilibrium, and students need to integrate the concept to reach a state of equilibrium.

The concept application phase provides students with opportunities to relate newly developed science concept to everyday applications through a cognitive process that Piaget referred to as organization. This phase helps learners to mentally organize new experiences by forming connections with previous experiences (Dogru-Atay & Tekkaya, 2008).

As the learning cycle was continuously used, researched, and refined over the years, the stages in the original cycle were modified and extended. The three stages in the cycle were extended to four sequential phases: engagement, exploration, explanation and extension. This 4E learning cycle model was later extended by some practitioners into a 5E model through the addition of a fifth stage known evaluation phase. (Sarac, 2018).

The 5E instructional model is the most frequently used constructivist learning cycle model in science education research studies. The model has been employed in many studies to enhance students' understanding of different science topics (Ayede, Kesercioğlu & Arabacioğlu, 2010; Bryce & McMillan, 2005).

2.8 The 5E Instructional Model as a Major Scientific Pedagogy

The 5E instructional model was initially proposed by Karplus, as part of the Science Curriculum Improvement Study (SCIS) project (Fuller, 2002). The 5E instructional model is made up of five phases: engagement, exploration, explanation, elaboration and evaluation.

Each phase of the model is characterized by a distinct group of activities initiated by the teacher. These activities allow learners to play a central role in the learning process. All the phases of the 5E model are interdependent. This therefore indicates that each phase of the model is dependent on the preceding phase. Explanations of the phases as presented by David (2003) and Khatayebeh (2005) are outlined below**:**

2.8.1 Engagement

The first stage of the 5E instructional model is the engagement stage. The purpose of this stage is to stimulate student's interests and focus their attention on the topic to be learnt. This phase is designed to help students to understand the nature of the topic to be learnt or learning task to be performed.

In line with this, students' interests in a topic are first stimulated by the teacher through the use of open-ended questions. The questions allow students to connect their previous learning experiences to the new learning situation. Students are prompted to identify their own questions relating to the topic to be learnt. Students explore the questions after they gain more understanding of the topic.

The teacher assesses what the students already know about the topic and helps them to make meaningful connections of the new knowledge with their existing knowledge and experience. Teachers also at this stage spell out the purpose and objectives of the lesson to the students in order for them to know what is expected of them at the end of the lesson.

Activities in this stage include reading, posing questions, defining problems and demonstrating a discrepant event using small group discussions which stimulate students' interests and fosters collaboration. In order to connect science to students' daily lives, important historical events such as natural disasters, scientific inventions and discoveries are used to stimulate students' curiosity and motivate learning.

2.8.2 Exploration

The exploration phase allows students to get involved in the topic to be learnt by providing them with a chance to build their own understanding. Students have the opportunity to get directly involved with the key concepts of a lesson through guided exploration of science topics.

Through the process of questioning and guided-inquiry, teachers facilitate the process of helping students to formulate their own understanding of the basic concepts in a lesson. Teachers observe the students as they interact with each other during the learning process. Teachers ask probing questions to help students to clarify their understanding of major concepts and redirect their investigations when necessary.

The engagement phase essentially allows students to thoroughly investigate questions they generate from the topic of study and the questions asked by the instructor. It provides hands-on experiences, which is later used to formally introduce students to science concepts, processes and skills.

2.8.3 Explanation

In this stage, the teacher formally introduces the students to key concepts in the lesson. Through readings and discussions, students gain understanding of the major concepts and verify answers to questions or problems posed earlier. Abstract concepts that were not thoroughly understood by the students at the exploration phase are re-introduced and explained by the teacher.

Students are guided by the teacher to formulate new ideas to explain observations made during the exploration phase. Students' explanations are clearly connected to the experiences they had in the engagement and exploration phases. Unanswered questions that still persist at the end of this phase are solved in the elaboration stage.

2.8.4 Elaboration

In the elaboration stage, students extend and expand upon what they have been learning in the earlier parts of the model. Students gain new information through formal experimentation, further research, or other sources. The teacher may give them additional information. They might ask new questions, seek clarification, or plan and carry out a new project.

Students apply the newly-learnt concept to a new context. They have opportunities to use new terms and definitions. The elaboration phase allows students to apply the concepts and skills gained from the lesson to different learning situations, resulting in a deeper understanding.

Students might also at this stage attempt to solve a new problem, make a decision, perform a task, resolve a conflict, and invent something based on the topic learnt.

Some misconceptions of students that were not thoroughly dealt with in the previous phases of the model are meticulously elaborated by the teacher at this stage. The elaboration phase also involves teachers providing closure to lessons by re-emphasizing the key points of the lesson and verifying students understanding through questioning.

2.8.5 Evaluation

Even though the fifth and final phase of the model is devoted to evaluation, a skillful teacher evaluates at each phase of the model, continually assessing students' progress in the lesson. The evaluation phase provides opportunities for teachers to evaluate students' progress towards attaining instructional objectives. The evaluation phase also provides students with opportunities to assess their own understandings and abilities.

Teachers help students to share their work with their peers, evaluate and compare their understanding with their prior knowledge. Using questions, teachers are able to assess students' comprehension of new vocabularies and concepts.

In addition to formative evaluation, summative evaluation can also take place during the evaluation phase. It may be in the form of an application problem to solve, a test, or a culminating project. Rubrics or other forms of criteria for summative evaluation are shared with the students at the beginning of the lesson.

In summary, even though each phase of the instructional model has a specific function, collectively they help to improve teachers' abilities to challenge and extend students' conceptual understanding and skills whiles providing new experiences through which students can develop deeper and broader understanding which can be applied to different learning situations (Bybee, 2006).

2.9 Academic achievement in Science

Promoting students' academic achievements in science has long been an important goal of science education across all educational levels (Biggie & Hunt, 1980). Students' academic achievements are commonly measured through examinations, tests, assignments, group work and other continuous assessments (Tomporowski, Davis, Miller & Naglieri, 2008).

Scores obtained by students' in classroom exercises, assignments, tests and examinations quantify students' academic achievements. Students' academic achievements provide teachers with useful insight on their learning progress. It enables teachers to assess the extent to which students have acquired knowledge and skills (Sukola, 2015).

Students' achievement in this study was determined by comparing their mean pretest and posttest scores on the genetics achievement test. By comparing students' scores, the researcher was ultimately able to determine the effect of the 5E instructional model on students' achievement in genetics.

Students' achievement in science have been noted to be significantly influenced by cognitive variables such as formal reasoning ability, prior knowledge and learning orientation.

2.9.1 Cognitive variables that influence students' achievement in science

Formal reasoning ability, learning orientation, and prior knowledge are important cognitive variables that influence students' achievement in science. Among all the cognitive variables, the role of students' formal reasoning in their achievement in science has received most attention (Dogru-Atay & Tekkaya, 2008).

Rips (2004) defines reasoning as a mental process that enables people to construct new representations from existing knowledge. It includes cognitive processing that is directed at finding solutions to problems by drawing conclusions based on logical rules or rational procedures (Mayer & Wittrock, 2006).

Formal reasoning encompasses the ability to formulate a problem, design scientific investigations to evaluate experimental outcomes and make causal inferences in order to form and modify theories related to the phenomenon under investigation (Teig & Scherer, 2016).

Formal reasoning is characterized by the rule of logic and mathematics, with fixed and unchanging premises (Teig & Scherer, 2016). Formal reasoning ability emanates from developmental psychology and includes the ability to identify and control variables and to use correlational, combinatorial, probabilistic, and proportional logic (Ertepinar, 1995).

Many researchers have reported that one of the strongest predictor of students' meaningful understanding of abstract scientific concepts like genetics is their formal reasoning ability. In a research on the relationship between formal reasoning ability, computer assisted instruction and chemistry achievement, Ertepinar (1995) found that formal reasoning ability is an underlying intellectual factor associated with science concept achievement.

Dogru-Atay and Tekkaya (2008) reported that students with high formal reasoning ability, who no longer require concrete materials to make rational judgments and are capable of hypothetical and deductive reasoning, performed better than students with low formal reasoning ability.

According to Dogru-Atay and Tekkaya (2008), students with high formal reasoning abilities are able to develop sound understanding of both concrete and abstract concepts. They are capable of looking for relations, generating and testing alternative solutions to problems, and drawing conclusions by applying rules and principles.

Low-formal students are concrete reasoners who are unable to develop sound understanding of abstract concepts. They are only able to understand concrete concepts. Students with low formal reasoning ability have not fully developed the ability to rationalize formal and abstract concepts.

In an earlier study, Lawson and Renner (1975) reported that interpreting and solving genetics problems requires formal-level operations such as probabilistic, combinational, and proportional reasoning that is in line with Piaget's developmental theory.

In testing the hypothesis that formal reasoning ability is essential for high school students to successfully deal with misconceptions and develop scientifically acceptable conceptions of genetics and natural selection following standard lecture-textbook-based instruction, researchers found that the number of misconceptions is consistently, statistically, and significantly related to reasoning ability (Dogru-Atay & Tekkaya, 2008).

Learning orientation has also been identified to have significant influence on students' science achievement. Cavallo and Schafer (1994) defined learning orientation as the extent to which learners use meaningful or rote approaches to learn new information. Students with a meaningful learning orientation try to make connections among concepts, whereas students who do not possess a meaningful learning orientation concentrate on memorizing ideas, concepts, and facts.

In their study, Cavallo and Schafer explored the relation between students' meaningful learning orientation and their understanding of meiosis. They found that meaningful learning orientation and prior knowledge were significant predictors of students' meaningful understanding of meiosis.

In another study, Cavallo (1996) explored the relations among students' meaningful learning orientation, reasoning ability, and acquisition of genetics topics. The study found that meaningful learning orientation best predicted students' understanding of genetics interrelations.

Also, students' formal reasoning abilities best predicted their capabilities to solve genetics problems. Cavallo concluded that students' use of meaningful learning was most important for understanding genetics concepts, whereas formal reasoning was most important for solving genetics problems (Cavallo, 1996).

Apart from reasoning ability and meaningful learning orientation, researchers have revealed that achieving meaningful understanding might also require relevant prior knowledge. Haidar (1988) compared high school chemistry students applied and theoretical knowledge of concepts on the basis of the particulate theory. The study revealed that students' formal reasoning ability and preexisting knowledge played a significant role in their conceptions and use of the particulate theory (Dogru-Atay & Tekkaya, 2008).

Kang, Scharmann and Koh (2005) examined the relations among Korean high school students' cognitive and motivational variables, cognitive conflict, and conceptual change regarding density concepts. The cognitive variables examined were logical thinking ability, field dependence or independence, and learning approach. The results of stepwise multiple regression analysis showed that logical-thinking ability, field dependence or independence and failure tolerance were statistically significant predictors of conception test scores (Dogru-Atay & Tekkaya, 2008).

2.10 Factors that Hinder Students' Achievement in Genetics

Certain factors have been noted to adversely affect students' achievement in genetics. These factors include poor teaching methods, the complex and abstract nature of genetics, poor usage of genetics terminologies and symbols, and poor understanding of the process and structures involved in the storage and transmission of genetic information (Elias & Zulu, 2017).

Teacher-directed instructional strategies like expository instruction conventionally employed in most science classrooms have been found to be inadequate in improving students' achievement in genetics (Banet & Ayuso, 1999). Expository instruction is largely characterized by lengthy explanation of concepts or processes and the use of teacher-led classroom discussions and demonstrations, thus it is noted to be a 'traditional' teaching method.

Traditional teaching methods take students prior knowledge into little consideration, therefore providing little opportunities for students to meaningfully construct their own understandings of the topic.

Traditional teaching methods scarcely considers the individual interests and learning needs of students, thus teachers may be unable to properly diagnose students learning difficulties and generate possible solutions to address them. Traditional teaching methods are considered to be poor teaching methods because of their inadequacy to sufficiently address the individual learning needs of students and their inability to encourage active students' participation.

Banet and Ayuso (1999) in a study on teaching genetics at secondary schools**:** a strategy for teaching about the location of inheritance information criticized the 'traditional' teaching approach as having had little impact on students' acquisition of meaningful understanding of genetics.

The adverse effect of poor teaching methods on students' achievement in science can be sufficiently addressed when teachers adopt and implement more effective and innovative students-centred instructional methods like the 5E instructional model.

The 5E instructional model as opposed to the traditional teaching methods comprise different set of activities that are uniquely designed to stimulate students' interests, encourage active participation and provide opportunities for students to apply the knowledge they have acquired to new learning situations (Settlage, 2000).

Students' will have better achievements in science only when they understand the science content delivered to them by their teachers. The 5E instructional method can help to promote this effort.

The abstract and complex nature of genetics have also been noted to be another factor that hinders students' achievement in genetics. In a study conducted in Scotland to identify the perceptions of students' and teachers on biology topics considered as difficult, Bahar Johnstone and Hansell (1999) found that five out of the six topics from the field of genetics were regarded as difficult.

The topics included meiosis, gametes, alleles, genes and genetic engineering, along with monohybrid and dihybrid crosses and linkages. These genetics concepts are basically abstract, thus requiring a high level of formal reasoning in order to understand them.

Students with low formal reasoning will experience considerable difficulties comprehending these abstract genetics concepts, thus causing them to have low achievement in the topics.

The structure of the knowledge of genetics is complex and students have to use this complex knowledge in solving complex genetics tasks (Collins & Stewart, 1989). Genetics is connected with the occurrence of ideas and concepts on different levels of thoughts, and students have difficulties linking different genetics concepts and processes (Kılıç, Taber & Winterbottom, 2016).

The complexity of genetics coupled with its abstract nature makes it quite difficult for students to attain significant achievements in the topic. In order to address the difficulties associated with genetics due to its abstract nature, the researcher recommends the combined use of appropriate teaching and learning materials and practical activities in teaching the topic.

The use of teaching and learning materials and practical activities to support sciences lessons enable students to appreciate abstract science topics like genetics better. Students are sometimes able to relate to abstract genetics concepts when they are involved in more practical activities. The researcher in this study conducted an experiment on monohybrid inheritance using red and white beans and observed that students participated more actively in the lesson.

In order to address the challenge associated with the complexity of genetics concepts, genetics content delivered to students by teachers ought to proceed from simple to complex. As specified in the science syllabus, basic genetics concepts such as the concept of inheritance should be taught first and illustrated with appropriate examples before moving onto more complex concepts like the application of Mendel's laws in genetic crosses and sex linkages.

Bahar, Johnstone and Hansell (1999) also agreed that teachers should confine themselves to teaching genetics starting from the simplest concepts and gradually progressing to the complex ones. Lessons should thus proceed from concepts students are already familiar with to the abstract concepts.

Marbach-Ad and Stavy (2000) reiterated the need for science lessons to be taught on the macroscopic level and then microscopic level, molecular level and symbolic level, step by step in order to address challenges associated with the inherent complexity of genetics.

Another factor considered to hinder students' achievement in genetics is their poor understanding and usage of genetics terminologies. Teachers and science textbooks are noted to be two of the important sources through which genetic terminologies are introduced to students (Banet & Ayuso, 1999).

Pearson and Hughes (1986) found that teachers sometimes present the definitions of genetics concepts to students in an unclear manner which promotes the misunderstanding of the concepts. Students have also been noted to misinterpret important concepts like gene, chromosome, allele, gamete, and zygote (Yu-Chien, 2008).

In addition, certain science textbooks have been found to contain incorrect definitions and use of basic genetics terminologies. Students' exposure to such textbooks will cause them to define and use genetics terminologies incorrectly and this may reflect in their academic work causing them to have low academic achievements in genetics.

In order to promote students' understanding and usage of genetics terminologies, Yu-Chien (2008) recommended that science textbooks writers and teachers need to be selective and specific in their use of genetics terms, and avoid using too many synonyms as students can be easily overwhelmed by the number of new genetics terms.

In certain situations, teachers could encourage pupils to explain genetic concepts in their own words in order to avoid rote-memorization of teachers' explanations. Through this both teachers and students can arrive at shared meaning (Johnstone & Selepeng, 2001).

Teachers also need to ensure consistency in use of genetics terminologies as so as to avoid generating confusion among students. Pearson and Hughes (1986) suggested that an adequate selection in the use of genetic terms should be made to prevent extensive terminologies and avoid confusion.

Finally, poor understanding of the process and structures involved in the storage and transmission of genetic information have been found to hinder students' achievement in genetics. Research findings reveal that there is a poor understanding of the processes by which genetics information is transferred, and a lack of basic knowledge about the role of the structures involved such as gene, chromosome and cell (Dogru-Atay & Tekkaya, 2008).

Similarly, Albaladejo and Lucas (1988) also found that students do not fully understand the nature of structures like the chromosomes, genes and alleles which are involved in the transfer of genetic information. Students have considerable challenges relating the structure of the DNA to its function as the storage unit of genetic information (Yu- Chien, 2008).

Students understanding of the structures and processes involved in genetics enables them to establish meaningful connections between different genetics concepts. When students have a poor understanding of processes and structures involved in the storage and transmission of genetic information, it ultimately affects their achievement in genetics.

In order to enable students to better appreciate of the role of certain structure like the genes, DNA and chromosomes in the transmission of genetic information, teachers can support their explanations with charts, models, computer simulations and other teaching and learning materials. These materials enable students to better visualize these structures and properly related them to their functions.

The instructional approach selected and used by teachers to teach genetics is also very important. The instructional strategy employed may either enhance students' understanding of genetics or generate misconceptions.

The 5E instructional model has been found to be effective in promoting students' understanding of different science topics, thus it is recommended by many researchers to be effective in sufficiently addressing the factors that impede students' achievement in genetics (Dogru-Atay & Tekkaya, 2008).

2.11 5E Instructional Model and Students' Achievement in Science

The 5E instructional model have been found in many studies to be an effective instructional strategy in the teaching and learning of science. The 5E instructional model has been found to improve students understanding of science concepts and consequently enhance their achievement.

Odom and Kelly (2001) in a study explored the effectiveness of concept mapping, the learning cycle (5E instructional model), expository instruction, and a combination of concept mapping/learning cycle in promoting conceptual understanding of diffusion and osmosis. They found that the concept mapping/learning cycle and concept mapping treatment groups significantly out-performed the expository treatment group in conceptual understanding of diffusion and osmosis.

Balci, Cakiroglu and Tekkaya (2006) in another study found significant differences among 5E model and traditional groups in favour of the 5E instructional model with respect to students' understanding of photosynthesis and respiration in plants.

Ndioho (2007) investigated the effect of constructivist instructional model on Senior Secondary students' achievement in biology using 5E instructional model. The study revealed that the constructivist 5E instructional approach was significantly more effective in increasing students' academic achievement than lecture method.

Özlem and Jale (2010) investigated the effectiveness of 5E instruction on students' achievement in the human circulatory system. The results obtained revealed that 5E instructional model improved students' achievement in human circulatory system compared to traditional instruction.

In similar studies, Cardak, Dikmenli and Saritas (2008) investigated the effect of 5E instructional model on students' achievement in the circulatory system. While the experimental group and the control group were the same at first, after implementation the 5E instructional model, there was an important difference in favor of the experimental group.

The findings of the empirical studies above clearly demonstrate the effectiveness of the 5E instructional model in enhancing students' achievement in science.

2.12 Students' Attitude and Academic Achievement in Science

The term attitude is derived from the Latin word '*aptus*' which is also the root of the word aptitude. Salta and Tzougraki (2004) defined the term attitude as the tendency to think, feel or act either positively or negatively towards objects or people in our environment.

Attitudes are acquired through learning and can be changed through persuasion using a variety of techniques that ultimately stimulate students' interest and curiosity (Adesina & Akinbobola, 2005). Attitude towards science refers to students' interests or feelings towards studying science (Yara, 2009).

Reid (2006) identified four target areas as important features of students' attitude towards science. These areas included students' attitudes towards the science subject itself, attitudes towards the learning of science subject (process of learning), attitudes towards the process of science (scientific attitudes), and attitudes towards themes, topics, issues arising in the study of a science subject.

Students are predisposed to either be interested or disinterested in studying science. Koballa (1988) found that there is a proportionate relationship between students' attitudes towards their subject of study and their achievement. Students' attitudes towards science have been a persistent concern in science education for many decades (Osborne, Simon & Collins. 2003).

Instructional strategies used by instructors have been found to have profound impact on students' attitude to science (Halladyna & Shaughnessy, 1982). Numerous studies report the effectiveness of the 5E instructional model in increasing students' achievement in science, promoting conceptual understanding and enhancing students' attitude towards science (Dogru-Atay &Tekkaya, 2008).

In a study to determine the effectiveness of the 5E instructional model in improving students' scientific attitudes, Faizin, Wahab and Jamaluddin (2018) concluded that the scientific attitudes of learners can be improved through the 5E instructional model.

In a research to determine the effect of the 5E instructional model on students' academic achievement, attitude, motivation and retention, Uyanık (2016) found that the 5E science instruction was more effective than teacher centered teaching at increasing motivation towards science learning, academic achievement and retentive learning.

Dogru-Atay and Tekkaya (2008) cited a study conducted by Hassan (1975) in Jordan to determine the influence of some selected instructional, student and home variables on students' attitudes toward science in secondary schools and found that out of the seven investigated variables, student's perception of his/her science ability had the most important effect on their attitudes toward science.

Studies on students' attitudes toward science revealed that students exhibit positive attitudes toward the utility of science, while their attitude towards science declines as they progress to the higher grades (George, 2006). Students' negative attitudes towards science has been identified as one of the important factors which restrict them from continuing their career in science (Ramsden, 1998).

The results of a multidimensional, longitudinal study of students' attitudes toward and achievement in science conducted by Simpson et al showed that boys had more positive attitudes towards science than girls even though girls were more motivated than boys to achieve in science (George, 2000).

Chuang and Cheng (2002) studied and investigated the correlations between gender, aptitude for biology, scientific attitudes, scientific process skills and rational thinking ability in China and concluded that a positive correlation existed between students" attitudes, and aptitude towards biology, scientific attitudes, scientific process skills and rational questioning ability. They also observed that higher scores on attitude and aptitude towards biology lead to higher achievement level of students in biology.

Empirical studies on students' attitudes and their academic achievements in science reveal that students' attitude toward science are the basis for higher achievements (Akinmade, 1992). Bassey, Umoren and Udida (2008) in their study on Nigerian secondary school students' attitude and performance in chemistry found that there was a significant positive relationship between students' attitude towards chemistry and their performance in chemistry.

2.13 Gender and Students' Achievement in Science

The term 'gender' according to Okeke (2008) describes the socially and culturally-constructed characteristics and roles which are ascribed to males and females in any society. It refers to the socially-constructed roles of and relationships between men and women.

Researchers have documented that science is one of the areas in which gender difference is most strongly pronounced (Halpern, Benbow, Gur, Hyde & Gernsbacher, 2007). Gender issues in science has been the concern of many science educators and researchers alike with series of researches still being conducted in this area.

Most of the gender studies pertaining to science education have been focused on identifying and addressing issues relating to the low participation and achievement of females in science (Miller, Slawinski & Schwartz, 2007).

In a study on gender and science achievement, Dahiru (2013) opined that even though sex plays no significant role in students' achievement in science and technology, female achievement in science, technology and mathematics was still not fully encouraging.

Young and Fraser (1994) in a study on gender differences in science achievement found significant gender differences in biology achievement in favour of boys. Njoku (2004) in a study reported that boys perform better than girls in science, technical and mathematical subjects. Boys have been found to be superior in the physical sciences, an area where most girls have been noted to experience considerable difficulties (Aigbomian, 2002)

Quite differently from the above findings, Stark and Gray (1999) reported that girls performed at significantly higher levels on tasks in which the content and context were drawn from the biological sciences and on written tasks assessing science skills. Philips, Chandrasekher, Barrow and Litherland (2000) in a study found that girls show greater participation in science than boys.

Alparslan, Tekkaya and Geban (2003) explored gender differences in the relative effectiveness of two modes of treatment (conceptual change instruction and traditional instruction) on high school students' understanding of respiration. They reported a significant difference between girls' and boys' performance in favour of the girls. They however found the interaction of treatment with gender difference to be non-significant for learning the concept of respiration.

Some researchers have however reported no significant differences between boys and girls with respect to science achievement. For example, Dimitrov (1999) indicated that there is no significant difference between girls and boys with respect to their achievement in life sciences.

From the foregoing, it is quite evident that researchers are not unified in their findings on whether or not students' sexes play a significant role in their achievement in science. Whiles some studies report either males or females making significant strides in their achievement in science yet still others report no significant difference in the achievements of males and female in science.

The researcher is of the opinion that students, irrespective of their sexes, possess the abilities to make significant achievements in science when provided with the needed learning support. Teachers therefore have a critical responsibility to play in ensuring that the selection and use of instructional strategies in science classrooms eliminates all sources of gender-biases and maximizes students' academic achievements.

Lawal (2009) in a gender and science related study found no significant difference in gender when students were taught using conceptual change instructional strategy, however a significant gender difference was produced when the students were exposed to the traditional instructional strategy. This clearly shows the importance of implementing instructional strategies that caters for the gender needs of students and encourages active participation of all students.

The researcher also believes that in recent times, female participation in science at the basic level has undergone significant improvement. A lot of effort however need to be invested in promoting female achievement in science as it has still been found not fully encouraging.

2.14 Overview of Empirical Studies Relevant to the Present Study

Many science educational studies have explored the effect of the 5E instructional model on students' academic achievement. Some examples of these studies are presented below:

Balcı, Çakıroglu and Tekkaya (2006) carried out a study to investigate the effects of the 5E learning cycle instruction, conceptual change text, and traditional instructions on high school students understanding of photosynthesis and respiration in plants. 101 high school students belonging to three intact classes in the same school were used in this study.

There were three groups formed in this study. Two of the groups were assigned as experimental groups. One of the experimental groups was taught using 5E learning cycle model and the other using conceptual change text instruction. The third group, defined as control group was taught using traditionally designed instruction.

The results showed that there were significant differences between the experimental and control groups in favor of the experimental group, with respect to students' understanding of photosynthesis and respiration in plants. On the other hand, there were no statistically significant difference between the students who were instructed using the 5E learning cycle instruction and the conceptual change texts, with respect to students' understanding of photosynthesis and respiration in plants.

In a related study, Cakiroglu (2006) investigated the effectiveness of the 5E instructional model on high school students' achievement on photosynthesis and respiration in plants.

Students' knowledge on photosynthesis and respiration in plants was determined by a test developed by Haslam and Treagust. This test was applied to 67 high school students in two classes of the same elementary school as pre-test and post-test.

The experimental group students (n=33) were exposed to the 5E learning cycle instruction whiles the control group students (n=34) were exposed to traditional instruction. The study found a significant difference between the experimental and control groups in favor of 5E learning cycle instruction.

Ndioho (2007) investigated the effect of constructivist instructional model on senior secondary students' achievement in biology using 5E learning cycle. The study adopted a quasi-experimental non-equivalent control group design. The three schools that were chosen for the study included two co-educational boys' schools and one girl school. From each school 30 students were selected. One group was assigned the experimental group while the other the control group.

The experimental group was taught genetics using the constructivist instructional approach and the control group was taught using lecture method. Genetics Achievement Test was used to post-test both groups. The result showed that the constructivist instructional approach was significantly more effective than the lecture method in increasing students' academic achievement.

Finally, Açışlı, Altun and Yalçın (2011) evaluated the efficiency of students guiding materials and the 5E teaching model on students' achievement. The materials were developed by the researcher, based on the instructional objectives for Movement and Force.

The study employed quasi experimental research design and included 60 sample students. The experimental and control groups comprised 30 students each.

The experimental group were given experiment booklets, which were prepared for each experiment on Movement and Force in accordance with the 5E learning model. The control group were however exposed to the lecture method of instruction.

In order to determine whether or not significant differences existed between the two group's academic achievements, achievement tests on Movement and Force were administered to the two groups, both at the beginning and at the end of the semester as pretests and posttests.

Students' pretest and posttest results were compared using student's t-test analysis. The results analysis showed that a meaningful difference existed between the two groups in favor of the experimental group.

In conclusion, the findings from the empirical studies above provide further evidence to support the fact that 5E instructional model is more effective than the lecture method and other traditional instructional strategies in promoting students' achievement in science.

2.15 Implications of the Reviewed Literature to the Present Study

All the literature reviewed in this chapter provided insight on the nature of the 5E instructional model, the philosophical underpinnings of the model and its effectiveness in promoting students' understanding and achievement in science. The literature reviewed in this study also highlighted the fact that the use of the 5E instructional model in science instruction had a positive effect on students' attitude to science.

The empirical studies reviewed in this chapter clearly showed the inadequacy of traditional teaching methods in enhancing students' achievement in science. Finally, the review of literature in this study provided opportunities for the researcher to support the effectiveness of the 5E instructional model in enhancing students' achievement in science with enough empirical evidence.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter describes how the study was conducted. The chapter begins with a detailed description of the research design used and a profile of the study area. It also covers the population, sample size and sampling techniques, research instruments and validity and reliability of research instruments. The concluding part of this chapter describes the procedure used in collecting and analysing data.

3.1 Research Design

Research design consists of the framework of methods and procedures chosen by the researcher to combine various components of research into a reasonably logical manner so that the research problem is efficiently handled (DeVaus, 2001).

According to Durkheim (2004), research design is a strategic framework for action that serves as a bridge between research questions and the execution or implementation of the research strategy. It constitutes the blueprint for the collection, measurement and analyses of data (Garg & Kothari, 2004).

The design employed in this study is the quasi-experimental research design. According to Shuttleworth (2008), quasi experimental design involves the selection of groups, upon which a variable is tested without any random pre-selection processes.

The lack of randomization in the assignment of research subjects to either a control or experimental group distinguishes quasi-experimental design from true experimental design (Shadish, Cook & Campbell, 2002).

Contrary to true-experimental designs, quasi-experiments typically exhibit a pronounce weakness in terms of demonstrating causation as other confounding variables influencing the outcome of the treatment may not be statistically controlled (Shadish, Cook & Campbell, 2002).

But despite this weakness, quasi-experimental research designs are particularly useful in situations where it is very difficult or practically impossible to individually assign subjects to a control and experimental group, as was the case in this study (Price, Jhangiani & Chiang, 2013).

Since this study was conducted during the school's regular instructional period, the researcher was not permitted to disorganise the form three classes, assign students' randomly to control and experimental groups for research purposes and then reconstitute them again. The researcher therefore resorted to using intact classes instead. The use of intact classes rather than the random assignment of individual students characterizes quasi-experimental research designs.

Quasi-experimental research designs are widely used in studies to evaluate the effectiveness of teaching interventions (Eliopoulos, Bradham, Baumgarten, Zuckerman, Fink & Perencevich, 2004). Quasi-experimental research designs are typically used to show an intervention's impact on a target population (Eliopoulos *et al.*, 2004).

This constitutes another reason why the researcher employed quasi-experimental design in this study. The study was primarily aimed at determining the effectiveness of the 5E instructional model on students' achievement in genetics.

The researcher in this study administered a genetics achievement test to both the experimental and control groups in order to measure their achievement in genetics before and after the implementation of the 5E instructional model and expository instruction respectively. This therefore influenced the researcher's choice of the pretest-posttest nonequivalent control group quasi-experimental design among all the different types of quasi-experimental designs.

One advantage of using the pretest-posttest nonequivalent control groups design in this study was that it provided the researcher with the opportunity to compare the students' scores before and after the treatments, 5E instructional model and expository instructional method, were administered in order to evaluate the effectiveness of the treatment.

The researcher was also able to determine which of the treatments was successful by comparing the mean scores attained by both the experimental and control groups in the Genetics Achievement Test (GAT).

Sukola (2015) summarized the overall benefits of the using pretest-posttest nonequivalent control groups quasi-experimental design in three main points which are presented as follows—the superiority of one instructional strategy over the other can easily be tested; it give indications of concept attainment ability or understanding gained by students after they have been exposed to a particular teaching treatment; and the pretest scores giving indication as to whether the groups are equal in the concepts they hold before interaction was given.

3.2 Study Area

The study was conducted at Uncle Rich Senior High School, a private senior high school in Winneba. Winneba is the administrative capital of the Effutu Municipal Assembly in the Central Region of Ghana.

Uncle Rich Senior High School together with Winneba Business Senior High and A.M.E Zion Girls Senior High School constitute the only three private senior high schools in the Municipality. The only public senior high schools in the Municipality are the Winneba Senior High School and Winneba Vocational Training Institute.

Uncle Rich Senior High School was founded in 2008 with the aim of providing quality private senior high tuition to all students, especially to those who were unable to secure admissions to public second cycle institutions (R. E. Baidoo, personal communication, December 11, 2019). The school also provides remedial tuition for students who were unable to obtain good grades in the West African Senior High School Certificate Examinations (WASSCE).

Uncle Rich Senior High School has a students' population of about 195 with 8 permanent teachers and four part-time teachers. The school offers programmes such as General Arts, General Science, Business, Visual Arts and Home Economics. The researcher conducted the study at Uncle Rich Senior High School because it was readily accessible and had adequate educational facilities and materials to facilitate the teaching and learning process.

3.3 Population of the Study

According to Kenton (2019), a population refers to the entire pool from which a statistical sample is drawn. Research population includes all the elements (individuals, objects and events) that meet the sample criteria for inclusion in a study. It is for the benefit of the population that researches are conducted.

The entire group of individuals or objects to which the researcher would like to generalize the findings of a study to is the target population whereas the accessible population refers to a subset of the target population to which the findings of a study can be applied to (Hassan, 2019).

The target population for the study included all the final year students in the senior high schools in Winneba. Among these schools, final year students from Uncle Rich Senior High School constituted the accessible population.

The rationale for the inclusion of only final year students in the study was based on the fact that the senior high school science syllabus specifies that genetics should be taught in the third year of the senior high school level due to its abstract and complex nature.

By virtue of the researcher's position in the school as a science instructor at Uncle Rich Senior High School, the researcher had the opportunity to interact extensively with the students before, during and after the implementation of both the 5E instructional model and expository instruction.

At Uncle Rich Senior High School, the researcher had access to the science laboratory where an experiment on monohybrid inheritance was conducted. The experiment was conducted purposely to allow students to observe and understand the outcomes of monohybrid crossings and also to identify dominant and recessive traits in a given species sample.

3.4 Sample Size and Sampling Technique

According to Mouton (1996), a sample refers to the elements selected with the intention of finding out something about the population from which they were taken. It is a subset of the population selected for measurement.

A sample of 84 form three students belonging to five intact classes namely: General Arts, General Science, Business, Home Economics and Visual Arts classes were involved in the study. The sample for the study comprised of 45 (54%) females and 39 (46%) males. The uneven number of males and females in the study sample could be attributed to the fact that the school has a greater number of female enrollment than males.

Since quasi-experimental research design permits the use of already existing groups in instances where is difficult to individually assign research subjects to either a control or experimental groups, the researcher resorted to using intact classes for the study. Simple random sampling was employed in assigning the intact classes to an experimental and control groups.

The experimental group comprised students from the General Science and Home Economics classes while the control group comprised students from the General Arts, Visual Arts and Business classes. The number of students in the experimental and control groups were 40 and 44 respectively.

3.5 Research Instruments

The study employed the use of two main instruments namely Genetics Achievement Test (GAT) and 5E Instructional Model Evaluation Questionnaire in gathering relevant data for the study. Detailed descriptions of each of these instruments are presented in the sub-sections that follow**:**

3.5.1 Genetics Achievement Test

The Genetics Achievement Test (GAT) used in this study was designed by the researcher purposely to measure students' achievement in genetics. The test provided the researcher the opportunity to assess students' understanding of basic concepts in genetics, inheritance and genetic crosses.

The GAT comprised 20 multiple choice items. The researcher's preference for multiple choice test items over essay-type test items was primarily based on the fact that the objective nature of multiple-choice items limited any scoring biases (Fisher & Frey, 2015). The use of the multiple-choice items in this study also provided the researcher with the opportunity to cover more content areas under genetics.

The items on the GAT were carefully selected from the West African Senior School Certificate Examination (WASSCE) past questions. Questions from the West African Senior School Certificate Examination are set by knowledgeable and experienced examiners and thus are considered to be standardized.

The selected questions for the GAT covered content areas under genetics such as monohybrid and dihybrid inheritance, sex determination, inheritance of sex-linked traits, ABO blood groupings and Rhesus factor, and inheritance of sickle cell disease and albinism.

In order to enhance the content validity of the GAT, the researcher ensured that the selection of the past questions was done in alignment with the instructional objectives specified by the science syllabus under each of the genetics-related topics taught during the study.

The GAT was administered as a pretest and posttest to both the experimental and control groups before and after the implementation of the treatments, 5E instructional model and expository instruction respectively. For scoring purposes, a correct response to each multiple-choice item attracted a numeric value of 1 and 0 if the response was incorrect.

3.5.2 5E Instructional Model Evaluation Questionnaire

The 5E instructional model evaluation questionnaire was developed by the researcher with the aim of evaluating the effectiveness of the 5E instructional model in the teaching and learning of genetics from the students' perspectives.

The questionnaire comprised 10 items structured on a five-point Likert scale. Likert scale was used by the researcher because it has often been found to provide data with relatively high reliability and is quite easy to construct and use (Gable &Wolf, 1993). Robson (2002) opined that Likert scales looked quite interesting to respondents and this accounted for the reason why they enjoyed completing questionnaires with Likert scales.

The use of the Likert scale in rating items on the 5E instructional model evaluation questionnaire also provided the researcher with the opportunity to compute percentages and frequencies, as well as statistics such as mean and standard deviation of scores (Ngman-Wara, 2011).

Each item on the 5E instructional model evaluation questionnaire comprised a statement with five options. The students in the experimental group were required to respond to each item on the questionnaire by selecting one of the five options that best expressed their level of agreement or disagreement with the statements.

The numeric value assigned to the five options were as follows; Strongly agree (SA)=5, Agree (A)=4, Undecided (U)=3, Disagree (D)=2, Strongly disagree (SD)=1. The minimum and maximum scores attainable in the completion of the questionnaire were 10 and 50 respectively.

3.6 Validity of the Instruments

Nitko (2001) defined the term "validity" as the soundness of the interpretation and use of students' assessment results. Middleton (2019) explained that assessment tools or methods employed in a study can be described as valid only when it measures what it claims to measure and yield results that closely correspond to real-world values.

Price, Jhangiani and Chiang (2013) opined that validity can be categorized into three basic kinds: face validity, content validity and construct validity based on the nature of evidence upon which evaluations and interpretations are made. Face and content validities were used in this study to ascertain the validities of the research instruments.

Face validity describes the extent to which an instrument appears to measure what it is meant to measure (McLeod, 2013). In order to determine the face validity of the GAT and the 5E instructional model questionnaire, they were given to four experienced science teachers to read and assess among other things the clarity, readability and simplicity or difficulty of the items. The science teachers were also made to vet the appropriateness of the items on the two instruments.

The comments and suggestions received from the teachers were duly noted and served as useful inputs in the modification of the instruments. This in many ways also helped to enhance the content validity of the instruments.

Unlike face validity, content validity is concerned with the degree to which an assessment instrument is relevant to, and representative of the targeted construct it is designed to measure (Rusticus, 2014). In order to establish the content validity of the GAT, the researcher carefully selected WASSCE past questions that conformed to the instructional objectives specified under each of the genetics topics taught during the study.

The items on the GAT were meticulously scrutinized by the supervisor of this study in order to determine whether or not they adequately covered the content areas in genetics as specified by the syllabus. The feedback obtained from the supervisor after assessment of the GAT facilitated the modification of the test items.

3.6.1 Pilot-testing

Pilot-testing of the research instrument was conducted at A.M.E Zion Girls Senior High School. The GAT was administered to 42 students belonging to an intact class comprising General Science and Home Economics students. The students did not participate in the actual study. The researcher administered the test with the help of a science tutor in the school. The test lasted for an hour. Problems and difficulties arising from the testing were carefully noted and served as useful input in the modification of the GAT. The GAT was re-administered to the students after a few weeks. The reliability of the GAT was computed using the Statistical Package for Social Science (SPSS) v.16.

3.7 Reliability of the Instruments

Reliability according to Cohen, Manion and Morrison (2001) refers to the consistency of test scores. Reliability is the consistency with which an instrument measures what it claims to measure at any given time (Bichi, 2002).

The reliability of the GAT was determined using the test-retest method. The test-retest reliability coefficient as computed using the Statistical Package for Social Sciences (SPSS) software version 16 was 0.67. The internal consistency of the items on the 5E instructional model evaluation questionnaire was determined using Cronbach Alpha. The reliability coefficient was found to be 0.71.

3.8 Administration of the Treatment

The experimental group and control group involved in this study were taught genetics using the 5E instructional model and the expository instructional method respectively. Both the experimental and control groups were taught by the researcher over a period of six weeks. The experimental and control groups were made to write a pretest and posttest before and after the implementation of the 5E instructional model and expository instructional method respectively.

Content areas under genetics as specified by the science syllabus and covered by the researcher for both the control and experimental groups include: concept of inheritance, Mendel's first and Second laws, Mendel's experiment on monohybrid and dihybrid inheritance, sex determination and sex-linked characters, ABO blood group system and Rhesus factor and inheritance of sickle cell disease and albinism.

Two instructional strategies namely expository instructional method and 5E instructional model were used in teaching the control group and experimental group respectively over a period of six weeks. Both the control and experimental groups were taught the same genetics topics by the researcher.

3.8.1 Using expository instruction for the control group

Students in the control group were taught genetics using the expository instructional method. The expository instructional approach used by the researcher in teaching the control group was mainly characterized by the use of lecture and classroom discussion methods. Each lesson began with a quick review of students' relevant previous knowledge on the genetics-related topic to be learnt.

The teacher then introduced the topic to be learnt, defined and explained key concepts related to the topic and initiated a classroom discussion on some important concepts such as the concept of inheritance, Mendel's first and second laws of inheritance and its application in genetic crosses, inheritance of sex-linked characters, and sex determination.

The classroom discussions were predominantly motivated by teacher-directed questions making the students passively involved in the lesson. A summarized note covering the definitions and key points on the topic under study was dictated to the students. Word problems on monohybrid and dihybrid inheritance were first solved by the researcher on the chalkboard and then explained to the students.

The researcher guided the students to solve similar problems on their own and frequently moved round to check if each student was able to correctly solve the problems. The researcher gave the students practice questions on monohybrid and dihybrid crosses to further reinforce their understanding of the concept of inheritance.

3.8.2 Using 5E instructional model to teach the experimental group

Students in the experimental group were taught by the researcher using the 5E instructional model. The 5E instructional model was used with the aim of maximizing students' participation in the teaching and learning process, improving students' understanding of genetics concepts and ultimately enhancing their achievement in genetics.

In line with the fact that the 5E instructional model is a student-centered instructional strategy, each of the lessons on genetics taught to the experimental group by the researcher was designed to include five stages with unique set of activities that sought to enable students construct their own understandings of genetics. The researcher played the role of a guide/facilitator in the teaching and learning process.

A detailed description of the teaching and learning activities related to each stage of the 5E instructional model as used in one of the lessons on monohybrid inheritance with the experimental group is presented as follows**:**

3.8.2.1 Engagement

The researcher began the lesson with a short and interesting story on Gregor Mendel's experiments on the garden pea plants. The researcher through the story unraveled how Mendel's experiments on the garden pea plants contributed to development of the concept of inheritance and served as the foundations for the field of genetics. The researcher's motive for introducing the lesson on monohybrid inheritance through story-telling was primarily to stimulate students' interests in the topic. The researcher observed that the use of story-telling in the introductory phase of the lesson was quite effective as it not only aroused students' interests in the lesson but it also encouraged their active participation in the activities organized in the subsequent stages of the lesson.

3.8.2.2 Exploration

The researcher began this stage by briefly explaining to the students the meaning of the concept of monohybrid inheritance. This was followed by a group activity designed by the researcher to further explore the concept of monohybrid inheritance. Five groups each made of seven students took part in the group activity.

Each group was given a beaker containing an unequal mixture of red and white bean seeds. In the protocol given to each group, the students were informed that the bean seeds in the beaker were offspring obtained from a cross between two bean plants that vary in only one characteristic, seed colour.

Each group was first required to determine the proportion of red bean seeds and white bean seeds present in the beaker. Based on the values obtained as the proportion of red and white bean seeds present in the beaker, the students were then asked to identify which of the two bean seeds colours in the offspring was dominant and to give reasons to support their answer.

As a follow-up question, each group was asked to use appropriate symbols to represent the possible genotypes of the parent bean plants. The students demonstrated excellent team work and cooperation during the group activity.

3.8.2.3 Explanation

The researcher at this stage initiated a class discussion on Mendel's laws of inheritance namely the law of segregation and the law of independent assortment. The discussions also focused on the applications of the two inheritance laws in monohybrid crossings.

The researcher provided the students with detailed explanations of how Mendel's laws of inheritance related to the topic under study. The researcher supported the explanations with appropriate examples. This was done to ensure that the students had a better understanding of the concepts.

3.8.2.4 Elaboration

In order to reinforce students' understanding of monohybrid inheritance, Mendel's laws of inheritance and its applications in monohybrid crossings, the students were at this stage given more challenging questions on monohybrid inheritance to solve. One of the questions required that the students determine the genotypic and phenotypic ratio of offspring resulting from a cross between a pea plant heterozygous for purple flowers (dominant) and a pea plant pure-breeding for white flowers (recessive).

In another question, the students were required to illustrate with appropriate diagrams the cross between a plant with green-coloured seeds and a plant with yellow-coloured seeds which produced offspring with only green seeds. In a similar question, students were asked to illustrate with appropriate diagrams the cross between a red-flowered plant and a white-flowered plant in which all the offspring produced were red flowered plants.

From their worksheet submitted for scoring, the researcher observed that the students were able to correctly apply Mendel's first and second laws in generating the genotypes and phenotypes of offspring in monohybrid crossings.

In addition, the researcher observed that in solving some of the questions, the students were able to correctly use the Punnett to generate all the possible genotypes of the second filial generation offspring. This indicated that the students understood the concepts taught (Appendix 3 contains the questions).

3.8.2.5 Evaluation.

Students' contributions to the class discussion on Mendel's laws of inheritance and its applications to monohybrid crossings during the explanation stage, together with their written answers to questions given by the researcher during both the exploration and elaboration stages provided the researcher with sufficient information to assess the students' understanding of the concept of monohybrid inheritance.

3.9 Data Collection Procedure

Data collected and used in this study was primarily quantitative. The procedure involved in the collection of data for this study involved three main phases**:** pre-treatment phase, treatment phase and post treatment phase. Permission was sought from the Headmaster prior to the actual collection of data.

The pre-treatment phase involved a general introduction of both the control and experimental to some introductory genetics concepts by the researcher over a period of one week after which the researcher administered the pre-Genetics Achievement Test (pre-GAT).

The general introduction of students to concepts like the definition of genetics, heredity, variation and key terms like alleles, genotype, phenotype, character/ traits, dominant and recessive traits, just to mention but a few was done through the lecture method of instruction. The purpose of the general introduction was to formally introduce students to genetics and also to revise the knowledge of some students who may have previously been taught genetics or had read about the topic.

The treatment phase involved a six-week period classroom instruction on selected genetics topics. During this period, the experimental and control groups were taught the same topics using the 5E instructional model and expository science instructional approach respectively.

At the end of the six-week instructional period, the researcher administered the post-Genetics Achievement Test (post-GAT) to the experimental and control groups. The purpose of administering the genetics achievement test in the post-treatment phase was to assess students' level of comprehension of the genetics concepts taught and the effect of the two instructional strategies, 5E instructional model and expository instructional method on the achievement of the experimental and control groups in genetics.

Finally, the researcher administered the 5E instructional model evaluation questionnaire to the experimental group for the purpose of evaluating the effectiveness of the 5E instructional model on the teaching and learning of genetics. The students were first informed about the purpose of the questionnaire and after a brief explanation on how to answer the items on the questionnaire, the students were allowed to complete the questionnaire on their own.

3.10 Data Analysis

The study collected and analysed only quantitative data. Students' pretest and posttest scores were first analysed using descriptive statistics such as mean and standard deviation. Students' t-test was subsequently used to test for the statistical difference between the mean pretest and posttest scores of the experimental and control groups.

Students t-test is an inferential statistic used to compare the means of two groups to determine if there is a significant difference between the two groups (Kenton, 2020). The two types of students t-test employed in this study were the dependent samples t-test and independent samples t-test.

Dependent samples t-test was used to test for the statistical difference between the mean pretest and posttest scores of the experimental group whiles the independent samples t-test was used to test for the statistical difference between the pretest and posttest scores of the experimental and control groups

The two types of students t-test employed in this study were computed using the Statistical Package for Social Sciences (SPSS) software v. 16. The tests were performed at 0.05 significance level. The items on the questionnaire were analysed using percentages.

3.11 Ethical Considerations

The adherence to research ethics is very essential in promoting the aims of a research and establishing the authenticity of findings generated (Kumar, Priya, Musalaiah, & Nagasree, 2014). It also helps to prevent errors in a research.

As part of the measures taken by the researcher in adherence to research ethics, the researcher made it a priority to ensure that any information provided by the research subjects on the Genetics Achievement Test (GAT) and 5E instructional model evaluation questionnaire were kept confidential. This was done purposely to gain the trust of the students and promote the integrity of the study.

None of the students was coerced into completing the items on the questionnaire, the researcher explained the purpose of the study to the participants and then asked them to voluntarily answer the items as it applies to them.

CHAPTER FOUR

PRESENTATION OF DATA, ANALYSIS AND DISCUSSION OF RESULTS

4.0 Overview

In this chapter, the results obtained from the analysis of data from the research instruments namely; Genetics Achievement Test (GAT) and the 5E Instructional Model Evaluation Questionnaire are presented in accordance with the sequence in which the research questions and hypotheses which guided the study were stated. The level of significance adopted for retaining or rejecting each of the null hypotheses was $p \leq 0.05$.

The concluding part of this chapter comprise discussions of the results obtained in relation to existing literature relevant to the study.

4.1 Analysis and Results Presentation

Research Question 1: To what extent does the use of the 5E instructional model affect students' achievement in genetics?

In order to answer research question one, the mean genetics achievement pretest scores and posttest scores of students in the experimental group were first compared. A summary of the comparison is presented in Table 2.

Table 2: A Comparison of the Mean Genetics Achievement Pretest and Posttest Scores of the Experimental Group.

Group	N	Test Type	Mean Score	Std. Deviation	Mean Difference
Experimental	40	Pretest	7.30	1.400	8.85
		Posttest	16.15	1.902	

The mean genetics achievement pretest score and posttest score of the experimental group as shown in Table 2 were 7.30 and 16.15 respectively with a mean difference of 8.85. The mean genetics achievement posttest score of the experimental group was higher than the mean genetics achievement pretest score.

In order to determine whether or not the difference between the mean genetics achievement pretest and posttest scores of the experimental group is statistically significant, null hypothesis one was formulated and tested using a dependent samples t-test and the results obtained have been summarized in Table 3**:**

H_O 1: There is no significant difference between the mean genetics achievement pretest and posttest scores of the experimental group.

Table 3: Dependent Samples t-test Analysis of the Mean Genetics Achievement Pretest and Posttest Scores of the Experimental Group.

Group	Test	N	d.f	Mean	SD	t-value	P-value
Experimental	Pretest	40	78	7.30	1.400	-23.702	2.18E-37
	Posttest			16.15	1.902		

It could be seen from Table 3 above that the computed p-value, 2.18E-37 was less than 0.05 indicating that there was a statistically significant difference between the mean genetics achievement pretest and posttest scores of students in the experimental group.

The null hypothesis one which states that there is no significant difference between the mean genetics achievement pretest scores and posttest scores of the experimental group was therefore rejected.

Research Question 2: What are the differences in the mean genetics achievement pretest and posttest scores of the experimental and control groups taught using 5E instructional model and expository instruction respectively?

In order to answer research question two, independent samples t-test analysis was used to determine whether or not a statistically significant difference existed between the mean genetics achievement pretests scores of the experimental and control groups. The analysis was done in order to establish the equivalence of the two groups prior to the administration of the treatments.

The results obtained from the independent samples t-test analysis of the mean genetics achievement pretest scores of the experimental and control groups have been summarized in Table 4.

Table 4: Independent Samples t-test Analysis of the Mean Genetics Achievement Pretest Scores of the Experimental and Control Groups

Groups	N	d.f	Mean	SD	t-value	P-value
Experimental	40	81	7.30	1.400	0.502	0.6173
Control	44		7.45	1.422		

As shown in Table 4, the computed p-value 0.617 was greater than 0.05 indicating that there was no significant difference between the mean genetics achievement pretest scores of students in the experimental and control groups. It could be inferred from Table 4 that the experimental and control groups had similar mean genetics achievement pretest scores, 7.30 and 7.45 respectively, with a mean difference of 0.15.

The similarity in the mean pretest scores highlighted the comparability of the experimental and control groups on the basis of their prior knowledge of basic genetics concepts before the administration of the treatments.

The mean genetics achievement posttest scores of the experimental and control groups was also analysed using independent samples t-test analysis. The analysis was carried out in order to determine whether or not a statistically significant difference existed between the mean genetics achievement posttest scores of the experimental and control groups taught using the 5E instructional model and expository instructional method respectively. The analysis was guided by the second null hypothesis which is stated below:

H_O 2: There is no significant difference between the mean genetics achievement scores of the experimental group and the control group taught using the 5E instructional model and expository instruction respectively.

Table 5 contains a summary of the independent samples t-test analysis of the mean genetics achievement posttest scores of the experimental and control groups.

Table 5: Independent Samples t-test Analysis of the Mean Genetics Achievement Posttest Scores of the Experimental and Control Groups

Groups	N	d.f	Mean	SD	t-value	P-value
Experimental	40	82	16.15	1.902	-8.206	5.256E-11
Control	44		11.36	1.313		

N=84, $p < 0.05$

It could be seen from Table 5 that the computed p-value 5.256E-11 was less than 0.05 indicating that there was a statistically significant difference between the mean genetics achievement posttest scores of the experimental and control groups. The second null hypothesis which states that there is no statistically significant difference between the mean genetics achievement posttest scores of the experimental group taught using the 5E instructional model and the control group taught using expository instruction was therefore rejected.

Research Question 3: What is the differential impact of the 5E instructional model on male and female students' achievement in genetics?

In order to answer research question three, the mean genetics achievement pretest and posttest scores of the male and female students in the experimental group were analysed using independent samples t-test.

The analysis was done in order to determine the differential impact of the 5E instructional model on the achievement of male and female students in the experimental group. The analysis was guided by the third null hypothesis.

H_O 3: There is no statistically significant difference between the mean genetics achievement pretest and posttest scores of male and female students in the experimental group

A summary of the results obtained from the analysis of the mean genetics achievement pretest scores of male and female students in the experimental group is presented in Table 6.

Table 6: Independent Samples t-test Analysis of the Mean Genetics Achievement Pretest Scores of Male and Female Students in the Experimental Group

Experimental Group	N	d.f	Mean	SD	t-value	P-value
Males	19	38	7.47	1.504	0.742	0.463
Females	21		7.14	1.315		

It could be seen from Table 6 that the computed p value 0.463 was greater than 0.05 indicating that there was no statistically significant difference between mean genetics achievement pretest scores of the male and female students in the experimental group. Independent samples t-test was employed in the analysis of the mean genetics achievement posttest scores of male and female students in the experimental group. Details of the results obtained from the analysis are presented in Table 7:

Table 7: Independent Samples t-test Analysis of the Mean Genetics Achievement Posttest Scores of Male and Female Students in the Experimental Group

Experimental Group	N	d.f	Mean	SD	t-value	P-value
Males	19	38	15.58	2.143	-1.862	0.070
Females	21		16.67	1.528		

It could be seen from Table 7 above that the computed p value 0.070 was greater than 0.05 indicating that was no statistically significant difference between the mean genetics achievement posttest scores of male and female students in the experimental group.

The null hypothesis three which states that there is no statistically significant difference between the mean genetics achievement pretest scores and posttest scores of male and female students in the experimental group was therefore retained. It was therefore concluded that the use of the 5E instructional model had no differential impact on mean achievement scores of male and female students in the experimental group.

Research Question 4: From the students' perspectives, to what extent does the use of 5E instructional model affect the teaching and learning of genetics?

In order to answer research question four, the responses of students in the experimental group to the items on the 5E Instructional Model Evaluation Questionnaire were analysed using percentages. A summary of the results obtained from the analysis of students' responses are presented in the Table 8.

Table 8: Analysis of Students' Perspectives about the Effect of the 5E Instructional Model on the Teaching and Leaning of Genetics.

S/N	ITEMS	SA (5)	A (4)	U (3)	DA (2)	SD (1)
1.	The use of the 5E instructional model helped to engage and focus my attention on genetics.	12 (30%)	16 (40%)	4 (10%)	6 (15%)	3 (5%)
2.	My interest in genetics was stimulated through the use of the 5E instructional model.	19 (47%)	10 (25%)	6 (15%)	3 (8%)	2 (5%)
3.	The use of the 5E instructional model in teaching genetics enabled me revise what I already know about the topic.	8 (20%)	21 (53%)	-	7 (17%)	4 (10%)
4.	The use of the 5E instructional model provided me with the opportunity to share what I already know about genetics	6 (15%)	24 (60%)	-	2 (5%)	8 (20%)
5.	The use of the 5E instructional model in teaching genetics encouraged me to actively participate in lessons	18 (45%)	10 (25%)	3 (7%)	7 (18%)	2 (5%)
6.	The use of the 5E instructional model enabled me to understand genetics better	23 (58%)	9 (22%)	1 (3%)	7 (17%)	-
7.	Through the use of the 5E instructional approach in teaching genetics, I was provided the opportunity to seek clarification on genetics concepts that still posed a challenge to me	20 (50%)	11(28%)	4 (10%)	5 (12%)	-
8.	The use of 5E instructional model encouraged me to work collaboratively with other students	9 (22%)	17 (43%)	3 (7.5%)	8 (20%)	3 (7.5%)
9.	Through the use of the 5E instructional model, I was able to extend and apply my knowledge in genetics to solve more challenging genetics-related problems	8 (20%)	16 (40%)	1 (3%)	11(28%)	4 (10%)
10.	The use of 5E instructional model in teaching genetics enabled me to assess my progress by comparing my current understanding of genetics with my prior knowledge of the topic.	6 (15%)	14 (35%)	5 (13%)	7 (17%)	8 (20%)

From the Table 8, it could be seen that out of the 40 students in the experimental group, 28 (70%) students agreed that the use of the 5E instructional model helped to engage and focus their attention on genetics during teaching and learning. Nine (20%) students disagreed with the statement whiles four (10%) students were undecided.

In responding to the second questionnaire item, 29 (72%) students agreed that the use of 5E instructional model helped to stimulate their interests in genetics whiles 11 (28%) disagreed. 29 (73%) students agreed with the third statement that the use of the 5E instructional model helped to revise their previous knowledge on genetics whiles 11(27%) disagreed.

In their response to the fourth item, 30 (75%) students agreed with the fact that the use of the 5E instructional model provided them with opportunities to share what they already know about genetics. Ten (25%) students disagreed with the statement.

28 (70%) students in their response to the fifth item agreed that the use of the 5E instruction model encouraged their active participation in genetics lessons. Three (7%) students were undecided in their response and 9 (23%) students disagreed with the statement.

32 (80%) students in their response to the sixth item agreed that the use of the 5E instructional model enabled them to understand genetics concepts better. 7 (17%) students however disagreed with the statement and only one (3%) student was undecided.

31 (78%) students agreed with the seventh item that the use of the 5E instructional model in teaching genetics provided them with opportunities to seek clarifications on challenging

problems. 5 (12%) students disagreed with the statement whiles four (10%) students were undecided.

26 (65%) students in responding to the eighth item agreed that the use of the 5E instructional model encouraged them to work collaboratively with other students, 11 (27.5%) students disagreed with the statement and 3 (7.5%) were undecided in their response.

24 (60%) students agreed with the ninth item that the use of the 5E instructional model enabled them to extend and apply their knowledge in genetics to solve more challenging genetics-related problems. 15 (38%) students disagreed with the statement and only one (3%) student was undecided.

Finally, in students' response to the last questionnaire item, 20 (50%) students agreed that the use of the 5E instructional model enabled them to assess their learning progress by comparing their current understanding of genetics with their prior knowledge about the topic. 15 (27%) students disagreed with the last item whiles five (13%) students were undecided.

In terms of the effect of the use of the 5E instructional model on the teaching of genetics, it could be inferred from the analysis of students responses to the questionnaire items that majority of the students agreed that the use of the 5E instructional model, first and foremost, helped to engage and focus their attention, stimulate their interests in genetics and adequately helped them to revise their previous knowledge on genetics.

Secondly, majority of the students agreed that the use of the 5E instructional model helped to promote teamwork, encouraged students to actively participate in lessons and provided opportunities for students to seek clarifications where necessary to address challenging problems they still had.

In terms of the effect of the 5E instructional model on promoting students' learning of genetics, majority of the students' agreed that the use of the 5E instructional model helped to promote a better understanding of genetics concepts, provided opportunities for students to extend and apply their knowledge of genetics in solving more challenging problems and finally enabled them to assess their learning progress by comparing their previous knowledge on genetics with their current understandings. It can therefore be concluded that the use of the 5E instructional model has an overall positive effect on the teaching and learning of genetics.

4.2 Discussions of the Results

The results obtained from the analysis of the data collected in this study are discussed in this section. The discussions were guided by the research questions and hypotheses which were tested at 0.05 significance level.

4.2.1 Research Question 1: To what extent does the use of the 5E instructional model affect students' achievement in genetics?

The dependent samples t-test analysis of the mean genetics achievement pretest and posttest scores of the students in the experimental group taught using the 5E instructional model as presented in Table 3 showed that a statistically significant difference existed between the mean genetics achievement pretest and posttest scores of the experimental group.

The mean genetics achievement pretest score of the experimental group before the administration of the treatment was 7.30. After the implementation of the 5E instructional model, the mean scores of students increased to 16.15, and this was recorded as the mean genetics achievement posttest score.

The improvement in the students mean genetics achievement posttest scores after the treatment therefore indicated that the use of the 5E instructional model had a positive effect on the achievement of the experimental group in genetics.

The positive effect of the 5E instructional model on students' science achievement is further confirmed by Cakiroglu (2006) who in a study on the effectiveness of 5E learning cycle instruction on students' achievement in photosynthesis and respiration in plants found that a statistically significant difference existed between the experimental group taught using 5E learning cycle instruction and the control groups taught using traditional instruction. The difference was in favour of the 5E learning cycle instruction.

Nuhoğlu and Yalçin (2006) in a related study on the effectiveness of learning cycle instruction on students' achievement in the physics found that the learning cycle instruction enabled students to learn effectively and organize their knowledge in a meaningful way. Learning cycle instruction was also found to enhance the longevity of the knowledge acquired. Consequently, students were more capable to apply their knowledge in other areas outside the original context.

The 5E instructional model like other learning cycle models has been widely recognized to improve student's conceptual understanding and achievement in science (Dogru-Atay & Tekkaya, 2008). Results from numerous studies have shown that the use of the 5E instructional model not only enhanced students' conceptual understanding of science concepts but also their science process-skills achievement (Dogru-Atay & Tekkaya, 2008).

4.2.2 Research Question 2: What are the differences in the mean genetics achievement pretest and posttest scores of the experimental and control groups taught using 5E instructional model and expository instruction respectively?

The comparison of the mean genetics achievement pretest scores of the experimental and control groups as shown in Table 4 helped to establish the equivalence of the experimental and the control groups prior to the administration of the treatments. Since there was no statistically significant difference between the mean genetics achievement pretest scores of the experimental and control groups, the two groups were therefore found to be comparable in terms of their background knowledge of genetics.

The mean achievement score of the experimental and the control group before and after the implementation of the 5E instructional model and expository instruction were 7.30 and 16.15, and 7.45 and 11.36 respectively. The mean difference between the achievements scores of the experimental group and the control group were 8.85 and 3.91, in favour of the experimental group. This therefore indicated that the 5E instructional model comparatively had a more positive effect on students' achievement in genetics than expository instruction.

Similar findings were made by Cardak, Dikmenli and Saritas (2008) who investigated the effect of the 5E learning cycle instruction on students' achievement in the circulatory system. They found that even though the experimental and control groups were the same at first, after the implementation of the treatment there was an important difference in favour of the experimental group.

Ozmen and Demircioglu (2004) also in a related study used 5E learning cycle instructional model to teach the topic “Factors Affecting the Solubility Equilibrium” in Lycee-2 chemistry curriculum and found that the experimental group students scored significantly higher achievement test marks than the control group.

Expository instruction has long been criticized as ineffective in promoting students’ achievement in science. Marek, Cowan and Cavallo (1994) reported that 5E learning cycle instruction was more effective than the expository instruction in promoting high school students' understanding of diffusion.

In contrast to the expository instruction which is mainly teacher-centered, the 5E instructional model employed in this study is a student-centered, inquiry based instructional strategy made up of five distinct phases namely engagement phase, exploration phase, explanation phase, elaboration phase and evaluation phase (Sarac, 2018).

Each phase of the instructional model comprised of different set of activities which were designed to stimulate students’ interests, expose their prior conceptions and enable them to make meaningful connections between past and present learning experiences and to use their understandings to generate new ideas (Sarac, 2018).

The researcher found that the use of the 5E instructional model encouraged students’ active participation, promoted teamwork among students and also challenged students to apply their knowledge and skill acquired in new learning situations. These accounted for some of the reasons why students in the experimental group performed better than those in the control group who were taught using expository instruction.

4.2.3 **Research Question 3:** What is the differential impact of the 5E instructional model on male and female students' achievement in genetics?

There was no statistically significant difference found between the mean genetics achievement pretest scores and posttest scores of the male and female students in the experimental group. This therefore indicated that the 5E instructional model had no differential impact on the achievement of students in genetics.

Similar findings were made by Sukola (2015). In a study on the impact of 5E teaching cycle on attitude, retention and performance in genetics among pre-NCE biology students with varied abilities, he found that there was no significant difference in the mean scores of the male and female students in the experimental group exposed to the 5E teaching cycle.

Similarly, Ajaja and Eravwoke (2012) in a study on the effects of 5E learning cycle instruction on students' achievement in biology and chemistry found that there was no statistically significant difference between the mean scores of male and females in the experimental group exposed to 5E learning cycle instruction.

The findings from the empirical studies cited above indicated that the use of the 5E instructional model promoted students' achievement in science irrespective of their sex. Teachers have a crucial responsibility as facilitators of the model to design activities that challenges students' curiosity, encourage students' active participation and enhance students' critical thinking skills irrespective of their sex, whether male or female.

The researcher's findings together with the findings from the empirical studies cited above give credence to the fact that 5E instructional model prioritizes the individual learning needs of students irrespective of their sexes and provides opportunities for those needs to be addressed.

The use of the 5E instructional model allows students to carry out investigation on their own and to arrive at a particular concept, it makes what they learn meaningful and promotes their understanding of the concept despite gender difference among the students (Sukola, 2012).

4.2.4 Research question 4: From the students' perspectives, to what extent does the use of the 5E instructional model affect the teaching and learning of genetics?

In order to evaluate the effectiveness of the 5E instructional model on the teaching and learning of genetics, the researcher analysed the responses of the experimental group on the 5E instructional model questionnaire. From the students' responses, it was quite evident that the use of 5E instructional model positively affected students' learning of genetics by helping to promote a better understanding of genetics, challenging students to apply their knowledge about genetics to other new learning situations and providing opportunities for students to assess their learning progress.

Unlike the traditional teaching methods which only focuses on presenting students with knowledge and skills, the use of the 5E instructional model provides students with the opportunities to construct their own knowledge by comparing their current understandings with prior knowledge (Yanchun, 2002).

Analysis of students' responses also revealed that the 5E instructional model had a positive influence on the teaching of genetics since it helped to adequately revise students' prior knowledge on genetics, stimulate their interests in genetics, engaged and focused their attention on the topic and encouraged them to participate actively in class lessons. The use of the 5E instructional model fostered team work and cooperation among students.

In conclusion, the researcher believes that the use of the 5E instructional model positively affects both the teaching and learning of genetics.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter provides the summary of the research findings, conclusions and the recommendations from the study. The discussions, conclusions and recommendations were made in accordance with the purpose of the study and research objectives. Finally, the areas for further research are suggested for consideration in future studies.

5.1 Summary

This study investigated the effect of the 5E instructional model students' achievement in some selected concepts in genetics. The objectives of the study were to:

1. Determine the effectiveness of 5E instructional model on students' achievement in genetics.
2. Determine the differences in the mean genetics achievement test scores of experimental and control groups taught using the 5E instructional model and expository instruction respectively.
3. Determine the differential impact of the 5E instructional model on male and female students' achievement in genetics.
4. Evaluate the effect of the 5E instructional model on the teaching and learning of genetics from the students' perspective.

In order to address these objectives, four research questions were developed together with three hypotheses which were tested at 0.05 level of significance.

The research questions that guided the study were stated as follows:

1. To what extent does the use of 5E instructional model affect students' achievement in genetics?
2. What are the differences in the mean genetics achievement pretest and posttest scores of the experimental and control groups taught using 5E instructional model and expository instruction respectively?
3. What is the differential impact of the 5E instructional model on male and female students' achievement in genetics?
4. From the students' perspectives, to what extent does the use of 5E instructional model affect the teaching and learning of genetics?

The following also represents the null hypotheses that guided the study:

H_O 1: There is no significant difference between the mean genetics achievement pretest scores and posttest scores of the experimental group.

H_O 2: There is no significant difference between the mean genetics achievement scores of the experimental group and the control group taught using the 5E instructional model and the expository instruction respectively.

H_O 3: There is no significant difference between the mean achievement scores of male and female students who were taught genetics using the 5E instructional model.

The background to the study sought to highlight the need for more effective instructional strategies like the 5E instructional to be adopted in the teaching and learning of science especially in the area of genetics. The background to the study provided more insight on student's challenges in learning genetics and its consequent effect on their achievements.

The problem statement pointed to the fact that the declining achievement of students in genetics as evidenced by the WAEC chief examiner's reports could be remedied by the implementation of the 5E instructional model. Empirical studies were cited to support the effectiveness of the 5E instructional model in promoting students understanding and achievement in different science topics.

Available literatures relevant to the study were reviewed in the second chapter of the study. Most of these literatures concluded that students' academic achievements in science can be enhanced using effective instructional strategies like the 5E instructional model which encourages active participation of students and promotes meaningful learning.

The research design used in this study was the quasi experimental design, specifically the pretest-posttest nonequivalent control group quasi experimental design. The sample population used for the study comprised 84 final year students at Uncle Rich Senior High School, Winneba. The sample population comprise 45 (54%) girls and 39 (46%) boys. The sample students belonged to five intact classes. These classes were randomly assigned to an experimental and control groups comprising 40 and 44 students respectively.

Two instruments namely Genetics Achievement Test (GAT) and 5E Instructional Model Questionnaire were used to collect data in this study. The GAT comprised of 20 multiple choice items which covered certain selected topics under genetics.

The 5E Instructional Model Questionnaire comprised ten items structured on a five-point Likert scale. The questionnaire was administered purposely to evaluate the effectiveness of the 5E instructional model from the students' perspectives. The reliability coefficients computed for the Genetics Achievement Test and the 5E Instructional Model Questionnaire were 0.67 and 0.71 respectively.

The treatments namely 5E instructional model and expository instruction were administered over a period of six weeks. Within this period, the experimental and the control group were taught selected genetics topics comprising the concept of inheritance, Mendel's first and Second laws, Mendel's experiment on monohybrid and dihybrid inheritance, sex determination and sex-linked characters, ABO blood group system and Rhesus factor and inheritance of sickle cell disease and albinism.

The data collected before and after the administration of the treatment were analysed using students t-test and descriptive statistics such as mean, standard deviation and percentages. A summary of the findings made is presented below:

5.1.1 Summary of Major Findings

- Statistically significant difference existed between the mean genetics achievement pretest and posttest scores of the experimental group. Since the mean genetics achievement posttest score of the experimental group was significantly higher than the mean pretest score, it therefore indicated that the 5E instructional model had a positive effect on the mean achievement scores of the experimental group in genetics.
- Statistically significant difference existed between the mean genetics achievement posttest scores of the experimental group taught using the 5E instructional model and the control group taught using expository instruction. The differences in the

mean achievement scores of the two groups was in the favour of the experimental group.

- There was no statistically significant difference between the mean genetics achievement pretest and posttest scores of the male and female students in the experimental group. This therefore indicated that the 5E instructional model had no differential impact on the achievement of students in genetics based on their gender.
- The use of the 5E instructional model has a positive effect on the teaching and learning of genetics. This conclusion was derived based on the evaluation of students' responses on the 5E instructional model evaluation questionnaire.

The findings made from the analyses of data gathered in the study revealed that students taught genetics using the 5E instructional model had a comparatively higher achievement in genetics than those taught using expository instruction. Also, the 5E instructional model had no differential impact on the achievement of students in genetics on the basis of their gender.

Based on the results obtained after the analyses of the data collected, null hypotheses one and two were rejected, whiles null hypothesis three was retained.

5.2 Conclusion

Based on the findings made, it can be concluded that in comparison with expository instruction, the use of the 5E instructional model promoted a better understanding of genetics and consequently enhanced students' achievement in genetics. This conclusion is evidenced by the comparatively higher mean genetics achievement posttest score attained by the experimental group.

Another conclusion derived from the analysis of the mean achievement test scores of male and female students in the experimental group was that the use of the 5E instructional model has no discriminatory effect on students' achievement based on their sex. This conclusion was made based on the fact that no significant difference existed between the mean genetics achievement pretest and posttest scores of male and female students in the experimental group taught using the 5E instructional model. In the light of this, the 5E instructional model was found to be gender friendly.

The final conclusion made in this study was derived from students' responses to the items on the questionnaire. It can be concluded that the use of the 5E instructional model has a positive effect on the teaching and learning of genetics. Out of the total of 40 students in the experimental group, more than half of the students agreed to the fact that the use of the 5E instructional model helped to promote a better understanding of genetics. This was clearly reflected by their mean genetics achievement posttest scores which was significantly higher than their pretest scores.

5.3 Recommendations

The following recommendations were made based on the findings of the study:

1. 5E instructional model is recommended to be regularly employed in science classrooms since it was found to encourage active students' participation, promote a better understanding of science concepts and increase students' achievement in science.
2. The 5E instructional model was found in this study to be gender friendly since it did not have any discriminatory effect on students' achievement in genetics on the

basis of their sex. The instructional model is therefore highly recommended to be incorporated in the teaching and learning of science across all educational levels and even extended to other subject areas.

3. Finally, the study recommends that the use of expository instructional methods in science classrooms should be creatively supported with teaching and learning resources such as models, charts, computer simulations and videos in order to stimulate students' interests and encourage their active participation in lessons.

5.4 Suggestion for Further Studies

1. Similar studies ought to be carried out to investigate the impact of the 5E instructional model on students' achievement in other genetics-related concepts that were not covered in this study.
2. In order to increase the scope of generalization, this study should be replicated in other senior high schools in Ghana.
3. There is a need for further studies to be carried out to investigate the effect of the 5E instructional model on students' science process skills acquisition.

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APPENDIX 1

GENETICS ACHIEVEMENT TEST

1. Two plants were crossed and all the F_1 plants were tall. Some of the F_2 plants were tall and the others short when the F_1 were selfed. What are possible genotypes of the original parental plants?
   A. TT and TT
   B. Tt and Tt
   C. Tt and tt
   D. TT and Tt

2. A cross between a pure-breeding tall plant and a pure-breeding dwarf pea plant takes place, where tallness is dominant over dwarf, and F_1 generations was selfed. The phenotypic ratio of F_2 generations will be……………………………………….
   A. 1:2:1
   B. 2:1:1
   C. 3:1
   D. 1:1:2

3. The results of a cross between two heterozygous characters is………………………….
   A. 25% recessive and 75% dominant
   B. 50% recessive and 50% dominant
   C. 100% recessive
   D. 100% dominant

4. Sex in humans is determined by ……………………………………………….
   A. dominant gene present in the female
   B. the presence of the **X** and **Y** chromosomes
   C. two homologous chromosomes
   D. two similar sex chromosomes in the female

5. Which of the following best defines sex-linked characters? Characters which are……...
   A. controlled by genes borne on the sex chromosomes
   B. duplicated during fertilization.
   C. transmitted from parents to offspring
   D. transferred to the offspring by the female parent

6. What proportion of the offspring will be haemophiliac when a haemophiliac man marries a woman who is a carrier for the gene for haemophilia?
   A. 25%
   B. 50%
   C. 75%
   D. 100%

7. A homozygous recessive plant is crossed with a heterozygous plant. The phenotypic ratio of the progeny will be ……………………………………
   A. 0:2
   B. 1:1
   C. 2:1
   D. 3:1

8. Which of the following is a sex-linked trait?
   A. Albinism
   B. Baldness
   C. Down syndrome
   D. Sickle cell anaemia

9. The F_1 generation of a cross between a red cock and a white hen were all red because the gene for the……………………………………………
   A. red colour was recessive
   B. red colour was dominant
   C. white colour did not segregate
   D. white colour was dominant

10. Which of the following is the genotypic ratio of F_2 offspring resulting from a dihybrid cross?
    A. 1:2:1
    B. 1:3
    C. 9:3:3:1
    D. 1:1:1:1

11. Assuming that *A* is the gene for a normal skin and is dominant while *a* is the gene for albinism and recessive. What is the likely genotype of a couple which had 50% normal and 50% albino offspring?
    A. *AA*, *aa*
    B. *Aa*, *aa*
    C. *AA*, *Aa*
    D. *Aa*, *Aa*

12. The probability that two consecutive children of the same parents will be female is …
    A. $\frac{1}{4}$
    B. $\frac{1}{2}$
    C. $\frac{3}{4}$
    D. 1

13. An individual with blood group **AB** can donate to individuals with blood groups………..
    A. A and B
    B. A and O
    C. B and O
    D. AB only

14. If a man of blood group **AB** is married to a woman of blood group **O**, then………………
    A. all their children will belong to blood group O
    B. all their children will belong to blood group AB
    C. half of their children will belong to blood group AB and other half in blood group O
    D. none of their children would belong to blood group O

15. When two carriers of sickle cell anaemia get married, the probability of giving birth to a sickler is …………………………………………
    A. $\frac{1}{2}$
    B. $\frac{2}{3}$
    C. $\frac{1}{4}$
    D. $\frac{3}{4}$

16. A Rh^- sample was transferred to a Rh^+. No reaction occurred because…………………
    A. the Rhesus factor is suppressed in the blood of the recipient
    B. there is no naturally occurring antibodies against the Rh^- factor
    C. the Rhesus factor is destroyed by lymphocytes
    D. Rh^+ blood is always compatible with Rh^- blood

17. In which of the following characteristics can discontinuous variation can be observed?
    A. Height
    B. Rh factor
    C. Skin colour
    D. Weight

18. How would an individual who is a carrier of haemophilia be expressed?
    A. $X^H X^H$
    B. $X^H Y$
    C. $X^h Y$
    D. $X^H X^h$

19. A colour-blind man marries a normal woman. The probability of them producing a colour-blind child will be ………………………………….
    A. 0.00
    B. 0.125
    C. 0.25
    D. 0.50

20. Two individuals homozygous for both blood groups **A** and **B** can give birth to child with blood group……………………………………………
    A. A
    B. AB
    C. B
    D. O

APPENDIX 2

MARKING SCHEME FOR GENETICS ACHIEVEMENT TEST

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

Total: 1 mark x 20 = 20 marks

APPENDIX 3

CLASSWORK ON MONOHYBRID INHERITANCE

The questions below were given to the students in the elaboration stage of the lesson on monohybrid inheritance:

1. Determine the genotypic and phenotypic ratio of offspring resulting from a cross between a pea plant heterozygous for purple flowers (dominant) and a pea plant pure-breeding for white flowers (recessive)
2. A cross between a pure-breeding tall pea plant and pure-breeding dwarf pea plant takes place where tallness is dominant over dwarfness. Determine the genotype and phenotype of the F_1 and F_2 offspring.
3. The offspring of a tall man and a short woman were all found to be tall. With the aid of the crosses, illustrate the above observation.
4. The offspring resulting from the cross between a red-flowered plant and a white-flowered plant were all found to be red. With the aid of appropriate crosses, illustrate the observation.
5. The offspring of a black and white rabbit were all found to be black. With the aid of appropriate crosses, illustrate the observation.
6. A plant with green-coloured seeds was crossed with a plant with yellow-coloured seed. All the offspring were observed to be green. Illustrate the above observation.

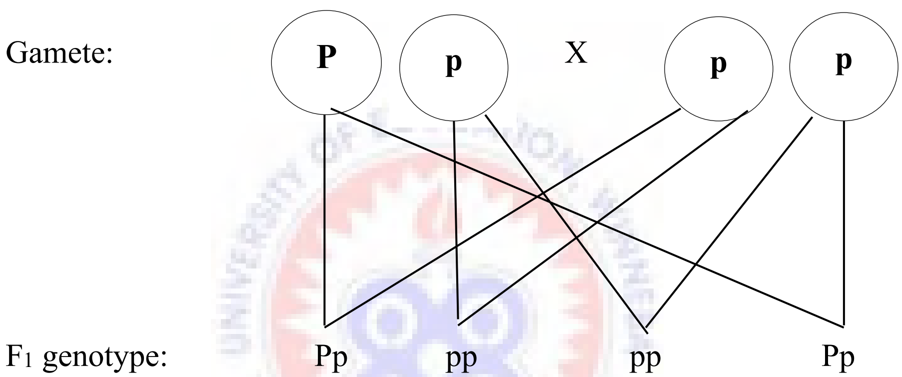
APPENDIX 4

MARKING SCHEME FOR CLASSWORK ON MONOHYBRID INHERITANCE

1. Let *P* represent dominant allele for purple flowers and *p* represent the recessive allele for white flower.

   Let *Pp* represent the genotype of the purple flowered pea plant which is heterozygous and *pp* represent the genotype of the white coloured pea plant which is recessive.

   Parental genotype: Pp X pp



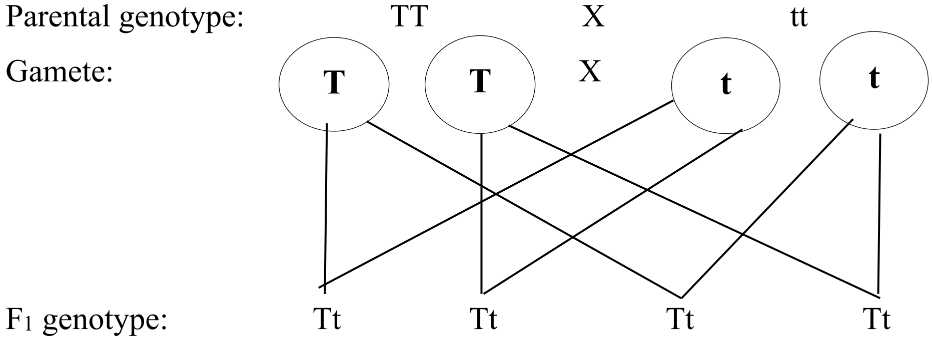
   F_1 phenotype: Two purple flowered pea plants and two white flowered pea plant

The genotypic ratio of the offspring was therefore determined to be 1 Pp: 1 pp whiles the phenotypic ratio is 1:1.

2. Let *T* represent the dominant allele for tall pea plant and *t* represent the recessive allele for dwarf pea plant.

   Let *TT* represent the pure-breeding tall pea plant and *tt* represent pure-breeding dwarf pea plant.

   Parental genotype: TT X tt

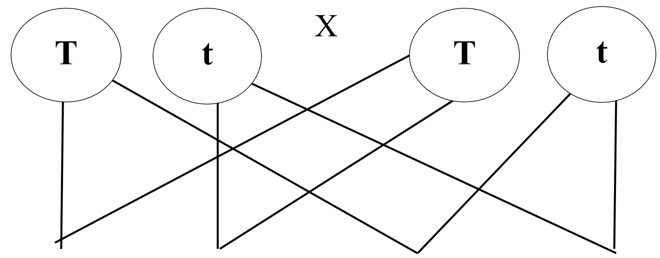


F_1 phenotype: All are tall pea plants

Selfing of the F_1 offspring:

F_1 offspring genotype: Tt X Tt

Gamete: X



F_1 genotype: TT Tt Tt tt

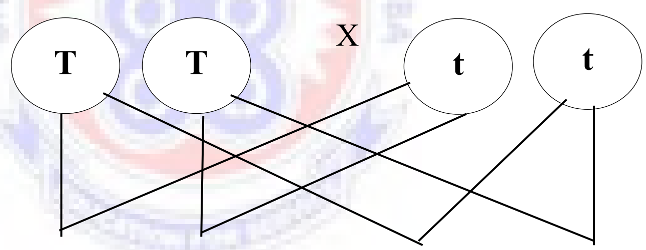
F_1 phenotype: 3 tall pea plants and 1 dwarf pea plant

3. Let *T* represent dominant allele for tallness and *t* represent recessive allele for shortness.

   Let *TT* represent tall man and *tt* represent short woman

   Parental genotype: TT X tt

   Gamete: X



   F_1 genotype: Tt Tt Tt Tt

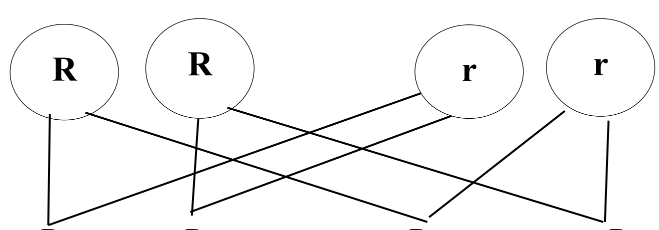
   F_1 phenotype: All are tall

4. Let *R* represent dominant allele for red-flowered plant and *r* represent recessive allele for red-flowered plant.

   Let *RR* represent red flowered plant and *rr* represent white flowered plant.

   Parental genotype: RR X rr

   Gamete:



   F_1 genotype: Rr Rr Rr Rr

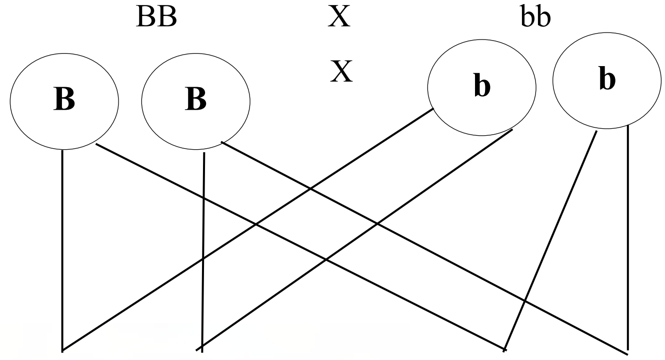
F_1 phenotype: All are red-flowered plants

5. Let *B* represent dominant allele for black rabbit and *b* represent recessive allele for white rabbit

   Let *BB* represent black rabbit and *bb* represent white rabbit

   Parental genotype: BB X bb

   Gamete: X



   F_1 genotype: Bb Bb Bb Bb

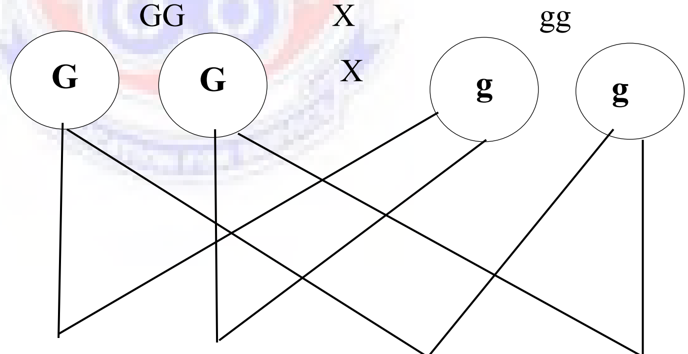
   F_1 phenotype: All are black rabbits

6. Let G represent dominant allele for green seeds and g represented recessive allele for yellow seeds.

   Let GG represent plant with green seeds and gg represent plant with yellow seeds

   Parental genotype: GG X gg

   Gamete: X



   F_1 genotype: Gg Gg Gg Gg

   F_1 phenotype: All are plants with green seeds

APPENDIX 5

QUESTIONNAIRE

EVALUATION OF THE 5E INSTRUCTIONAL MODEL

This questionnaire was designed purposely to evaluate from your perspective the effectiveness of the 5E instructional model on the teaching and learning of genetics. Your individual names or identification number is not required and will not be associated with your responses. Your responses will be kept strictly confidential.

Please read the following statements and kindly provide the information required.

A. Background Information

Please tick [√] in the appropriate space provided below and supply answers where required.

Gender**:** Male [ ] Female [ ]

B. Students' perceptions about the effectiveness of the 5E instructional approach

Please tick [√] against each statement that best represents your personal opinion. Against each statement, there are five items.

SD - Strongly Disagree

D - Disagree

U - Undecided

A - Agree

SA - Strongly Agree

S/N		SA	A	U	DA	SD
1.	The use of 5E instructional model helped to engage and focus my attention on the genetics.					
2.	My interest in genetics was stimulated through the use of the 5E instructional model.					
3.	The use of the 5E instructional model in teaching genetics enabled me revise what I already know about the topic.					
4.	The use of the 5E instructional model provided me with the opportunity to share what I already know about genetics					
5.	The use of the 5E instructional model in teaching genetics encouraged me to actively participate in lessons.					
6.	The use of the 5E instructional model enabled me to understand genetics better.					
7.	Through the use of the 5E instructional approach in teaching genetics, I was provided the opportunity to seek clarification on genetics concepts that still posed a challenge to me					
8.	The teaching of genetics using the 5E instructional model encouraged me to work collaboratively with other students					
9.	Through the use of the 5E instructional model, I was able to extend and apply my knowledge in genetics to solve more challenging genetics-related problems					
10.	The use of 5E instructional model in teaching genetics enabled me to assess my progress by comparing my current understanding of genetics with my prior knowledge of the topic.					