

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT (AAMUSTED)
ASANTE MAMPONG**

**ENHANCING STUDENTS' LEARNING OUTCOMES IN GENETICS: THE
USE OF GENERATIVE LEARNING STRATEGY**

DANIEL SOBREH ASSUAH

JANUARY, 2024

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BY

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**A thesis submitted to the School of Graduate Studies in Akenten Appiah-Menka
University of Skills Training and Entrepreneurial Development in partial
fulfilment of the requirements for the award of a Master of Philosophy degree in
Science Education**

JANUARY, 2024

DECLARATION

Student's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Daniel Sobreh Assuah

Signature:

Date:.....

Supervisors' Declaration

We hereby declare that this thesis was prepared and presented under our supervision in compliance with the thesis supervision requirements established by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

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ABSTRACT

The study investigated the use of the Generative Learning Strategy (GLS) in enhancing students' learning outcomes in genetic concepts. The study adopted a mixed-methods research design with a sample of 106 SHS 3 Biology students from Sefwi-Wiawso Municipality, Ghana. Two intact classes were randomly selected, treated as one group, and exposed to the same treatment conditions. Two research instruments, the Genetic Concepts Test (GCT) and a semi-structured interview guide, were used to collect the quantitative and qualitative data, respectively. The reliability index of the GCT was 0.784, indicating substantial agreement. The quantitative data were analysed using SPSS version 26 by employing descriptive and inferential statistics through the use of paired-samples t-test and One-Way ANCOVA, and thematic analysis for the qualitative data. The results showed a significant difference in students' performance in the genetic concepts after GLS use. The study found no significant difference in performance between high and low achievers after using the GLS; however, the GLS seemed to favour the low achievers, as evidenced by the higher mean difference of 16.37 among the low-achievers as compared to the mean difference of 13.00 among the high-achievers. Also, the interview results revealed that SHS Biology students perceived that GLS significantly improved their performance, motivation, retention, and self-directed learning of genetic concepts, thereby ultimately enhancing their learning outcomes. Finally, it was recommended that SHS Biology teachers in the Sefwi-Wiawso Municipality employ the Generative Learning Strategy in the teaching and learning of genetics in order to improve SHS Biology students' academic performance.

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DEDICATION

I dedicate this work to my Mum, late Dad, brothers, sisters, nephews, nieces, and all my lovely friends for their prayers and support.

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CHAPTER ONE

INTRODUCTION

1.0 Overview

The study's background is presented in this chapter, a statement of the problem, the justification of the research, and an outline of the purpose of the study. Also, the goals, queries, and research aim of the hypotheses that guided the study are outlined in this chapter. The chapter finally highlights the significance of the research, its delimitation, limitations, and organisation.

1.1 Background to the Study

Science education does not only strive to give students insights into the world around them but also a foundational understanding of scientific principles. Moreover, it seeks to foster a favourable mindset toward interacting with science and foster a person's advancement of scientific literacy (Kung & Marnie, 2012). Understanding how the living world functions can be gained from studying genetics. It might be claimed that every person has to have some grasp of the issues involved, given the significant impact of modern genetics research on medicine, food production, health, and life styles. Furthermore, without an understanding of genetics, it is impossible to come to grips with current issues related to genetically modified organisms (GMOs), DNA fingerprinting, gene therapy, genomics, and cloning (Didem, Keith, & Mark, 2016).

A growing body of research in journals, books, and media indicates that scientific educators are coming to the same conclusion: students need to learn basic genetic principles more thoroughly (Thomson & Stewart, 1985, as cited by Didem et al., 2016).

Consequently, there is a need to give the topic of genetics more emphasis in the classroom because of the topic's growing significance in our daily lives. Hott, Huether and McInerney (2002), also accentuated that the topic of genetics needs to receive more attention in the science curricula of schools given the growing significance of genetics in our daily lives. Ashelford (2008) added that Senior High School genetics teaching offer a significant opportunity to examine contemporary ethical and social issues. Owing to this, students in Senior High Schools should be able to comprehend what they read and hear about genetics and as well be able to respond intelligently to personal or social concerns with a scientific content (Lewis, Leach, & Wood-Robinson, 2000).

Relevant genetic education must be undertaken in schools if the general public is to comprehend such matters. However, there have been reports globally over the years regarding the issue of poor Biology performance among students (Alfiraida, 2018; Etobro & Fabinu, 2017; Gungor & Ozkan, 2017; Aivelo & Uitto, 2015; Agboghroma & Oyovwi, 2015), and particularly in genetics (Fauzi, Rosyida, Rohma, & Khoiroh, 2021; Fauzi & Mitalistiani, 2018; Thörne & Gericke, 2014; Gericke & Wahlberg, 2013). In Ghanaian Senior High Schools as well, there are similar problems with genetic concepts among students (Amoah, Eshun, & Appiah, 2018; Gbore & Daramola, 2013; Adeyemi, 2006; WAEC Chief Examiners' Reports, 2020; 2019; 2017; 2016; 2015; 2013; 2011).

Concern over this issue and the need to identify the reasons why the students performed poorly in Biology have been identified by stakeholders and educators. For example, Francis, Hutchinson, & Pavlevic (2014) and Whittle, Telford, & Benson (2018) argued that there are a number of elements that lead to children performing poorly in Biology

and genetic concepts, including the teaching strategies used by teachers. Recent studies have touted that, one of the teaching strategies that could positively impact students' performance if utilised well in the Biology classroom is the Generative Learning Strategy (Fasanya, 2022; George & Abumchukwu, 2021; Onanuga, Abayomi, Adewale, Onyeanwusi, & Chinneye, 2020; Appiah-Twumasi, 2019; Awolere, Omiola, & Awujoola-Olarinoye, 2019; Prawita, Prayitno, & Sugiyarto, 2019; Bot, 2018; Soekamto, 2017; Adeyemi & Awolere, 2016; Olagbaju, 2014; Ogunleye & Babajide, 2011).

As opined by Al-Zahrani (2018), one of the well-known constructivist-based Science teaching methods is the Generative Learning Strategy (GLS), which is a method that relies on the brain's activation and stimulation to develop new concepts and cognitive structures by linking previously taught concepts with those that need to be learned. The goal of the Generative Learning Strategy is to create connections between knowledge that has already been learned and new information. It enables the learner to use a series of creative processes to connect both new and old information in his cognitive structure. It is also founded on the constructivist perspective regarding education, maintaining that it is a dynamic process of construction that is built on a person's existing knowledge, according to Bonwell and Eison (1991), as referenced by Garvin (2021).

The interest in Generative Learning Strategy is primarily centered on the cognitive structures that are retained in the learner's memory and serve as the foundation for the selection and attention given to practical stimuli. The linkages that are created between the stimuli that the learner is exposed to, and the patterns of storage in the learner's cognitive structure are also of interest. Attention is also given to the interpretation of

the meanings generated by concrete inputs and information (Ali, 2005). According to Çimer (2004), teaching strategies and methods used by teachers when teaching Biology can have a significant impact on how effectively students understand the subject.

For optimum conceptual understanding, teachers are advised to teach Biology ideas using constructivist teaching approaches, according to the Curriculum Research and Development Division (CRDD) which developed the Ghanaian Senior High School Biology syllabus (2010 version). Although the Elective Biology syllabus directs teachers to adopt constructivist teaching methods, it does not specify which constructivist methods should be used to be able to optimise students' performance in the subject. Therefore, it stands to reason that, in order to address the problem of students' poor performance in Biology, useful constructivist teaching strategies that are used in other nations should be taken into account when instructing students about biological topics. From experts' point of view, such as Larbi and Monney (2022) in relation to the Ghanaian Elective Biology designed by the CRDD (2010), "Genetics" as topic can be segregated into the subtopics as "Applied genetics", "Mendel's experiments" and "Variation." The rationale behind choosing these subtopics is that genetics at the Senior High School level consist mainly of "heredity" and "variation," which are rooted from "Cell Biology," (CRDD, 2010). If the subtopics are arranged in this way, it would encompass all of the fundamental concepts around which additional concepts are constructed.

For instance, per the 2017 WAEC Chief Examiners' Report (pp. 246-248), "Candidates showed a deficiency of sufficient Biology content, as demonstrated by their incorrect creation of genetic diagrams, and they struggled to explain recombinant DNA

technology and its uses.” This question in particular is a fused one; with ‘genetic diagram creation’ falling under “Mendel’s experiment” while ‘DNA technology’ falls under “Genetics and applied genetics.” Similarly, per the 2016 WAEC Chief Examiners’ Report (p. 16), “majority of candidates avoided answering questions about agglutination and gene interaction (the ABO blood group system), and the ones who did were not very good at answering them”. This question also falls under “Genetics and applied genetics.” In the end, as indicated in the literature, this would result in the capture of all the selected genetic concepts that SHS Biology students find it difficult to understand.

This will help to improve students’ academic performance in the subject. Studies in science education have indicated that using student-centered constructivist teaching strategies increases students’ performance in science (Kim, 2005; Magak, 2016; Adak, 2017). As asserted by Onanuga et al. (2020) and Soekamto (2017), the Generative Learning Strategy is effective at improving learners’ performance and motivation by letting them actively engage in the process of teaching and learning. This is because it focuses on the needs of the individual student. The Generative Learning Strategy, according to Awolere et al. (2019), is successful in raising students’ academic achievement in Biology.

The use of generative learning methodologies also motivates students to actively participate in understanding concepts, which in turn equips them with the skills needed to address biological challenges. The learners are able to recognise misconceptions and fix them since they are engaged in a variety of learning activities, as the authors highlighted. According to Awolere (2015), the student-centered nature of the strategies

or activities used in the Generative Learning Strategy is beneficial in raising students' academic performance and aiding in the development of practical skills in Biology. Furthermore, he stressed how flexible teaching and learning are made possible by Generative Learning Strategy, which also encourages students' collaboration and communication for efficient learning.

Onanuga et al. (2020) discovered that the students' uneven academic performance in Senior Secondary School Biology can be effectively addressed by using the Generative Learning Strategy in their study to evaluate the relative effectiveness of the strategy on students' academic attainment. According to Fasanya (2022), Appiah-Twumasi (2019), Appiah-Twumasi (2018) and Carnine and Kinder (1985), the Generative Learning Strategy is useful in raising low-achieving students' academic perception. As a consequence, more students have their performance improved and move up from the low-achieving group to the average or even the high-achieving group. However, there has not been much research done to determine how successfully Ghanaian Senior High School teachers can use the Generative Learning Strategy to teach Genetics, how it can improve low-achievers performance as well as how its impact is perceived by students.

Additionally, when determining the effectiveness of the Generative Learning Strategy in the Ghanaian educational system, students' perceptions of the teaching strategy were taken into consideration in addition to their academic performance. Examining how students interpret the new method was important because it will highlight students' opinions about it (Beatty & Albert, 2016), which can influence students' acceptance of it and help educators design engaging lesson plans (Yoon et al., 2014).

According to Tudor et al. (2010) and Johnson (2016), students' perceptions of teaching methods are pertinent to the teaching and learning activities, and this is because their opinions of the methods used in the classroom influence their academic performances (Uiboleht et al., 2019). As said by Ferreira and Santoso (2008), students give better performance when they have a favourable opinion of the teaching methods used in the classroom. Consequently, in order to determine whether the Generative Learning Strategy is beneficial for teaching genetic ideas in the senior high Biology context of Ghana, this study sought to determine the effectiveness of the Generative Learning Strategy.

1.2 Statement of the Problem

The performance of students, particularly in Biology, is unimpressive, even though teachers have been employing a variety of mandated teaching methods (Amoah et al., 2018). Over the years, the West African Examination Council's (WAEC) Chief Examiners' Reports have noted Senior High School students' low performance in genetic concepts (WAEC Chief Examiners' Reports, 2020; 2019; 2017). The WAEC Chief Examiners Report (2020) declared that the majority of the candidates could not list the organelles in cells that are involved in protein synthesis. Also, in the 2019 WASSCE, the Chief Examiners' Report noted that most candidates failed to clearly explain the differences between DNA and RNA. Similarly, the WAEC Chief Examiners Report for 2017 indicated that the candidates' Biology coursework was inadequate, with the erroneous creation of genetic diagrams serving as one example. Candidates also had difficulty providing an explanation of recombinant DNA technology and its applications.

There seems to be a consistent poor performance by students in genetics, which finally affects their general performance in Biology. For example, in studies conducted by Onyejekwe et al. (2018), Çimer (2012), and Yu-Chien (2008) on investigating problems faced by students in Biology learning in Nigeria, Turkey, and Taiwan, genetics was found to be at the top-spot, which resulted in low academic performance amongst students in the subject. This clearly indicates that students' difficulty learning genetics in Biology is not only peculiar to Ghanaian schools but globally as well. Literature has highlighted the benefits of the Generative Learning Strategy on the learning objectives of students across different learning domains which could be used to enhance learners' understanding in genetics.

Empirically, this learning strategy has been reported to affect students' performance positively in such areas as Physics by Fasanya (2022), Chemistry by George & Abumchukwu (2021), Appiah-Twumasi (2019) in Physics, Olagbaju (2019) in Summary Writing, Bot (2018) in Geometry and Esfandiari (2003) in Applied Statistics. However, there seems to be a study gap in the use of the Generative Learning Strategy in the teaching and learning of Biology, and genetics, for that matter. Also, there have not been extensive studies to examine how the Generative Learning Strategy could be used to improve the academic performance of low and high achievers in the study of Biology and, for that matter, genetics. Moreover, it appears that there is a dearth of research on how students perceive the application of the Generative Learning Strategy in the teaching and learning of Biology and, for that matter, genetics. It is in line with these findings that this study adopted the Generative Learning Strategy with the mind of helping students from Sefwi-Wiawso Municipality in Ghana to enhance their performance in the study of Biology, specifically genetics.

Additionally, the study aims to investigate how the Generative Learning Strategy could be employed in teaching to improve low-achievers and high-achievers performance, find out how its impact is perceived by students in the teaching and learning of genetics and Biology in general, and finally fill this study gap.

1.3 Purpose of the Study

The purpose of the study was to examine the use of the Generative Learning Strategy to enhance Senior High School Biology students' performance in the study of genetic concepts.

1.4 Research Objectives

The objectives of the research were to:

1. determine difference in academic performance of SHS Biology students instructed in genetic concepts before and after the use of Generative Learning Strategy.
2. find the difference that exists between genetics test scores of higher achievers and lower achievers instructed with the Generative Learning Strategy.
3. investigate the perceptions of students about the relevance of Generative Learning Strategy in teaching genetic concepts.

1.5 Research Questions

The following research questions guided the study:

1. What is the difference in academic performance of SHS Biology students instructed in genetic concepts before and after the use of Generative Learning Strategy?
2. What difference exists between genetics test scores of higher achievers and lower achievers instructed with the Generative Learning Strategy?
3. What are the perceptions of students about the relevance of Generative Learning Strategy in teaching genetic concepts?

1.6 Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance to guide the study:

H₀₁: There is no significant difference in the academic performance of SHS Biology students instructed in genetic concepts before and after the use of the Generative Learning Strategy.

H₀₂: There is no significant difference between the genetic test scores of high achievers and low achievers after exposure to Generative Learning Strategy.

1.7 Significance of the Study

The persistent application of the traditional teaching methodology has resulted in subpar students' performance in Biology throughout time. In order to assist students do better in the topic, innovative teaching methods must be implemented. This study is important because it would lead to the widespread and stable application of the Generative Learning Strategy, which would enhance students' performance of Senior

High School students within the Sefwi-Wiawso Municipality. The results of this study would also contribute to efforts made by Ghanaian educators to prepare students in the Sefwi-Wiawso Municipality for entrance into higher educational institutions. The improvement in students' academic performance would likewise be advantageous to society.

In addition, it would also result in more students from the Sefwi-Wiawso Municipality enrolling in Science programmes at higher education institutions. This would ultimately result in more people working in fields connected to Biology, which would benefit the nation's overall health, agriculture, and other services. Additionally, curriculum designers who are always searching for efficient ways to teach various facets of science, particularly in Senior High Schools within the Sefwi-Wiawso Municipality, will be able to use the empirical data from this study to help them meet their objective of raising students' academic performance. It would equally function as an essential component of curriculum innovation in Ghanaian education, most especially the Sefwi-Wiawso Municipality as it is intended to add to the body of knowledge already available to aid in improved performance in the field of teaching. Due to the strategy's applicability, it necessitates its inclusion in Ghanaian Senior High Schools' curricula for application in the process of teaching and learning. The study's findings would also be helpful to writers, most especially within the Sefwi-Wiawso Municipality since they may utilise the method to make their texts more applicable to people, institutions of higher learning, groups with similar interests, and the country as a whole. Consequently, it would encourage additional study in this field of Science, namely Biology, most especially, within the Sefwi-Wiawso Municipality.

1.8 Delimitation of the Study

There are a number of concepts in the Elective Biology syllabus for Senior High Schools that students find difficult to understand, as well as a number of teaching methodologies; however, this study concentrated on the usage of the Generative Learning Strategy in the teaching and learning of genetic concepts and also focused on SHS 3 Biology students.

1.9 Limitation of the Study

The study was limited to a single-group made up of two intact classes without a control group that was pre-tested, and post-tested after exposure to treatment conditions during the intervention phase. Hence, the results and findings from this study may not be generalisable to other populations or settings due to the unique characteristics of the sample.

1.10 Operational Definition of Terms

Generative Learning Strategy (GLS) is a methodical teaching approach based on the views and experiences of students who are actively participating in their education. Ogunleye and Babajide (2011) added that the Generative Instructional Strategy model is a functional paradigm of instruction as opposed to a methodical one.

Performance refers to a student's achievement in a particular academic area or subject, as demonstrated by grades, test scores, and other measures of learning.

Learning outcomes are the expected knowledge, understanding, skills, experiences, etc., to be acquired at the end of a lesson (Common Core Programme, 2020).

Concepts are mental constructs that assist us in comprehending and organising the environment we live in by grouping similar ideas, objects or experiences together.

Genetics refers to the scientific study of genes, heredity, and genetic variation in organisms.

1.11 Organisation of the Study

The study is divided into five chapters, each of which focuses on a distinct area of the investigation. The study's introduction, background, problem statement, purpose, objectives, questions, and hypotheses are all covered in the first chapter. Other topics covered include the study's significance, delimitation, limitations, operational definition of terms, and organisational structure. Also, chapter two, which is the study's literature review, covers the theoretical framework, conceptual framework of the study, a review of empirical studies, teaching methodologies, the concept of Generative Learning Strategy, problems associated with the teaching and learning of genetic concepts, the application of the generative learning strategy approach in the teaching and learning process, and the benefits of using the Generative Learning Strategy in the teaching process. The study's research technique is covered in Chapter three. It provides an explanation of the study area, research paradigm, type, overall research design, study population, population sample and sampling technique, research instruments, data collection process, and data analysis process.

In Chapter Four, the study's data are analysed and presented. The research questions that directed the study were followed when conducting the discussion. Evaluation of the study's results was done, and their practical and theoretical implications were looked at in relation to the state-of-the-art theory at the time. Furthermore, a review of

the major discoveries and their interpretations, together with inferences made in light of the findings, are provided in chapter five. Additionally, recommendations and suggestions for further research were made.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter presents the theoretical framework, the conceptual framework of the study, the concept of Generative Learning Strategy, a review of empirical studies, teaching methodologies, problems associated with the teaching and learning of genetic concepts, the application of the Generative Learning Strategy approach in the teaching and learning process, and a summary of the empirical review on Generative Learning Strategy.

2.1 The Concept of Generative Learning Strategy

The definition of the word “generative”, which is derived from the Latin word “beget,” is “having the power or function of generating, originating, producing, or reproducing”. Thus, Generative Learning Strategy scribes the mental operations involved in the creation of individual knowledge or meaning. Knowledge, according to generative learning theorists, is the intentional comprehension of information that results from the building of links between novel pieces of knowledge and between novel knowledge and memory. The core premise of the Generative Learning Strategy (GLS) is that students are not merely passive recipients of knowledge. Instead, they actively participate in the educational process and work to develop a deep comprehension of the knowledge they encounter in their environment Fiorella and Mayer (2016).

Research in various subfields of cognitive psychology, including as information processing, cognitive development, human learning, human capabilities, and aptitude

treatment relationships, influences the methodology. Creating links between concepts in the subject matter and between it and the knowledge that students already possess is essential to the Generative Learning Strategy, a teaching strategy that aims to make students actively involved in and responsible for creating meaning from class activities (Wittrock, 1974). According to Esfandiari (2003), the goal of the Generative Learning Strategy is to minimise students' roles as passive information consumers and maximise their participation in the learning process by assisting them in:

- (i) comprehending the connections between the subject's or topic's many components;
- (ii) creating connections between the various components of the subject or topic;
- (iii) establishing connections between their expertise of the subject at hand and the newly learned material and
- (iv) applying the new knowledge to resolve issues and provide answers in the actual world.

Additionally, the Generative Learning Strategy has been defined as a learner-centered instructional strategy with predetermined activities intended to promote active cognitive processing throughout the session. The internal processing of external stimuli is necessary for generative learning processes, according to Wittrock (1974). The learner, teacher, or instruction should not assume a dominant role during any of the steps or activities in the Generative Learning Strategy; rather, they should be considered collaborators in the process. Awolere et al. (2019) claim that one key method for teaching students to change their negative and positive attitudes toward Biology in particular and Science in general is generative learning.

Our educational institutions typically need introductory Science classes like Biology, Chemistry, and Earth science in order to improve students' attitudes toward Science in general (Faralhnaz, 2012). It is essential to provide the students with the freedom to infer meaning from happenings in order to teach these Science courses in a meaningful way. According to Awolere (2015), the Generative Learning Strategy enables learners to be able to freely express their opinions regarding the topics under discussion because they also have information to share and statements to make. Here, the teacher only needs to embrace the feelings of his students, value their contributions, and recognise and direct their thoughts.

The teacher also guides factual knowledge by posing provocative questions to the students that can increase their (students') engagement. In 1974, Merlin Wittrock released the initial version of Generative Learning Theory at a time when cognitivism was the prevalent educational philosophy and the role of the individual in the learning environment was the subject of instruction. Wittrock postulated four elements for his model of Generative learning, namely, processes for generation, learning, motivation, and formation (Wittrock, 1991). These four processes result in the active and dynamic meaning making that leads to the rearrangement, reconceptualisation, elaborations, and relations that improve knowledge (Wittrock, 1991).

Thus, generative learning differs from information processing in that it goes beyond changing the information for storage to involve the learner in creating new meaning through the four different processes. The brain's neuronal system receives, attends to, and integrates information from several senses selectively (Wittrock, 1991). Similar to sensory input, short-term memory, and long-term memory as stated in other learning

theories, the four processes as explained and shown in Table 2.0 below are described in a linear form, and there is a close connection between the procedures.

Table 1.0 The Four Processes Components of Generative Learning Theory by Wittrock (1974/1991)

	Brain Functional Unit	Learner Action	Determines	Characteristics to Promote Process
<i>Motivational Processes</i>	Attentiveness and arousal.	Recognise new content only when it is interesting and feels in your control.	Recognizing stimuli and fresh material, as well as whether generation takes place.	Enhance the sense of self in students, highlight the learners' ownership of and accountability for their own learning. Connect effort to learning.
<i>Learning Processes</i>	Attentiveness and arousal.	Concentrate on and respond to the newly acknowledged content.	Deciding to codify and include new data.	Captivate students' attention and direct them to the content's meaning. Describe how the subject is relevant to the student. Give behavioral learning goals.
<i>Knowledge Creation Processes</i>	Integration of sensory data.	Combine and evaluate new information iteratively in comparison to prior understanding .	Depending on memory, beliefs, and values, the quality and type of connections that are made.	Rely on the interest and prior knowledge of the learner. Enhance the metacognition of the learner. Keep track of learners' misunderstandings and preconceptions.
<i>Generation Processes</i>	Organisational and executive planning.	Integrate, arrange, reframe, and elaborate to establish new connections.	Degree of understanding , success in retrieving and recalling fresh content.	Give learners the chance to modify information and make connections.

Source: Wittrock (1974/1991).

For instance, the “knowledge production processes” and the “generation processes” work together when a learner makes connections to new information while drawing upon prior experiences and knowledge (memory). As the connections become an integral part of memory, they are internally labelled and are stimulated by the learner’s physical and mental activity with the new material.

Motivational processes. On his knowledge of Luria’s functional units of the brain, Wittrock based the four process elements (Wittrock, 1974). Learning and motivational processes are linked to the Luria’s arousal and attention units of the brain (Lee, Lim, & Grabowski, 2008). This practical tool helps the learner become conscious of environmental stimuli and select which ones to pay attention to and which ones to ignore (Languis & Miller, 1992; as cited by Wilhelm-Chapin & Koszalka, 2016). Learners are motivated to respond to new information by their own intrinsic motivational processes, such as interest and control over their own learning.

Learning processes. The processes of learning and motivation in a learner occur almost simultaneously. When new information is accepted, motivational processes turn on learning mechanisms that direct the learner's focus to it. The learner is subsequently directed to focus on the new knowledge through learning processes. During the learning process, the learner's attention may fluctuate as they “tune in” or “tune out” to the plethora of stimuli in their surroundings. The personal habits and tendencies that control how much attention is paid to new information or content are known as learning processes.

Knowledge creation processes. The learner who is paying attention to the stimulus starts to create a new model that includes the newly learned information based on their prior knowledge, beliefs, and values. These processes of knowledge formation are based on the second functional brain unit of Luria, known as sensory input and integration (Languis & Miller, 1992; as cited by Wilhelm-Chapin & Koszalka, 2016). The newly acquired data are currently being gathered, examined, and recorded. Learners' past knowledge and experiences are taken into consideration while creating sequences and patterns (Wittrock, 1991). Relationships between new content and prior knowledge are qualified by the learner's knowledge creation processes. The process of creating knowledge results in the formation of connections and linkages. Wittrock claimed that the development of relationships between and among concepts during knowledge creation processes, including metacognition, determines the caliber of the meaning that the learner creates.

Generation processes. The coding or merging of the information is referred to by Wittrock as the generation processes. The unit in charge of organising and planning, Luria's third functional unit of the brain, is where generative learning processes are mapped (Languis & Miller, 1992; as cited by Wilhelm-Chapin & Koszalka, 2016). As knowledge is arranged and integrated for subsequent memory and retrieval, the learner mentally identifies the connections and linkages between relationships as the process proceeds.

The final point made by Wittrock (1991) was that learners should be in charge of their own generative processes. Since it lets students know their development, self-monitoring is a crucial procedure in this situation (Yorks & Kasl, 2002). The

management of effort and resource availability, as well as the modification of learning strategies, are all based on self-monitoring by students in order to provide meaning. The learners actively build connections between old memories and new information in order to summarize it and give it significance. They are engaged in this knowledge creation process cognitively and employ a variety of learning techniques.

Ogunleye and Babajide (2011) claim that the Generative Learning Approach is a step-by-step learning method that is based on the opinions and experiences of students who are actively participating in their education. They added that the Generative Learning Strategy model is not a structural paradigm of instruction, but rather a functional approach. As a functional model of instruction, Ogunleye and Babajide (2011) concluded that it focuses on the mental processes that learners utilise to comprehend ideas as well as the methods of training and teaching that can improve understanding. The Generative Learning Strategy is a student-centered approach where students voluntarily explain and modify bits of knowledge that have been pulled from their memories about a certain concept.

Individualised learning is made possible by the Generative Learning Strategy, which also gives students the freedom to express their own opinions. The Generative Learning Strategy is predicated on the theory of schemata, according to Wittrock (1974), as mentioned by Appiah-Twumasi (2018). According to the schemata notion, new information is added to each student's long-term memory and eventually becomes a part of that student's knowledge base.

This suggests that learning is founded on memory that was previously stored in each person's brain. The fundamental tenet of the Generative Learning Strategy of instruction is that the student is an active participant in the process of learning, striving to generate meaningful knowledge of information gleaned from the immediate environment. Wittrock (1974), as cited by Appiah-Twumasi (2018). Literature suggests that the Generative Learning Strategy's phases and activities differ. George (2011), for instance, pointed out that the two categories of generative learning activities are as follows: The students are first asked to make organisational linkages between the main concepts, the location, the graphs, the title, the concentration, the questions, the objectives, and a summary.

By using metaphors for examples, such as analogies, interpretations, paraphrases, and conclusions, the students are required to create cohesive connections between what they hear, see, and understand. Awolere (2015) also came out with seven components or phases, namely: introductory phase, focusing phase, activity phase, discussion phase, application phase, conclusion, and summary. Maknun (2015), the generative learning paradigm, on the other hand, has five steps: orientation, disclosure of ideas, challenges and reconstruction, implementation, and evaluation.

According to Pappas (2014), the Generative Learning Strategy has four primary fundamental elements that teachers can incorporate based on the needs of the students and the materials used for teaching and learning. The following are Pappas' four key ideas for the generative learning model:

RECALL: This happens when a learner uses knowledge that has already been ingested to learn content that is fact-based by accessing knowledge that has been stored in his or

her long-term memory. Asking the learner to repeat information or go over a concept again and again until he or she understands it completely is an illustration of a recall task.

INTEGRATION: This happens when a learner combines newly acquired knowledge with information that has already been gathered and stored in the brain. The goal is to change previously stored information into a format that makes it easier for the learner to remember and access it in the future. Making parallels to explain previously acquired knowledge that has been stored in the brain is an example of integration.

ORGANISATION: This requires students to effectively connect previously learned material to new concepts. Making lists or outlining the key ideas of a topic is an example of organisation in action.

ELABORATION: This requires that, in evaluating concepts, the teacher encourage the students to draw connections between previously learned material and novel concepts. Extending on ideas and visualising mental images are two examples of elaboration.

While various works of literature, including those by Awolere (2015), George (2011), Pappas (2014), and Maknun (2015), suggest that the activities of the Generative Learning Strategy differ, its capacity to foster concept mastery is undeniable. This conceptual mastery in the Generative Learning Strategy may be linked to students' intellectual prowess, which is connected to their cognitive capacities. If a learner can define concepts, create organisational associations such as the title, the concentration, the questions, the aims, a summary, the graphs, the location, and the major ideas, that student is said to possess cognitive talents.

Additionally, by using metaphors, for instance, children with cognitive capacities can create integrated linkages between what they hear, see, and understand. Activities utilising the Generative Learning Strategy are linked to all of these cognitive capacities, as was previously mentioned by George (2011) and Awolere (2015). The Generative Learning Model, as described by Wittrock in 1991, is a functional learning model of instruction, according to Prawita et al. (2019). It was developed using knowledge of the brain and cognitive processes involved in understanding, learning, paying attention, motivating, and transferring information.

The Generative Learning Approach required the students to study independently, explore their knowledge from multiple learning sources, concentrate on the issue at hand, execute an experiment to build concepts they had learned, and then apply those concepts to situations they encountered on a daily basis (Wena, 2009). In order for all of the activities that the students engage in to be focused on helping them build knowledge via discovery, they are expected to do more than just passively listening to the teacher's vocal explanations. According to Prawita et al. (2019), there are four stages that may be used to categorise the steps of activities in the teaching and learning process that incorporate generative learning:

1. Exploration stage;
2. Focusing stage;
3. Challenge stage;
4. Application stage.

At the exploration stage, students are given the chance to use their five senses as much as possible to examine the issues being presented before reading the numerous sources that are linked in order to pique their curiosity and develop high-level thinking skills.

The exploration stage allows students with low reading motivation to gain the chance to create concepts by connecting the knowledge they have already acquired from their daily activities. At the focusing stage, students are free to brainstorm solutions to the problems and complete assessments. At the challenge stage, students take on the challenge of thinking, comparing viewpoints, and arguing for the superiority of each viewpoint using facts.

The learners' opportunities to generate ideas and sharpen their analytical thinking skills are increased by this interchange of viewpoints, which also increases understanding (Purwo, 2016). At the application level, students are given the chance to use their newly acquired concepts to solve issues.

2.2 Theoretical Framework

There are several perspectives on how people learn, and as a result, various ideas on how people learn have been developed. Instructors employ a range of instructional techniques in their classrooms that are based on various learning theories. Some of the main theories of learning are behaviorism, cognitivism, and constructivism. This study's conceptual foundation was constructivism philosophy. This is not implausible given that the study focuses on learners' thinking and academic development. The constructivist hypothesis has a number of well-known proponents. Among them are prominent figures like John Dewey (1859–1952), Jean Piaget (1896–1980), Lev Semyonovich Vygotsky (1896–1943), and Jerome Seymour Bruner (1915–2016). The nature of human knowledge, particularly the nature of scientific knowledge, as well as beliefs about how learning occurs and methods for verifying learned information, are crucial to constructivism theory. In essence, constructivism is a hypothesis about the

nature of learning that is founded on study and observation. It makes clear that individuals construct their own knowledge of the world when they engage in experiences and think back on those experiences (Woolfolk, 2016). According to the constructivist view of learning, learners use a range of learning activities and interactions to generate knowledge and meaning from their experiences, whether working alone or in groups (Kazeni & Onwu, 2012).

According to Bhutto and Chhapra (2013), under constructivism, teachers assist students' growth by creating an inspiring and encouraging learning environment for them while taking into account their unique needs, past experiences, and learner-oriented objectives through effective social communication. Therefore, the role of the teacher is to act as a facilitator while the students learn in groups (Allah-Nawaz, 2012). According to Husain (2018), learners' roles are to actively investigate new concepts and build them, as the instructional method effectively involves them all in the learning process. Basically, it can be claimed that the constructivist understanding of learning is the foundation for the adoption of the Generative Learning Strategy. Understanding human knowledge and the characteristics of scientific knowledge are essential to constructivism. It also involves how knowledge is certified once it has been learned, as well as how the learning process is perceived. These ideas are highly crucial in the teaching of Science. Constructivism does serve as a very potent theoretical resource that maximises students' learning (Treagust, Duit, and Fraser (1996); as referenced by Dzidzinyo, 2020). Additionally, constructivism makes it easier to comprehend the results of instruction and contributes to the explanation of key scientific findings about the significance of students' pre-instructional beliefs in the learning process.

This highlights the constructivist viewpoint's primary contribution to research, teaching, and learning. There are three basic subcategories of constructivism: radical constructivism, social constructivism, and cognitive constructivism (Doolittle, 1999). Although each of the three major constructivism subcategories takes into account the concept of students creating their own knowledge, they all share the same fundamental premise (Singh & Rajput, 2013). The foundation of cognitive constructivism is the idea that humans acquire knowledge by actively generating it in their thoughts and applying what they already know to interpret fresh experiences (Okoroma, 2013).

In the particular instance of radical constructivism, Belbase (2014) contended that knowledge is best built by a person rather than passively received through the senses or through communication, and that the adaptive nature of inferring aids people in establishing the world they perceive rather than in discovering experience of the world. As a reflective being, a learner creates knowledge through real-world actions by modifying methods and resources from others in the community (Mishra, 2014). According to Mishra (2014), social constructivism as a form of constructivism involves students engaging with one another to create knowledge in the classroom, which is a social situation.

It has been determined that social constructivism is the philosophy that best supports teaching and learning. Contrary to cognitive constructivism, which holds that people create information on their own in their minds, social constructivism is concerned with how people create knowledge in social contexts. The founder of social constructivist theory is regarded as Lev Semyonovich Vygotsky (Zhou & Brown, 2015). Within the zone of proximal development (ZPD), which is defined by the learner's social and

interactive boundaries, is where knowledge is formed for each individual. These are the main elements of Vygotsky's theory.

People acquire information through the mediation process between people; people absorb culture; and knowledge is generated inside the ZPD (Taylor & MacKenney, 2008). According to Vygotsky, the zone of proximal development is the area between an individual's potential development as indicated by their capacity to solve problems under the supervision of an adult or in collaboration with a peer who possesses a higher level of development than they do, and their actual level of development as determined by their ability to solve problems independently (Vygotsky, 1978; as cited by Quainoo, 2019). The ZPD discusses concepts such as a learner's current developmental stage, the next stage of growth that the student can achieve is by use of mediation, resources in the surroundings, and assistance from an experienced adult or colleague (Shabani, Khatib, & Ebadi, 2010).

The reaction between a person with greater ability and someone with less ability on an activity, where the latter thereafter completes the task on their own, is the focus of ZPD, according to Chaiklin's (2003) explanation. The learner is supported in raising her existing academic achievement to a higher level by the more experienced person, who acts as a scaffold (Pathan et al., 2018). According to Shabani et al. (2010), the ZPD promotes the premise that people learn best when they collaborate, and it is via such collaborative activities that students better understand and gain new knowledge while receiving assistance from more experienced individuals. For instructional approaches, the zone of proximal development has some repercussions.

According to Christmas, Kudzai, & Josiah (2013) analysis of ZPD's implications, a competent peer or instructor must provide the learner with advice, and the teacher must also promote collaborative learning among the students. The new concept being learned should be at an acceptable level of difficulty when taught using the ZPD approach. The learning job should not be so simple that the learner does not need help, which might be boring, nor should it be so challenging that the learner gives up trying to understand the new concept. The learning assignment should be challenging enough for students to learn the new ideas without assistance from someone with greater knowledge.

According to Orey (2010), social constructivism is founded on three assumptions, which are rooted in Vygotsky's (1978) arguments.

- (1) Reality: According to social constructivists, reality is created by society as a whole, therefore it cannot be determined;
- (2) Knowledge: It is thought that knowledge is created culturally as people interact with their surroundings;
- (3) Learning: According to social constructivism proponents, learning is a social process that is not determined by external factors or internal factors but rather occurs constructively when learners interact socially.

According to Amineh and Asl (2015), humans reason their experiences by creating models of how the social world functions, according to this theory, which has two main tenets: language is the major instrument individuals use to construct reality. According to social constructivism's underlying tenets, even while students actively produce their own knowledge, social interactions have a substantial impact on its development; additionally, as children grow, verbal interaction with others in their environment is a

key element that aids in information comprehension (Walker & Shore, 2015). Social constructivism holds that interactions with the environment have an impact on how knowledge is conceptualised (Allah-Nawaz, 2012).

As a result, knowledge is not something that people autonomously construct in their minds; rather, it is made and replicated by individuals in specific situations who utilise their culture to collaborate on a shared objective (Yüksel, 2009). Adams (2006) outlined some recommendations that teachers can take into account while setting up a social constructivist classroom for effective learning. The rules state that learning should take precedence over student performance, that students should be seen as co-creators of conceptual understanding, that learners should be actively involved in activities that they find meaningful, and that learners should be evaluated by acknowledging and recognising shared understanding.

Cooperative learning is encouraged in the social constructivist classroom because Moreno (2010) noted that when students share ideas with one another, it fosters comprehension because they evaluate each other's ideas, make required corrections, and embrace new concepts that are similar to their own (Allah-Nawaz, 2012). Therefore, the teacher's responsibility is to act as a facilitator while the students learn in groups (Allah-Nawaz, 2012). According to Husain (2018), learners' jobs are to create new ideas through active inquiry since the instructional approach effectively involves everyone in the learning process. Constructivism has been the subject of comparable opinions from other writers.

For instance, constructivists contend that although they acknowledge the reality of the world, our understanding of it is based on our own interpretations of our experiences. The study conducted by Ertmer and Newby (2013), comparing the critical features of behaviourism, cognitivism, and constructivism from the view point of instructional design indicated that the interpretations we make of our experiences are original to us. In other words, rather than acquiring meanings, we elucidate them on our own to arrive at them. The notion that cognition (learning) is accomplished through the process of “mental building” is another tenet of constructivism, according to Bada (2015), which is a teaching and learning strategy.

Incorporating new knowledge into what is referred to as the relevant prior knowledge is what is meant when something is being mentally constructed in this situation. This suggests that knowledge is acquired by students through integrating new knowledge with existing knowledge. We must therefore make sense of new information as it is presented to us in order to make it fit with our preexisting beliefs and experiences. This can mean that we have to reevaluate our original conclusions or consider the new information as unimportant. We actively build the knowledge we possess in every kind of event. In order to accomplish this, we must look into, assess, and pose inquiries.

Numerous instructional practices in the classroom may be suggested by the constructivist theory of learning. In general, it entails motivating students to create new knowledge using active methods like experiments, real-world problem solving, or case studies, as well as to analyse and communicate how their knowledge is evolving. Therefore, it is the responsibility of the teacher to ensure that he or she is aware of the students’ preconceived notions and to direct the activity to help resolve and build upon

them (Oliver, 2000). Accommodation and assimilation are two key ideas in the constructivism learning theory that aid in comprehending how someone creates new information.

An individual can assimilate new experiences into their past ones with the aid of assimilation. This prompts the person to take on new views, reconsider previous misunderstandings, and determine what really counts, eventually altering their viewpoints. On the other hand, accommodation entails molding the outside environment and novel experiences to match the mind's current capacity. People initially have a preconceived notion of how the universe ought to operate. When something doesn't work within that framework, it is then taken into account and the outcomes are revised. As a result, constructivism is predicated on the premise that learning is influenced by both the context in which a concept is presented and the values and behaviours of the students.

This indicates that different learners may generate various meanings from the same knowledge when it is learned by them in various circumstances and with various beliefs and attitudes. If the constructivism theory is recognised as the best explanation for learning, it follows that in order to encourage students' learning, it is required to establish learning environments that introduce the learner to the subject matter being studied explicitly. This is the case because the learner can derive meaning from the world through practical interaction. The conclusion that follows is that the constructivist learning environment is the only appropriate learning environment in which to apply the constructivism learning theory.

One of the fundamental principles of constructivism is that learning must be an active process (Tam, 2000). As a result, any constructivist learning environment has to include opportunities for active learning (Bada, 2015). Honebein (1996) identifies seven pedagogical aims for constructivist learning environments, and Bada (2015) summarised these aims as to encourage the use of diverse modalities of representation, be it video, audio, text, audio-visual, animations, etc. This means that using a variety of modalities of representation, such as audio, video, audio-visual, texts, animations, and so on, motivates students to actively engage in classes. So, the learners can develop their own knowledge in many representational contexts.

Furthermore, Bada (2015) noted that constructivist principle postulates that learning is facilitated by challenge and prevented by threat. Students should feel challenged in the classroom, but not in any way threatened. This means that, according to the constructivist school of thought, challenges that require students to construct information effectively help them learn best. Bada additionally noted that constructivism's effects on teaching and learning requires the constructivist teacher to engage students in situations that highlight inconsistencies to original understandings and then invites discussion.

This is comparable to assisting students to reject false beliefs or alternate conceptions by giving them examples that defy their theories. When that occurs, students are more likely to be open to learning and remembering concepts that have been approved by science. Additionally, the constructivist teacher's function of involving students in experiences and fostering dialogue between himself or herself and the students is consistent with the notion of mediation. According to social constructivists, even while

knowledge is created by individuals, that creation is socially controlled (Bada, 2015). The social constructivism of Vygotsky, which emphasizes the role of language in meaning creation, is where this idea comes from.

It also creates the impression that, despite the fact that students create their own interpretations of novel events, this process is always rooted in the students' particular social context. This suggests that the study of scientific concepts should follow a progression that involves the students' capacity for thought, comprehension, and decision-making with the help of the teacher. Consequently, activity alone is insufficient for learning to occur meaningfully. This suggests that the assistance provided by the teacher to students is an essential element in constructivist learning situations. It is anticipated that this will help students build an understanding of the scientific community's accepted notions and hypotheses.

Finally, the knowledge that students are expected to acquire must be specifically stated in the instructional objectives set by constructivist teachers (Mutimucuo, 1998, as cited by Dzidzinyo, 2020). Accordingly, it is necessary for teachers to take into account the concepts and anticipations that students bring to class (i.e., learners' prior knowledge and expectations of topics to be studied). Instructors should focus on clearly defining the distinction between scientific knowledge (i.e., a system of relations, definitions, and principles) and conventional commonsense information (i.e., knowledge created via everyday experience or by contact between members of a non-scientific group).

The primary source of students' pre-instructional beliefs, which are frequently rather challenging to change through instruction, is common-sense knowledge. This is

because they influence how students make sense of the knowledge they get from their teachers or from the books they read.

2.3 Conceptual Framework

The constructivism theory, which was used to drive the study, asserts that people build their own knowledge of the world as they engage in experiences and reflect on those experiences, which is fundamental to understanding how people perceive the world (Woolfolk, 2016). According to the constructivist theory of learning, students generate insight and significance derived from their encounters by working in groups or independently on a variety of learning tasks (Kazeni & Onwu, 2012).

In line with constructivism, teachers support students' growth through establishing a supportive and encouraging learning environment for individuals that considers their unique requirements, past experiences, and learner-oriented objectives through skillful social communication (Bhutto & Chhapra, 2013). This aids learners in deepening their conceptual comprehension through experiences, ultimately improving their academic achievement. This theory served as the foundation for conceptualising how the research variables interacted, as shown in Figure 1.0.

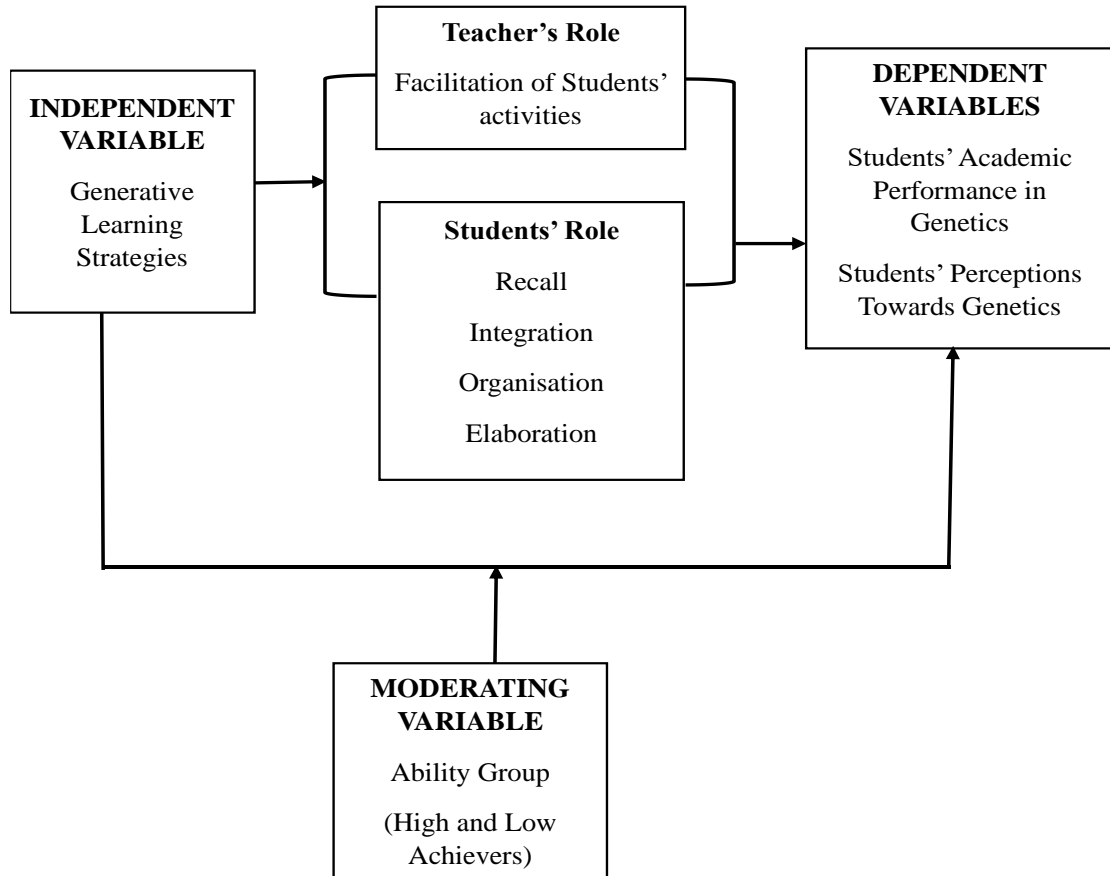


Figure 1.0: Conceptual framework of the study

As shown in Figure 1.0, the conceptual framework for this study shows the interaction between the Generative Learning Strategy and the achievement levels, that is, high and low achievers which is crucial to understanding the differential impact on learning outcomes. By examining these interactions, one can determine how the Generative Learning Strategy can be optimised or adapted to benefit students with varying levels of prior achievement. As illustrated in Figure 1.0, the Generative Learning Strategy is the independent variable, students' learning outcomes serves as the dependent variable, with high and low achievers as moderating factors.

The Independent Variable (IV) which the Generative Learning Strategy refers to the instructional techniques that encouraged students to actively generate knowledge rather

than passively receive it in the teaching and learning process. Examples include summarizing, teaching others, and generating questions. The Dependent Variable (DV), which is the learning outcomes are the measurable educational results or achievements that the study aims to assess. This could include test scores, conceptual understanding, retention rates, and application of knowledge. The Moderating Variables, which are achievement levels which categorizes students into high achievers and low achievers based on their prior academic performance.

The Generative Learning Strategy is expected to either positively or negatively impact learning outcomes. If the Generative Learning Strategy is effective, students who are engaged in generative activities are likely to have better understanding and retention of the material because they are actively involved in the learning process. The moderating variables, achievement levels, influence the strength or direction of the relationship between the Generative Learning Strategy and learning outcomes. Specifically, they determine whether the impact of the Generative Learning Strategy varies between high achievers and low achievers or not.

The high achievers are students that typically already have effective learning a strong foundation of prior knowledge. The Generative Learning Strategy might lead to significant improvements in learning outcomes, but subjected to their incremental gains during assessment. The low achievers are students that may have inadequate effective foundational knowledge. This is where active engagement required by the Generative Learning Strategy would be mostly examined to ascertain whether it would be able to help improve their understanding in order to bridge the performance gap between them and the high achievers. The Dependent Variable (DV), which is the learning outcomes

refers to the expected knowledge, understanding, skills, experiences, etc., to be acquired at the end of a lesson.

The Generative Learning Strategy is thought of to enhance learning outcomes for all students due to its active learning approach, in that, the students' role is to actively partake in learning activities involved in the Generative Learning Strategy, thus recall, integration, organisation and elaboration under the guidance of the teacher. The teacher's role is to guide and facilitate students' activities and provide support where necessary. One special attribute of Generative Learning Strategy is its tailored strategies to better support low achievers.

2.4 Teaching Methodologies

For instructors to become competent, efficient, and productive in their area of specialization, the proper use of instruction has been one of their most important roles. According to numerous studies such as (Marinko, Marinko, Baužiene, Kairiene, Knyviene, Perkumiene, & Daniels, 2016; Qutoshi & Poudel, 2014; (Sawant & Rizvi, 2015), the key to effective teaching and learning is the adoption of instructional methodologies that are appropriate for the learners' diverse needs and interests. In general, institute days, team meetings, seminars, and the media introduce teachers to a steady deluge of teaching approaches that promise to enhance both instructional strategies and student learning. Teachers who employ effective teaching techniques provide students with the opportunity to relate things they have learned in class to circumstances they will encounter in real life. It gives students the chance to express their knowledge. By utilising various forms of evaluation, teachers are also

effectively able to monitor and assess student achievement, which is another advantage of employing effective teaching strategies (Appiah-Twumasi, 2020).

The fundamental concept, pedagogy, and supervision procedures employed in classroom education are referred to as “teaching methodology” (Teach.com, 2023). Teaching methods are more comprehensive strategies for creating lesson plans and implementing curricula. Teaching methodologies include all forms of learning strategies that instructors use to help students learn or increase their understanding of a subject. They enable teachers to create a learning experience that is both fun and practical, and they can also encourage learners to take an active role in their education. The intention of employing teaching methodologies beyond subject conceptual understanding is to develop students who are self-reliant critical thinkers. With time and effort, it is hoped that students will be able to choose the best approaches on their own and employ them successfully to finish tasks (Persaud, 2018).

According to Persaud (2018) and Newman (2009), introducing new teaching methods into a classroom is not a simple effort but is one that is profitable for both the teachers and the students. The idea of change and the effect it might have on their children make many teachers uneasy. The only change in the classroom is formative assessment, and it is a shift for the better. Teachers would not have to significantly alter their lesson plans; they would only know more about how their students are progressing. After formative assessments have been used, differentiation will naturally occur because the teacher will be able to easily identify the demands of the students and will wish to modify the lesson to accommodate those needs.

In essence, teaching methodology, according to Westwood (2015), involves considering the notable variations among students with regard to their aptitude (or impairment), learning speed, language competence, reading comprehension, and numeracy abilities before utilising this understanding to modify the way the curriculum and assignments are presented. The degree of additional support that particular students may require is also determined by these differences. A teaching methodology is a strategy that encourages educators to address pertinent differences among individual students while upholding high standards for everyone.

To reduce learning failure, it must be used in conjunction with efficient, evidence-based instructional strategies. When used effectively, because they ensure that nearly all students immediately understand the concepts, information, and abilities being taught, these strategies actually reduce the need for significant differentiation. Teachers today deal with students who all have different learning preferences, cultural backgrounds, physical and mental abilities, family dynamics, and other characteristics. It is now obvious that a one-size-fits-all approach to learning is not in the best interests of students, as education has advanced.

Creating tailored learning plans by considering the unique developmental, cognitive, and cultural requirements of every kid is a practice that is part of various instructional methodologies. These customised learning programmes use a range of tools, technology, and even performance standards, depending on the needs of each child. Different teaching methods give teachers the flexibility to meet the needs of every student. After determining how much of the subject each student already understands

through a pre-assessment, the teacher can choose a teaching strategy that best suits their learning style.

As an illustration, some children learn new information by reading, while others remember it by listening to a recording (Arkansas State University, 2017). When deciding to differentiate instruction, teachers take into account the value of incorporating a range of teaching strategies into their methodology. In order to differentiate instruction, teachers should take into account student personalities, needs, and learning preferences. They must recognise the necessity of using a variety of teaching tools in their classroom to cater to different student learning styles and skill levels.

Persaud (2018) highlighted that in examining various teaching methodologies, teachers discover that there is something satisfactory to suit everything and serve as the foundation for teaching. When used properly, these methodologies can also support critical thinking in students and help them understand content and learning experiences on a deeper level, going beyond simple retention and surface comprehension. These approaches and techniques sometimes stem from educational theories that predict behaviour in particular teaching contexts. Teachers are expected to provide excellent instruction and learning experiences in today's society.

In order to meet these demands and standards for high-quality education, educators need to possess an abundance of knowledge and proficiency in both instruction and evaluation techniques. The core competencies of the twenty-first century include critical and problem-solving thinking, creativity and invention, teamwork and

communication. These abilities are clearly interconnected in many different ways, and the improvement of problem-solving abilities in particular is frequently addressed through active learning methods. These teaching methods are often driven by the goal of equipping students with the skills and knowledge necessary to become highly autonomous, self-directed lifelong learners.

Collaborative and cooperative learning, brainstorming in groups, and team-based problem solving are a few examples of these teaching techniques. Teachers should use efficient teaching and learning practices that help foster the development of these essential 21st-century abilities in their students. According to Ross (2017), all learners from cradle to profession, require new skills and knowledge to prosper in today's internationally and digitally interconnected society. Twenty-first century skills are vital if we want to give our children the best chance of succeeding in their educational endeavours, careers, and daily lives.

Now, more than ever, students need to develop these 21st-century abilities. Moreover, Slade and Griffith (2013) asserted that teaching approaches are instruments in the teacher's toolbox. They can be used skillfully or carelessly, properly or improperly, just like any other tool. No teaching strategy can make up for a teacher who is incompetent in his or her subject area, is not clear on the learning objectives, organises an activity that is not focused, or lacks the leadership and management abilities necessary to organise efficient classroom operations. Teaching approaches, according to the Alberta Learning Centre (2002), are the methods teachers employ to guide their students toward becoming independent and savvy learners.

Operationally, these refer to the teaching methods that instructors utilise to make their lessons simple to comprehend while also grabbing the students' interest and attention. Osei-Owusu (2022) defines teaching methodologies as procedures used by instructors to guide and trigger adjustments in their students' learning behaviours in order to achieve a specific goal. He added that a teacher needs to consider a number of variables before selecting a certain teaching approach. The physical infrastructure, age, student achievement levels, time frame, available resources, and materials are just a few of these variables.

Teacher-centered and student-centered are the two main categories or "approaches" that educationists have come to divide educational methods into over time. In contrast to the latter, which refers to techniques that actively involve the learner in the planning and execution of classroom instruction, the former includes traditional teaching approaches that are typically teacher-directed and follow a cookbook of activities and demonstrations (Harris & Johnson, 2001). The traditional approach, sometimes known as the "chalk and talk" method, involves the instructor giving students direct instruction. Their primary duties as educators are to transfer knowledge and conduct assessments and evaluations.

According to student-centered pedagogies, the teacher serves as a facilitator and a mentor who encourages students to actively participate in their own learning (Teach.com, 2023). The student-centered method uses techniques including peer instruction, cooperative learning, observations, and inquiry. Since teachers started experimenting with more avant-garde teaching methods in the late 1960s and early 1970s, there has been debate over the two main approaches to learning (Donnelly,

2014). The debate about traditional teaching methods will undoubtedly continue, and these criticisms serve as the impetus for improvements and changes that are ultimately beneficial to the global advancement of education.

Whatever the pedagogical school of thought, the anticipated outcome of the teaching and learning process is undeniably evident. Teaching is successful only when it results in learning that is tied to purpose, according to Coe et al. (2014), they characterise good teaching as producing results that are important to students' future success while also increasing student achievement. Therefore, the teacher's role, behaviour, and approaches must be consciously derived from the curriculum, defined mission and goals, and accepted pedagogical practices (Wiggins & McTighe, 2007). Every teaching method is a tool in the teacher's arsenal. No matter how powerful the instrument is when used alone, nothing magical happens.

This analysis considers the contextual pressures on teachers' work in modern educational policy, educational systems, and schools (Lingard, Hayes, & Mills, 2003), and it asserts that good teaching is unquestionably a blend of many strategies, methods, and approaches that are all knit together to produce measurable student gains. The discussions here are intended to strengthen the role of the science teacher as a dependable participant in science education who should be encouraged to assess the current situation, plan lessons, get materials, and oversee interactions in the classroom for the learner's best growth and development.

2.5 Structure of the Ghanaian Senior High Genetic Content

The content of the Ghanaian Senior High Genetic Content involves basic terms used in genetics such as gene, genotype, phenotype, dominant, recessive, allele, locus, test cross, back cross, and others. It also includes the structure of chromosomes, the concept of inheritance, which is supposed to include hereditary units, thus genes (which is traced to Gregor Mendel's experiments), replication of DNA, gametes as vehicles of inheritance, Mendel's First and Second Laws of Inheritance, Mendel's experiments on monohybrid and dihybrid inheritance, sex determination, as well as sex-linked characters such as hemophilia, red-green color blindness, baldness, and hairy ear lobes. Details of the structure of Ghanaian Senior High Genetic Content according to the SHS Biology Syllabus (CRDD, 2010) are presented and shown in Table 2.1.

Table 2.0: Structure of the Ghanaian Senior High Genetic Content

UNIT	SPECIFIC OBJECTIVES	CONTENT
UNIT 5 HEREDITY	The student will be able to:	
	2.5.1 explain the term genetics.	Genetics
	2.5.2 explain and define some terms used in genetics with examples.	Basic terms used in genetics eg: gene, genotype, phenotype, dominant, recessive, allele, locus, test cross, back cross etc.
	2.5.3 explain that chromosomes form the basis of heredity.	Structure of chromosomes.
UNIT 6 VARIATION (inclusive)	2.5.3 explain the concept of inheritance.	Concept of inheritance Note: The study should include hereditary units-genes, traced to Gregor Mendel's experiments.
	2.5.4 state and explain Mendel's first and second laws of inheritance.	Replication of DNA, gametes as vehicles of inheritance. Mendel's First and Second Laws
	2.5.5 explain how hybrids are formed.	Mendel's experiments on monohybrid and dihybrid inheritance.
	2.5.6 explain the terms linkage, sex determination, sex-linked characters.	Sex determination and sex-linked characters eg: Hemophilia, red-green colour blindness, baldness, hairy ear lobes.

Source: Extract from GES / CRDD Biology Syllabus for S.H.S. (2010)

2.6 Problems Associated with the Teaching and Learning of Genetic

Concepts

According to Knippels, Waarlo, and Boersma (2005), who reviewed studies in the area of genetics education, students have significant difficulties with domain-specific vocabulary and terminology, as well as the mathematical content of Mendelian genetics

tasks. Also, “cytological processes” is one of the difficulties students have with genetic concepts, and lastly, the abstract and complex nature of genetics as perceived by them. Genetics is a challenging subject to teach students because genetic phenomena are invisible and difficult to access (Duncan & Reiser, 2007). Additionally, Banet and Ayuso (2000) noted that one of the factors contributing to the complexity of comprehending genetics is the need for a certain degree of abstract thinking. In order to formulate a general or abstract formulation of a relationship, formal operational thinking must be used to think of reality from a multivariate perspective. Shayer and Adey (1981), as cited by Didem et al. (2016).

The fact that the subject of genetics covers ideas like genes, proteins, cells, tissues, organs, processes, and others that pertain to various biological creatures’ macro, micro, and molecular levels is another factor contributing to the difficulty of studying and teaching genetics-related topics. Students must be given information about several levels in an integrated manner in order to comprehend the fundamental mechanisms of genetic phenomena (Bahar, Johnstone, & Hansell, 1999; Duncan & Reiser, 2007; Marbach-Ad & Stavy, 2000). Additionally, there are numerous phrases in genetics that have similar appearances and sounds (Didem et al., 2016). Due to the fact that there are numerous synonymous words used in genetic terms (Pearson & Hughes, 1988; referenced by Didem *et al.*, 2016), students frequently misunderstand these concepts and have trouble learning genetics.

Over the years, the West African Examination Council’s (WAEC) Chief Examiners’ Reports have noted low performance in genetic concepts among Senior High School students (WAEC Chief Examiners’ Reports, 2020; 2019; 2017; 2016; 2015; 2013;

2011). In 2020, the WAEC Chief Examiners' Report on the West African Senior School Certificate Examination (WASSCE) specified that the majority of the candidates could not list the organelles in cells that are involved in protein synthesis. Also, candidates in the 2019 WASSCE were questioned to state five differences between a DNA and an RNA molecule. The Chief Examiners' Report noted that most candidates failed to clearly explain the differences between DNA and RNA (WAEC Chief Examiners' Report, 2019). In the same vein, according to the 2017 WAEC Chief Examiners' Report, Candidates showed a deficiency of sufficient Biology content, as demonstrated by their incorrect creation of genetic diagrams, and they struggled to explain recombinant DNA technology and its uses.

Nevertheless, it was noticed in the 2016 WASSCE that majority of candidates avoided answering questions about agglutination and gene interaction (the ABO blood group system), and the ones who did were not good at answering them. In addition, the WASSCE 2015 Chief Examiners' Report stated that Biology candidates struggled with production of mRNA from a DNA sequence, appropriate presentation of genetic diagrams, and spelling of scientific words. To add to these, in the 2013 WASSCE, the task assigned to the students was to explain the structure of deoxyribonucleic acid and list the three structural variations between it and ribonucleic acid. Responses from candidates to this question were reported in the Chief Examiners' report as not outstanding (WAEC Chief Examiners' Report, 2013).

Similarly, it was stated in the WAEC Chief Examiners' Report (2011) that Biology candidates were unable to correctly define basic genetic concepts as diploid and polygenic inheritance. Additionally, the examiners noted that candidates had difficulty

with the role of ribonucleic acid (RNA) in the synthesis of proteins in a cell (WAEC Chief Examiners' Report, 2011). Students' performance on questions on genetic concepts appears to be consistently poor, which ultimately affects students' total performance in Biology and, as a result, their prospects of continuing their study. All of the points raised above make it clear that students' performance in Senior High School Biology, particularly genetics, is not encouraging. This assertion of students' subpar performance in Biology is supported by the research works of Amoah et al. (2018), Abimbola (2013), Gbore & Daramola (2013) and Adeyemi (2006).

2.7 Generative Learning Strategy Approach in Teaching

The many learning objectives can be addressed by teachers using a variety of approaches, methods, and teaching styles called "teaching strategies." Teaching methods include how lessons are presented, how classrooms are set up, how students are grouped, how lessons are guided, and how material is provided to support learning. In order to improve the learning environment in which the student is actively participating, teaching tactics are essential to the teacher's mission. The complete physical and mental environment to which the students are exposed at a given time constitutes the learning environment, and improving the environment means enhancing the students' access to a more favourable learning environment in both the physical and mental realms.

Students must be taught using cutting-edge teaching methodologies in light of the modern (computer) era. This will help them develop the capacity for critical thought, environmental exploration, and the acquisition of the mindset and abilities required to succeed as scientists in the future. Even at the university level, research has

demonstrated that lecturing is not the most effective method of instruction for developing students' depth of knowledge in Science, Technology, Engineering, and Mathematics (STEM) subjects (Brewer & Smith, 2011; Smith & Wood, 2016). Since science serves as the foundation for the study of nature and humanity, teachers nowadays must employ creative teaching methods to raise Secondary School Students' academic achievement in the subject.

Various authors have offered a variety of teaching strategies for science. For this reason, it is advised that STEM courses be taught utilising approaches and procedures that promote active learning, i.e., student-centered instructional methodologies. According to Smith and Wood (2016) and Vickrey et al. (2015), this maintains students' interest in certain areas. Furthermore, Smith and Wood (2016) reported that their meta-analysis of their data indicated that there was a notable improvement in the learning of students who were taught utilising student-centered, active learning techniques mixed with peer discussion and other group activities needing analytical thought.

Additionally, it was discovered that using these strategies helped lower the undergraduate STEM dropout rate. Every time experiences trigger mental processes that result in meaningful learning, active learning is considered to be taking place. Thus, it is evident that constructivism is a component of active learning. Researchers have suggested the following active teaching techniques to ensure active learning when teaching science in general and "Genetics" in particular. Concept mapping (Jibrin & Zayum, 2012), conceptual cartoons (Keogh & Naylor, 1996; mentioned by Dzidzinyo, 2020), video demonstrations, experimentation, case studies, role playing, class presentations, and group projects are some examples of concept mapping approaches.

It is important to note that practically all of the genetics lectures available online on YouTube, for instance, combine these active teaching and learning methodologies. Learning new concepts and gaining an understanding of them is the major objective of the educational process. According to Grabowski and Small (1997), as referenced by Wilhelm-Chapin and Koszalka (2016), instruction is a compilation of informative, instructional, and learning resources, each of which serves as a foundation for learning. The main content and course of education are supported by informative and instructional resources, however.

Regardless of their type, learning resources, whether they are analog, digital, social, or human, fully involve students in the learning process. Students can be engaged physically and cognitively with content to help them grasp and develop new knowledge by incorporating the principles of the Generative Learning Strategy into learning tools. According to the Generative Learning Strategy, features of learning resources could be extremely beneficial to learners because they will encourage them to participate in tasks like taking specific notes, explaining content, labelling connections between new content and prior knowledge, and creating images and analogies that show understanding to aid learners in coding new information.

Learners can be helped to make new connections when studying information via activities that get them to react to questions, use offered organisers, and pay attention to how new concepts relate to past knowledge. The capacity of learning resources to support learners in deep learning is thus improved by incorporating these sorts of prompts into the learning resources themselves or as integrated instructional prompts. The exercises mentioned above, when used in conjunction with the Generative

Learning Strategy, would give the students the chance to “play with” knowledge in their minds to gain a personal comprehension of the subject being studied.

Studies across several areas with students of all ages and abilities provide strong support for the Generative Learning Strategy. The benefits of creating meaningful connections between new content and existing knowledge and experience have been covered in the corpus of work on the Generative Learning Strategy. In the beginning, transfer designs that focused on learners past knowledge in relation to new content were used to study Generative Learning Strategy (Wittrock, 2010; Wittrock & Carter, 1975; as cited by Wilhelm-Chapin & Koszalka, 2016). This research looked at how much recall improved for learners when summarising and headings were employed as generative strategies during instruction.

Students in elementary school and college who used the Generative Learning Strategy fared better in reading and science than the control groups, who were not encouraged to use the strategies. The investigations concentrated on how new knowledge was received and then transferred to learner beliefs, values, and prior experiences. These preliminary studies generally endorsed the Generative Learning Strategy and urged further investigation into how learners connect new knowledge to what they already know. Studies on the Generative Learning Strategy have continued, and two different versions have been used (Grabowski, 2004).

These can be broken down into two categories: Coding techniques, where students establish connections between different content-related elements, and Integration strategies, where students integrate newly learned material with what they already

know. Taking notes, asking supplementary questions, underlining, organisation headers, concept maps, and visual organisers are some coding techniques. The generative integration techniques of elaborations, images, interpretations, analogies, and summaries have been researched in a variety of subject areas. Studies on coding techniques that looked at note-taking and underlining as coding strategies have revealed enhanced comprehension (Peper & Mayer, 1986; Rickards & August, 1975; as cited by Wilhelm-Chapin & Koszalka, 2016).

According to studies, learning results are influenced by the standard of the notes, how much the learner elaborates when taking notes, and how notes are used for review. Peper and Mayer (1986), quoted by Wilhelm-Chapin and Koszalka (2016), looked at how students who were learning about vehicle engines encoded their notes. Their research revealed the creation of external connections as well as a benefit of note-taking for long-term memory, which is not true for fact recall in the near term. According to these researchers, taking notes while physically engaging with the material does appear to aid in helping students encode new information, although the effectiveness of various note-taking methods on subsequent memory and mental actions varies.

The timing, frequency, kind, intended learner response, style of feedback, and type of learning, whether unintentional or purposeful, have all been investigated in studies on the use of questions to spur the development of new knowledge (Grabowski, 2004, Rickards, 1979, Anderson & Biddle, 1975; as cited by Wilhelm-Chapin & Koszalka, 2016). In general, it has been discovered that asking questions after presenting content and requiring learners to explicitly react to them all improve comprehension (organising, integrating, and understanding new information). Concept maps and

headers are among the organisers that have been found to improve understanding. By drawing attention to connections within new content and between new content and past knowledge, interventions were made to improve learning. Variables such as learner characteristics, material structure, and organiser source affected recall and retention differently. Integrating new content with prior knowledge is done through integration techniques. In order to supplement their prior knowledge, learners name links based on their views, values, and preconceptions. When compared to students who employed instructor-created strategies, those who generated their own images and analogies had better long-term memory (Grabowski, 2004).

For instance, elementary children demonstrated greater levels of comprehension than those who were not encouraged to apply Generative Learning Strategy after reading stories by drawing pictures and making analogies (Linden & Wittrock, 1981; as cited by Wilhelm-Chapin & Koszalka, 2016). In more recent studies, the Generative Learning Strategy's concepts of higher-order thinking and self-regulation of learning have been examined. For the majority of learners with prior topic knowledge, Lee and Nelson (2005) found that those who created their own maps did better than those who were given instructor-generated maps.

Contrarily, concept mapping exercises were less helpful for students who had little to no prior knowledge of the subject than simply looking at an instructor-made map. Lee, Lim, & Grabowski (2008) suggested that a learner's metacognitive and self-regulation capacities operated to inform, manage, and monitor the generating process of the learner in a study of undergraduate students. The use of Generative Learning Strategy to improve knowledge acquisition and deepen understanding has been the subject of

research based on Generative Learning Strategy. Studies focused on memory, comprehension, and higher order thinking abilities as particular knowledge acquisition levels. Based on the learning methodologies employed, student aptitude, and degree of content to be mastered, these studies produced a range of findings.

Depending on whether the transfer task was designed for long-term retention or short-term memory, results frequently varied. However, the majority of studies revealed that learners gained more knowledge when they were actively participating in the subject matter (Lee et al., 2008). These results are consistent with the active learner engagement hypothesis put forth in the Generative Learning Strategy. This implies that the Generative Learning Strategy's principles can be used to improve the value of learning resources.

2.8 Empirical Review on Generative Learning Strategy

Generative Learning Strategy is a method of instruction whereby students actively create ideas on their own. It is an environment-based paradigm that suggests allowing learners to create their own learning rather than having them solve a pre-defined problem by creating their own issues, and as well resolve the issues. Instead of just memorising the information offered, students who engage in generative learning must create their own meaning by fusing new knowledge with prior knowledge (Grabowski, 2004).

Academic Performance

Several studies have demonstrated the positive impact of Generative Learning Strategy on academic performance. For instance, a study by Fiorella and Mayer (2016) showed

that students who engaged in generative activities, such as self-explaining and teaching others, performed significantly better on comprehension and transfer tests compared to those who did not engage in such activities. The researchers found that the process of generating explanations helped students to organize and integrate new information with their prior knowledge, leading to improved learning outcomes.

In addition, the Generative Learning Strategy has been shown to facilitate deeper understanding and retention of scientific concepts. Chi, Adams, Bogusch, Bruchok, Kang, Lancaster, & Watts (2018) found that when students generated explanations for scientific phenomena, their performance on subsequent tests improved markedly. This finding is corroborated by the work of Wiley and Voss (1999), who reported that students who generated self-explanations while studying biology texts showed better understanding and recall than those who did not. Similarly, a study conducted by Appiah-Twumasi (2019) also concluded that students perform better in Physics concepts when instructed with the Generative Learning Strategy compared to using lecture with discussion and demonstration methods.

Retention of Knowledge

The effectiveness of Generative Learning Strategy in enhancing knowledge retention has also been supported by empirical evidence. A meta-analysis conducted by VanLehn, Chi, Baggett, Murray, Jones, & Avrahami (2011) revealed that students who used generative learning strategies exhibited better retention of information over time. The study analysed data from multiple experiments and concluded that active generation of knowledge helps reinforce learning, making it more durable. Also, Generative Learning Strategy has been shown to improve students' retention and

understanding of complex concepts. For instance, a study by Fiorella and Mayer (2016) found that students who engaged in generative activities such as self-explaining and drawing performed significantly better on retention tests compared to those who engaged in passive learning activities.

Additionally, a meta-analysis by Schneider, Rittle-Johnson, & Star (2018) confirmed that Generative Learning Strategy led to better retention in mathematics, highlighting the effectiveness of these strategies in enhancing long-term memory. According to Chi et al. (2018), the Generative Learning Strategy enabled students who engaged in active learning strategies, including generating explanations and diagrams, showed improved retention of scientific concepts. Another study by Van Meter and Garner (2005) found that generative strategies such as summarizing and teaching others led to higher retention rates in science subjects. These findings suggest that Generative Learning Strategy facilitates deeper cognitive processing, which is crucial for retaining complex scientific information. In the context of language arts, Generative Learning Strategy has been found to enhance students' retention of vocabulary and comprehension skills. A study by Zhang and Quintana (2012) showed that students who created concept maps and generated summaries of reading materials retained more information compared to those who did not use these strategies.

Critical Thinking and Problem-Solving Skills

Generative learning strategies have been found to enhance critical thinking and problem-solving skills. Chi et al. (2018) conducted a study where students engaged in activities such as creating concept maps and generating questions based on their reading materials. The results indicated that these students developed better critical thinking

skills and were more adept at solving complex problems compared to their peers who did not use generative strategies. Additionally, a study by Rittle-Johnson and Loehr (2017) demonstrated that students who engaged in generative activities, such as creating concept maps, showed significant improvements in critical thinking and problem-solving abilities. This finding is supported by research from Heijltjes, van Gog, and Paas (2014), which found that Generative Learning Strategy led to better performance in critical thinking assessments among university students.

Motivation and Engagement

The Generative Learning Strategy have also been shown to increase student motivation and engagement. A study by Guthrie and Wigfield (2000) found that students who participated in generative learning activities, such as collaborative group work and inquiry-based projects, reported higher levels of intrinsic motivation and engagement in the learning process. This increased motivation was linked to the active and participatory nature of generative learning, which makes learning more relevant and interesting for students.

In addition, research has demonstrated that Generative Learning Strategy can significantly enhance student motivation. For instance, a study by Şen and Yılmaz (2012) investigated the impact of Generative Learning Strategy on eighth-grade students' motivation and achievement in science. They found that students who engaged in generative learning activities reported higher levels of intrinsic motivation and performed better on science assessments compared to those who received traditional instruction. The researchers attributed these results to the increased sense of

autonomy and competence experienced by students when they actively constructed their own knowledge.

Similarly, Barak and Dori (2005) explored the use of Generative Learning Strategy in high school chemistry classes. Their study showed that students who participated in generative activities, such as creating concept maps and generating hypotheses, exhibited higher motivation levels and greater interest in the subject. This increase in motivation was linked to the students' enhanced understanding of complex concepts and the active engagement required by Generative Learning Strategy. A study by Vansteenkiste, Simons, Lens, Sheldon, and Deci (2004) examined the effects of Generative Learning Strategy on motivation and learning in a sample of high school students. The findings indicated that students who engaged in generative tasks, such as problem-solving and peer teaching, demonstrated higher intrinsic motivation and greater persistence in solving challenging mathematical problems. The researchers suggested that the autonomy-supportive nature of Generative Learning Strategy contributed to these motivational gains.

Furthermore, Rosenzweig and Wigfield (2016) investigated the impact of Generative Learning Strategy on middle school students' motivation in mathematics. Their research revealed that students who were encouraged to generate their own problem-solving strategies reported increased interest and enjoyment in mathematics. This heightened motivation was attributed to the sense of ownership and personal relevance that Generative Learning Strategy fostered among students.

2.9 Summary of Empirical Review on Generative Learning Strate

The following are some of the research findings highlighting the opportunity of using Generative Learning Strategy to enhance learning outcomes:

1. It allows learners to organise, generalize, and simulate knowledge (Fiorella, 2023).
2. When employing video lectures, the Generative Learning Strategy results in better learning performance (greater accuracy and quicker reaction time in students (Pi, Zhang, Liu, Zhou, & Yang, 2023).
3. Also, it has the capacity to induce positive views toward twenty-first-century educational technology like augmented reality (A.R.) (Buchner, 2022).
4. Additionally, it integrates previously learned material with recently acquired ideas, improving the students' academic performance (Boby, Rahmi, Fibrika, & Nova, 2021).
5. Moreover, it allows teachers to empower their students or learners to take charge of their own learning while also serving as a coach or facilitator for the learning process (Appiah-Twumasi, 2019).
6. Furtherly, encourages communication and cooperation for successful learning among the students or learners, and it makes teaching and learning flexible (Awolere, 2015).
7. It as well, encourages learners to actively interpret the material they are learning and combine it with what they already know (Fiorella & Mayer, 2016; Wittrock, 1991).

CHAPTER THREE

METHODOLOGY

3.0 Overview

The research's study field is covered in this chapter. It also explains the research strategy, which uses a quasi-experimental methodology to gather study data. The demographic, sample, and sampling methods that were employed to determine the study's sample size are further described in this chapter. The research tools that were utilised to gather data for the study are also thoroughly described in this chapter. In this chapter, the study instruments' validity and reliability are also covered. The process of gathering data and the analysis of the resulting data round out the chapter.

3.1 Study Area

It was carried out in the Municipality of Sefwi-Wiawso. Located in Ghana's Western North Region, Sefwi-Wiawso Municipal is one of the country's nine districts. Initially established as an ordinary district assembly in 1988 under the name Sefwi-Wiawso District. The remaining portion of the Municipality was kept as Sefwi-Wiawso District until the southwest portion of the district was divided off to create Sefwi-Akontombra District on February 29, 2008. Afterward, the district was upgraded to Municipal Assembly status in March 2012 (effectively June 28, 2012) to become Sefwi-Wiawso Municipal Assembly. The capital city of the Municipality is Sefwi-Wiawso, and it is situated in the northeastern section of the Western North Region.

The Municipality covers an area of 1,1011.6 sq km, representing 7 percent of the land area of the Western North Region. Major towns within the Municipality include Sefwi-Asawinso, Sefwi-Datano, Sefwi-Wiawso, Sefwi-Boako, Sefwi-Dwenasi, and Tanoso,

among others. Within the Municipality, there are four (4) public Senior High Schools and one (1) private Senior High School. The public Senior High Schools are Sefwi-Wiawso SHS and Sefwi-Wiawso SHTS, both located at Sefwi-Wiawso; Sefwi-Asawinso SHS, also located at Sefwi-Sefwi-Asawinso; and St. Joseph SHS, located at Datano. The single private SHS in the Municipality is Bennie Appenteng SHS located at Sefwi-Boako. All these schools offer Biology as an elective subject (Ghana Statistical Service, 2022).

3.2 Research Paradigm

A paradigm is a common set of beliefs that guides researchers' knowledge acquisition and interpretation of any data they may gather (Brierley, 2017). Belief systems in this context, according to Creswell (2009), can be interpreted as "worldviews." That is how a researcher thinks a particular study should be conducted. According to Creswell (2009), a researcher adheres to this "worldview," which offers the framework for the study's research and practice. In other words, it offers direction for each stage of the inquiry process, such as choosing a research subject, formulating research questions, assessing the nature and nuances of reality, knowledge, techniques, and the importance of the study project (Khatri, 2020; Shannon-Baker, 2016).

Also, Chilisa, and Kawulich (2019) claim that no single theoretical framework or paradigmatic approach is "correct," and that it is up to the researcher to choose their own paradigmatic perspective and how it guides their research designs to best address the topic under consideration. There are different perspectives or viewpoints that guide the conduct of research. These include positivism, post-positivism, interpretivism, pragmatism, constructivism, and transformative paradigms. Nevertheless, this study

operated from a post-positivist perspective. The core tenets of post-positivism are that truth is probabilistic rather than absolute and that reality is flawed (Kivunja & Kuyini, 2017), recognising that we cannot be “positive” about our claims of knowledge when studying the behaviour and actions of humans because of the complexity of social phenomena (Kirby, 2013).

That is, regardless of how closely a researcher follows the scientific process, post-positivists believe that research findings are neither totally objective nor inherently certain (Chilisa & Kawulich, 2019). Additionally, Kivunja and Kuyini (2017) expand that the researcher can only uncover reality within a specific range of probability or approximation. It is for this reason that post-positivism, as Kirby (2013) explains, is based on using diverse techniques to capture as much of reality as possible, which includes using both quantitative approaches that rely on (low-level) statistical analyses and qualitative methods that can be analysed in an organised way, possibly using statistics.

In this way instead of only collecting empirical data to represent the truth, researchers also discuss the topics brought up in the interviews, the responses from the participants, and their interpretations of these complex concepts (Turyahikayo, 2021). In view of this, this study sought to function in the post-positivism paradigm by adopting quantitative and qualitative methods for research question 1, quantitative methods for research question 2, and qualitative methods for research question 3.

3.3 Research Design

In this study, by adopting the mixed-method post-positivist paradigm, the quasi-experimental one-group pretest/posttest design was employed, where two intact classes were randomly selected and treated as one group and exposed to the same treatment conditions. The use of a quasi-experimental design was due to the fact that participants were not randomly selected from the population.

Therefore, in order to identify the performance of test scores of students instructed using the Generative Learning Strategy in the teaching and learning of genetics, quantitative data, specifically test results, were collected. This gave accurate figures that were statistically assessed and generated findings that were used to gauge the extent of performance. In addition, qualitative data, which was an open-ended interview, were collected, which presented a variety of perspectives from students on the effectiveness of the Generative Learning Strategy to enrich and strengthen the research results. According to Brophy (2019), using several techniques for data collecting and analysis to investigate the same phenomenon guarantees a thorough comprehension of the impact of the Generative Learning Strategy on SHS Biology students' performance in the teaching and learning of genetics.

3.3.1 Overall Study Design

A diagrammatic representation of this study's design is represented in Figure 3.0. As seen in Figure 3.0, this study adopted a mixed-method (post-positivist) approach where quantitative and qualitative methods were employed. However, the design employed for this study was the quasi-experimental design, which involved a single-group

pretest/posttest design formed from two intact classes without random selection of participants.

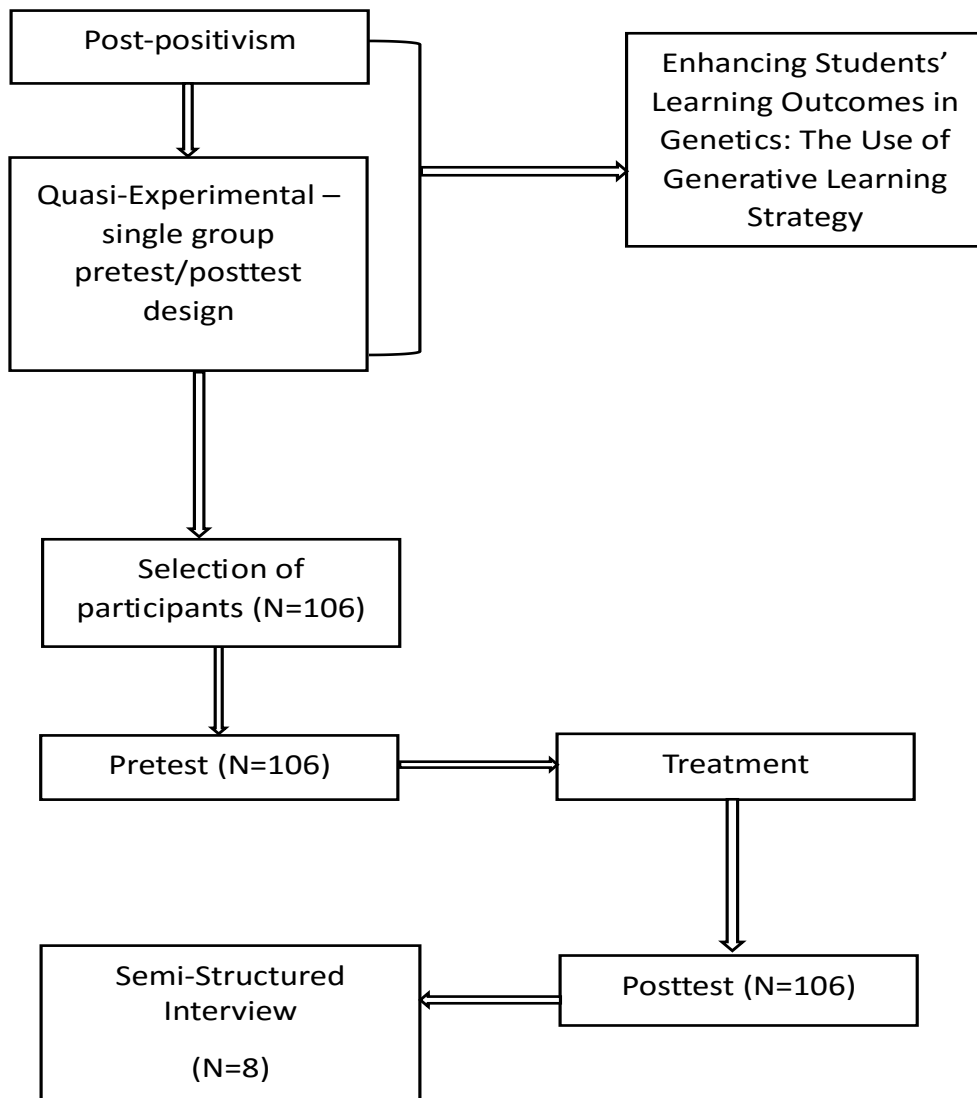


Figure 2.0: A Flowchart of the Overall Study Design

As seen in Figure 2.0, the participants were pretested to determine their entry characteristics prior to the intervention. After the pretest, participants were exposed to the treatment; thus, they were taught using a Generative Learning Strategy. The effectiveness of the intervention was then determined by the introduction of the post-intervention test. After the post-intervention test, eight (8) students were selected and interviewed to ascertain their perceptions towards the use of the Generative Learning

Strategy through a semi-structured interview. This helped augment the quantitative findings and provided a holistic understanding concerning the effectiveness of the Generative Learning Strategy in the teaching and learning of genetic concepts.

3.4 Population

The target population for this study included all SHS 3 Biology students in the Sefwi-Wiawso Municipality, but the accessible population comprised all SHS 3 Biology students in Sefwi-Wiawso SHS.

3.5 Sample and Sampling Technique

In this study, each phase of the design contained a different sampling technique. As a result, the sampling technique employed in this study was multi-stage sampling. This is shown in Table 3.0

Table 3.0: Multi-stage Sampling Procedure Employed in the Study

Stage	Sampling procedure	Activity	Sample Size (N)
Quantitative Phase	Simple Random Sampling	Selection of one public SHS from the Sefwi-Wiawso Municipal	1
	Purposive sampling	Selection of SHS 3 Biology students	
	Simple Random Sampling	Selection of two intact SHS 3 Biology classes	106
Qualitative Phase	Stratified random sampling	Selection of SHS 3 Biology students for interview	8

From Table 3.0, to select schools that participated in the quantitative aspect of the study, simple random sampling was used to select one SHS in the Sefwi-Wiawso Municipality

since all schools offered Biology as an elective subject. However, purposive sampling was used to select SHS 3 Biology students on the basis that genetics is studied in SHS 3, according to the CRDD (2010). Again, simple random sampling was employed to select one intact Science class that studied Biology and one intact Home Economics class that also offered Biology. This, therefore, resulted in a sample size of 106 SHS Biology students.

In the qualitative phase however, stratified random sampling was used to select eight (8) SHS 3 Biology students from the accessible population to participate in the interview. The rationale for using stratified random sampling was to use an equal proportion of high- and low-achieving students. However, this selection was based on students' willingness to participate in the interview, hence the use of purposive sampling.

3.6 Research Instruments

The research instruments used in this study include an achievement test, that is, a Genetic Concepts Test (GCT), and a semi-structured interview guide.

3.6.1 Genetic Concepts Test (GCT)

The GCT was also designed by the researcher and consisted of twelve questions with nine (9) multiple-choice and three (3) essay-type questions that covered the concepts of genetics. This was used to assess the performance of SHS Biology students before and after the intervention. Since it contained essay test items, students' answers to the test items were scored polytomously. The content selection of the GCT is presented in Table 4.0

Table 4.0: GCT and Content Selection

Concept	Questions	Sample of the Questions
Genetics and Applied Genetics	1, 2, 3, 4, 10	1. The greatest contribution to genetic studies was made by... A. Charles Darwin. B. Gregor Mendel. C. Robert Hooke. D. Thomas Morgan. 10. Define the following terms: (i) gene; (ii) chiasma; (iii) mutation; (iv) test cross; (v) monohybrid cross.
Mendel's Experiments	5, 6, 7, 12	5. According to Mendel's first law of inheritance, segregation of genes occurs when... A. tall plants and short plants are crossbred. B. tall plants are crossbred. C. short plants are crossbred. D. plants are crossbred. 12. Mr. Abugri who does not have the sickle cell anaemia trait is married to Boaduwa who is a sickler, yet he claims the sickler child born to them is not his child. Determine by aid of a genetic diagram whether his claim is true.
Variation	8, 9, 11	8. The following features make fingerprints useful in crime detection except that... A. it is unique to an individual person. B. it imprints on objects handled. C. its patterns in individuals are permanent. D. its patterns are more distinct in black people. 11. Give two examples each of: (i) continuous variation; (ii) discontinuous variation.

From Table 4.0, it can be seen that the items that comprised the GCT covered the concepts of “Genetics and applied genetics”, “Mendel’s experiments”, and “variation”. The rationale behind choosing these subtopics is that “heredity” and “variation,” which are rooted from “cell biology,” are covered in genetics at the Senior High School level (CRDD, 2010). If the subtopics are arranged in this way, it would encompass all of the fundamental concepts around which additional concepts are constructed. In the end, as

indicated in the literature, this would result in the capture of all the selected genetic concepts that SHS Biology students find it difficult to understand (Larbi & Monney, 2022). These concepts were taught to both intact classes during the intervention stage of the study. Of these concepts, five (5) questions covered the concepts of Genetics and Applied Genetics, four (4) questions from Mendel's Experiments; and three (3) questions from Variation.

3.6.2 Interview Guide

The interview guide, also prepared by the researcher, aimed to qualitatively determine the perceptions of SHS Biology students on the effectiveness of the Generative Learning Strategy after the intervention. The interview guide contained five (5) open-ended questions where students were given the freedom to express their opinions. However, under the direction of the researcher, regarding the employment of a Generative Learning Strategy. This therefore rendered the interview a semi-structured one (Cohen, Manion, & Morrison, 2018).

3.7 Validity of the Instruments

In order to determine the validity of the research instruments, the GCT and the interview guide were given to six (6) experts in the field of Biology and Science Education to proofread and make their inputs. This was done to determine the appropriateness of each item on the instruments for their accuracy, suitability, and relevance in relation to the content covered in the study, as well as their conformity with the curriculum. After the experts' evaluations, Lawshe's (1975) formula was used to determine the content validity of the items on the instrument (GCT).

Table 5.0: Content Validity Index and Ratio for theory GCT Items

Item	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6	Agreement	CVI**
1	X	X	X	X	X	X	6	1.000
2	X	0	X	X	X	X	6	0.833
3	X	X	X	X	X	X	6	1.000
4	X	X	0	X	X	X	5	0.833
5	X	X	X	X	X	X	6	1.000
6	X	X	X	X	X	X	6	1.000
7	X	X	X	X	X	X	6	1.000
8	X	X	X	X	X	X	6	1.000
CVR								0.958

CVR=CVI/8, where CVR=Content Validity Ratio, CVI=Content Validity Index

According to Lawshe, CVR ranges from -1.000 to 1.000, where high scores of CVR indicate the agreement of panelists on the relevance of an item in the instrument. As presented in Table 5.0, in this study, the content validity ratio of the GCT was 0.958, which, per Lawshe's criteria, indicates a valid instrument.

3.8 Pre-Testing of the Instruments

The GCT was pretested to determine the reliability of the scores of the instruments. The was pretested at Sefwi-Wiawso Senior High Technical School, using third-year students who shared similar characteristics with the research participants but did not take part in the main study. Third-year students were used because they had studied cell biology which is perquisite for the study of genetics and were therefore the appropriate participants to answer the questions on the instruments for the pretesting. Hertzog (2008) suggests that a sample size ranging from ten (10) to forty (40) per group is appropriate for determining the suitability of a research instrument. Accordingly, the sample size for the pilot study was fifty-three (53) SHS 3 Biology students in the Sefwi-Wiawso Senior High Technical School.

3.9 Reliability of Instruments

Reliability, according to Bhattacharjee (2012), is the degree of consistency or dependability of a construct's measure. Put otherwise, given that the underlying phenomenon remains constant, will we obtain essentially the same result each time we use this scale to measure the same construct. Thus, Bhattacharjee (2012) concluded that consistency but not precision is a need for reliability. Hence, the internal consistency reliability of the objective test of GCT was determined by using Cronbach Alpha value as shown in Table 6.0. Internal coherence, a measure of consistency amongst various objects belonging to the same concept is called dependability. If a multiple-item construct measure is administered to respondents, the extent to which respondents rate those items in a similar manner is a reflection of internal consistency.

3.9.1 Reliability of GCT

Fifty SHS 3 Biology students from Sefwi-Wiawso SHTS were used for pre-testing of the GCT. The test question papers and response sheets were collected from the students shortly after the test, which took 40 minutes for them to finish. The range of scores obtained by students on the GCT items was 8 to 22. Since the test consisted of both objective and essay questions, students' responses were scored polytomously. The reliability of the GCT was determined using Kappa's measure of agreement and the result is shown in Table 6.0

Table 6.0: Internal Consistency for "Section A" of GCT

Reliability Statistics	
Cronbach's Alpha	N of Items
0.789	9

As represented in Table 6.0, the Cronbach Alpha value, which measured the internal consistency of the multiple test items of the GCT scores was 0.789. This value, according to Pallant (2011) indicates a preferable internal consistency of the scores.

3.10 Data Collection Procedure

Three steps were involved in gathering both quantitative and qualitative data for the study. These are the pre-intervention stage, the intervention stage, and the post-intervention stage.

3.10.1 Pre-intervention Stage

At this stage, which was the first stage of the data collection process, official permission was sought from the Headmaster, Head of Science department, and Biology teachers from the schools that were selected for the study by presenting an introductory letter from the department of the researcher to the heads of the schools of the participants. The purpose, importance and uses of the results of this study were explained to the authorities and participants from the selected schools while assuring them of the confidentiality of the results and information provided by the students. Thus, to ensure confidentiality and data entry purposes, students were not allowed to write their names on their answer booklets during the pretest and posttest. Instead, for identification and data entry purposes, students were given identification numbers, which were used throughout the study. Rapport between the researcher and the participants was established during his routine visits to the school before the subsequent activities regarding the study were undertaken.

The study was carried out when there were no significant activities taking place in the school. The sampled classes were then visited to begin the administration of the pretest. The pretest served two basic purposes in this study. That is, it was used to determine students' entry characteristics prior to the intervention, and also to categorise students into high and low achievers. In order to ensure that they were prepared for the test, students were informed one week earlier. The researcher administered the GCT with the help of Biology teachers from the selected schools. During the administration of the test, students were given a period of 40 minutes to answer the test items.

3.10.2 Intervention Stage

At this stage, the teaching method, which was the independent variable in this study, was implemented. The researcher taught the subject matter to the students (participants) in order to account for teacher differences. The intervention stage, which lasted for a period of four (4) weeks, involved teaching the same material and using the same treatment activities (Generative Learning Strategy) to both intact classes. Table 7.0 provides a summary of the various contents that were covered during the research. Additionally, the weekly learning plan for implementation of the intervention can be found in appendices G1, G2, G3 and G4.

Table 7.0: Content of Genetics Taught to Participants (Students)

Period	Content Taught
Week 1	Genetics and Applied Genetics
Week 2	Genetics and Applied Genetics
Week 3	Mendel's Experiments
Week 4	Variation

3.10.2.1 Intervention Activities

Both intact classes were exposed to Generative Learning Strategy during the teaching and learning of genetic concepts. Table 8.0 gives a description of how the Generative

Learning Strategy was implemented with their accompanying weekly learning plans for the intervention implementation shown in appendix G1 to G4.

Table 8.0: Stages of Generative Learning Strategy for Intervention

Implementation		
Stage	Generative Learning Strategy	Activity
Introduction	Recall	Elicitation of students' previous knowledge. For example, using multimedia resources, diagrams, and interactive simulations to introduce basic genetics concepts.
Development	Integration	Addition and modification of previous knowledge on genetics concepts using cooperative brainstorming activities in which students explore and illustrate the connections between these concepts and ideas.
	Organisation	Connecting previous knowledge with new knowledge on genetics concepts through hands-on experiments or simulations that allow students to observe genetic principles in action. For example, using Punnett squares with physical representations of alleles (like beads or coloured counters) to model genetic crosses.
	Elaboration	Application of new knowledge on genetics concepts to other areas or real-life situations. For example, introducing case studies that highlight the application of genetics in diverse fields, such as medicine, agriculture, or forensics.
Closure		Summary of the main concepts of the lesson using reflective activities where students articulate their understanding of genetics concepts and connect them to their own lives.
Evaluation		Assessment of attainment of lesson objectives through oral presentations, class tests and assignments.

Adapted from Appiah-Twumasi (2018)

Introduction

This stage introduced the lesson and subject matter to the students. The generative learning activity employed at this stage is “recall.”

Recall: Using an advanced organiser, the instructor evaluated the students’ previously stored knowledge about the current subject. The main goal was to motivate students to develop an idea based on facts and details they were already familiar with.

Lesson Development

This stage is also characterised by connecting the prior knowledge of students to the new knowledge to be learned in the lesson, as well as expanding the new knowledge learned. The generative learning activities employed at this stage include “integration,” “organisation,” and “elaboration.”

Integration: Supplement what they already know with new information. The primary goal was to alter the content to make it more readable and memorable. Asking students to paraphrase the material or creating analogies to explain concepts are two examples of this type of learning activity.

Organisation: Students efficiently make connections between new concepts and their prior knowledge, which aids with memory. A few examples of organisation techniques are making lists, assigning grades to specific items, or analysing a concept's essential components.

Elaboration: Students were expected to make original connections between new ideas and what they previously knew. Thinking about how the new information fits with prior knowledge or everyday tasks is an example of an elaboration technique. The students gave themselves an explanation of the lesson's specifics. In this phase, students identified the most pertinent information, provided an in-depth explanation of each aspect, arranged the information using deductions, and integrated new information with what they already knew.

Closure

Students were allowed to appraise the weaknesses of the old concepts they had already conceived. Students were also encouraged to recall the material and concepts they learned during the lesson.

Evaluation

The teacher gave end-of-lesson assignments and quizzes to assess the attainment of lesson objectives.

3.10.3 Post-Intervention Stage

After the intervention stage, students were given one week to revise their notes, after which the posttest (GCT) was conducted. The conduct of the posttest was also done by the researcher with the help of Biology teachers from the various schools. Students were given 45 minutes to answer the test items.

After students had completed the posttest, eight (8) students were sampled to solicit their perceptions through a semi-structured person-to-person interview concerning the implementation and extent of effectiveness of the new method (Generative Learning Strategy) with which they were taught genetics. During the interview session, the sampled students were generally asked about their opinions about the new method with which they were taught genetics with. Students were not coerced to participate in the interview, and their views and opinions were recorded with their permission for further transcription and analysis.

3.11 Data Analysis Procedure

The data were analysed quantitatively and qualitatively, as shown in Table 3.6. The scores and from GCT were analysed using SPSS for windows version 26 by employing descriptive and inferential statistics through the use of paired-samples t-test and One-

Way ANCOVA, while the views and opinions of students from the semi-structured interview were analysed thematically. The following statistics and analytical techniques were used to answer specific research questions and test hypotheses, at probability level of 0.05, thus ($p < 0.05$). This is illustrated in Table 3.6.

Table 9.0: Data Analysis Technique

Research Question	Type of Data	Descriptive Statistics (To answer research questions)	Inferential Statistics
Research Question 1	Scores from GCT	Means, standard deviations, mean differences, and effect size	Paired-Samples t-test
Research Hypothesis 1	paired-samples t-test on pretest and posttest scores	Degrees of freedom, mean difference, Eta squared value	Paired-Samples t-test
Research Question 2	Scores from GCT	Percentages, means, standard deviations and mean differences	One-Way ANCOVA
Research Hypothesis 2	One-way ANCOVA of scores from GCT with scores from pretest as covariates at alpha level 0.05	Levene's test statistic, sig. value	One-Way ANCOVA
Research Question 3	Transcribed data from the semi-structured interview	Thematic analysis	-

Research questions 1 and 2 comprised the quantitative components of the study; therefore, the data collected from the GCT were analysed descriptively using mean, standard deviation, mean difference, and effect size. Inferentially, research questions 1 and 2 were formulated into null hypotheses and tested using a paired-samples t-test and a one-way ANCOVA, respectively. The paired sample t-test was used because this study was made up of two intact classes treated as a single group that was exposed to the same treatment conditions. This therefore helped to determine the impact of using

the Generative Learning Strategy in teaching genetics by comparing the means of the pre- and post-test scores of the participants, as well as the difference that existed in the performance between high-achieving students and low-achieving students in the learning of genetics in Biology. The One-Way ANCOVA was also used to find the variance changes of the dependent variable (posttest scores) due to change in covariate (pretest scores) and differentiate it from the variance changes due to changes in the level of particular variable so as to lessen unsettled adjustments of the dependent variable (error), make true results, and increase analytical power. This was followed by the testing of hypotheses to find out the extent to which the difference between the means of the pre- and post-test scores is statistically significant.

Also, research question 3 was thematically analysed since it formed the qualitative aspect of the design. This was possible using the transcribed data from the interview. This made it possible to ascertain how SHS Biology students felt about the efficacy of the generative learning strategy when it came to teaching and understanding genetic concepts.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

The study's results and discussions are shown in this chapter. Presented are the findings, which correspond to the research inquiries. Descriptive and inferential statistics have been used to analyse the data that were gathered. The participants' data were combined, organised, and coded using the 26th version of the Statistical Package for the Social Sciences (SPSS). The following research questions form the basis for how the results are presented:

1. What is the difference in academic performance of SHS Biology students instructed in genetic concepts before and after the use of Generative Learning Strategy?
2. What difference exists between genetics test scores of high achievers and low achievers instructed with the Generative Learning Strategy?
3. What are the perceptions of students about the relevance of Generative Learning Strategy in teaching genetic concepts?

4.1 Distribution of Participants

In this study, 106 SHS 3 Biology students participated. Among the 106 participants, 55 were selected from the Science class, while 51 were selected from the Home Economics class; however, they were treated as one group. The distribution of the students according to their abilities is presented in Table 10.0.

Table 10.0: Distribution of Participants According to Ability

Group	Frequency	Percentage
Low Achievers	44	41.51%
High Achievers	26	24.53%

As presented in Table 10.0, among the 106 participants, 44 were low achievers, representing 41.51%, and 26 were high achievers, representing 24.53% of the total participants.

4.2 Data Suitability

Normality analyses were performed to ensure that the data were appropriate before the study's results were analysed. The next subsection presents the findings:

4.2.1 Normality Analyses of the Scores

To decide whether to utilise parametric or non-parametric tests for evaluating hypotheses, the pretest and posttest scores from this study were put through a normality test. Normality tests were conducted using numerical and graphical methods. Thus, numerically, the Kolmogorov-Smirnov test and Shapiro Wilk test were used, while graphical methods employed histograms, normal quantile-quantile plots (normal Q-Q plots), and box plots. Normality tests were conducted on the premise of the null hypothesis that the data sets are normally distributed (Pallant, 2011a).

This means that the null hypotheses are rejected when the alpha (p) values for both the Kolmogorov-Smirnov test and the Shapiro-Wilk test are less than 0.05. The results of the tests of normality are presented in Table 11.0

Table 11.0: Results of Normality Tests for Pretest and Posttest Scores

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pretest	.108	55	.168	.960	55	.062
Posttest	.101	55	.200*	.979	55	.439

*. This is a lower bound of the true significance. a. Lilliefors Significance Correction

As can be seen from Table 11.0, the alpha (p) values of both Kolmogorov-Smirnov and Shapiro-Wilk tests for pretest and posttest scores were not significant ($p > 0.05$). However, according to Mishra, Pandey, Singh, Gupta, Sahu, and Keshri (2019), the Shapiro-Wilk test of normality is more powerful when considering a sample size of 50 or more participants. As a result, from Table 11.0, the Shapiro-Wilk test of normality for pretest and posttest scores revealed nonsignificant values of 0.960 ($p = 0.062$) and 0.979 ($p = 0.439$) respectively. Therefore, as presented in Table 4.4, the pretest and posttest scores were approximately normally distributed. This can also be confirmed by a visual inspection of the histograms and normal quantile-quantile plots (normal Q-Q plots), as shown in Appendices A1 to A6. Per the results in Table 11.0, parametric tests were used to test hypotheses in this study.

4.3 Results of the Study

4.3.1 Results for Research Question 1

What is the difference in academic performance of SHS Biology students instructed in genetic concepts before and after the use of Generative Learning Strategy?

A quantitative and qualitative analyses were conducted to compare the academic achievement of SHS Biology students who were taught genetic concepts before and after utilising the Generative Learning Strategy. Statistical analysis was performed to ascertain the difference between the students' pretest and posttest scores using

quantitative descriptive statistics, namely mean, standard deviation, and mean difference. Table 12.0 presents the descriptive statistics of the pretest and posttest results obtained before and following the implementation of the intervention.

Table 12.0: Descriptive Statistics of the Pretest and Posttest Scores of Students

N	Pre-test		Post-test		Mean Difference
	Mean	SD	Mean	SD	
106	8.01	2.040	21.81	2.515	13.80

As indicated in Table 12.0, students had a pretest mean score of 8.01 (SD = 2.040) and a posttest mean score of 21.81 (SD = 2.515). This led to a mean difference of 13.80. Based on the test findings, it can be concluded that students' performance on the genetic concept's exam differed before and after the Generative Learning Strategy was put into practice.

Also, qualitative analysis was done to determine individual students' differences in their pretest and posttest scores to assess differences in their performance. The qualitative analysis involved a review of the pretest and posttest scores of 51 systematically sampled students from the total participants, using professional judgment. This was done to determine the degree to which students had learned genetics content or improved their performances by comparing the two sets of scores qualitatively (Brophy, 2019) (Appendix C).

As seen from Appendix C, all SHS 3 Biology students taught genetics using the Generative Learning Strategy improved their scores, with apparently large differences ranging from 8 to 19. For instance, students with IDs 13, 35, and 105 scored 4 marks as the lowest score in the pretest but their posttest scores were increased to 23, 22, 24

respectively after the intervention. Similarly, students with ID 11, 23, and 55 scored 12 as the highest score in the pretest and had their posttest score increased to 27, 23, and 23 respectively. This indicates that the students grew in their understanding of genetic concepts after the intervention, proving that the use of the Generative Learning Strategy was effective.

4.3.2 Testing of Hypothesis 1

The results of research question one was tested as hypothesis 1 in this study. Thus, to test this hypothesis, research question 1 was formulated into a null hypothesis and tested at a probability level of 0.05. Hypothesis 1 states that “*there is no significant difference in the academic performance of SHS Biology students instructed in genetic concepts before and after the use of the Generative Learning Strategy.*” Therefore, to test this hypothesis, a paired-samples t-test was conducted on the pretest and posttest scores of students taught using Generative Learning Strategy. The results are presented in Table 13.0

Table 13.0: Results of Paired Samples t-test on Pretest and Posttest Scores of SHS Biology Students taught Using Generative Learning Strategy

	MD	T	Df	Sig. (2-tailed)	Eta Squared
Posttest-Pretest	13.80	48.246	105	.000	0.957

Df – Degrees of freedom; MD – Mean Difference

As presented in Table 13.0, the difference between the pretest and posttest scores was significant (Mean Difference = 13.80, $t_{(105)} = 48.246$, $p = 0.000$), with the difference favouring the posttest scores, as observed in Table 4.3. The eta squared statistic (See Appendix B) indicated a large effect size of 0.957, according to Cohen et al. (2018).

This means that 95.7% of the variances in posttest scores was explained by the independent variable (Generative Learning Strategy). Therefore, the null hypothesis was rejected. Thus, there is a significant impact of Generative Learning Strategy on students' academic performance in genetic concepts.

4.3.3 Main Finding from Research Question 1 and Hypothesis 1:

From the results of research question 1 and hypothesis 1, the Generative Learning Strategy had a significantly greater effect on SHS Biology students' academic performances in genetics.

4.3.4 Results for Research Question 2

What difference exists between genetics scores of high-achievers and low-achievers after exposure to Generative Learning Strategy?

This research question sought to determine the difference in academic performances in pretest and posttest scores between the high-achievers and low-achievers after introduction to the intervention. To categorise students into high achievers and low achievers, students' scores in the pretest were used. Specifically, students' pretest scores were ranked according to their percentiles, and divided into three, thus 33rd percentile, 66th percentile and 100th percentile. That is, students whose pretest scores were ranked from 1st to 33rd percentile were considered high achievers; 34th to 66th percentiles were considered average achievers; and 67th to 100th percentiles were considered low achievers. Subsequently, the pretest scores for average achieving students were removed since they were not the focus in this study.

The performance differences between high- and low-achieving students who were taught utilising the Generative Learning Strategy were ascertained by the computation of descriptive statistics. The mean and standard deviation of the GCT pretest and posttest results obtained before and after the implementation of the Generative Learning Strategy are displayed in Table 14.0

Table 14.0: Descriptive Statistics of Pretest and Posttest Scores of High Achievers and Low Achievers

Ability Group	N	Pre-test		Post-test		MD*	% Change
		M	SD	M	SD		
Low Achievers	44	6.26	0.806	22.63	1.770	16.37	262.50%
High Achievers	26	10.73	0.799	23.73	2.576	13.00	121.16%

*Mean Difference

From Table 14.0, it can be seen that the low-achievers obtained a pretest mean score of 6.26 (SD = 0.806) and a posttest mean score of 22.63 (SD = 1.770), while the high-achievers obtained a pretest mean score of 10.73 (SD = 0.799) and a posttest mean score of 23.73 (SD = 2.567). This resulted in mean differences of 16.37 and 13.00 for the low-achievers and high-achievers respectively, favouring the low-achievers. Consequently, there was a higher percentage change in performance among the low-achievers (262.50%) as compared to the high-achievers (121.16%) after using the Generative Learning Strategy to teach genetic concepts.

4.3.4.1 Testing of Hypothesis 2

The results of research question 2 was tested as hypothesis 2. Therefore, the research hypothesis, which states that “*there is no significant difference between the genetic test scores of high-achievers and low-achievers after exposure to the Generative Learning*

Strategy.” was examined using a one-way analysis of covariance (one-way ANCOVA) with the pretest results acting as covariates to find any significant difference between the two groups' posttest scores at an alpha level of 0.05. That being said, a one-way analysis of covariance makes the assumption that the dependent variable (scores on the posttest) and the covariate (pretest) should go hand in hand. Moreover, the group's covariate-dependent relationship (also known as the homogeneity of regression slopes) should be the same.

Other assumptions include the reliability of the covariate, which is the pretest scores (Table 16.0), and the homogeneity of variances, that is, the variances between the posttest scores for both participants must be equal, in addition to the normal distribution of the posttest scores (Table 15.0). These assumptions were tested and the results are presented below.

4.3.4.2 Results for Test of Assumption of Homogeneity of Regression Slope

This presumption addresses how test scores, which are the covariate, and posttest scores, which are the dependent variable, relate to each other for both high and low achievers. According to Pallant (2011a), the covariate and the treatment or experimental modification should not interact in any way. The results are presented in Table 15.0

Table 15.0: Test of Homogeneity of Regression Slope

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	13.415 ^a	3	4.472	.918	.444
Intercept	127.032	1	127.032	26.082	.000
Teaching Method	1.644	1	1.644	.337	.566
Pretest	.065	1	.065	.013	.909
Teaching Method * Pretest	3.000	1	3.000	.616	.439
Error	146.114	30	4.870		
Total	18330.000	34			
Corrected Total	159.529	33			

a. R Squared = .084 (Adjusted R Squared = .007)

The results showed that there was no significant interaction ($p = 0.439$) between the covariate, thus the pretest scores of students, and the treatment, thus the teaching methods, as observed in Table 15.0. Therefore, from Table 15.0, the assumption of homogeneity of the regression slope was not violated.

4.3.4.3 Results for Assumption of Linear Relationship Between Dependent Variable (Posttest Scores) and Covariate (Pretest Scores)

The assumption of Analysis of Covariance is that there should be a linear connection between the covariate (pretest scores) and the dependent variable (posttest scores) for both the group's high achievers and low achievers (Pallant, 2011b). According to Pallant (2011b), a sign of a curvilinear relationship indicates that this presumption has been broken. This assumption was tested, and the results are graphically presented in Figure 4.0. Violation of this assumption, Pallant asserts, is probably going to lower the analysis of covariance tests' power (sensitivity), given one of the goals of introducing variables was to make the analysis of covariance tests' power higher.

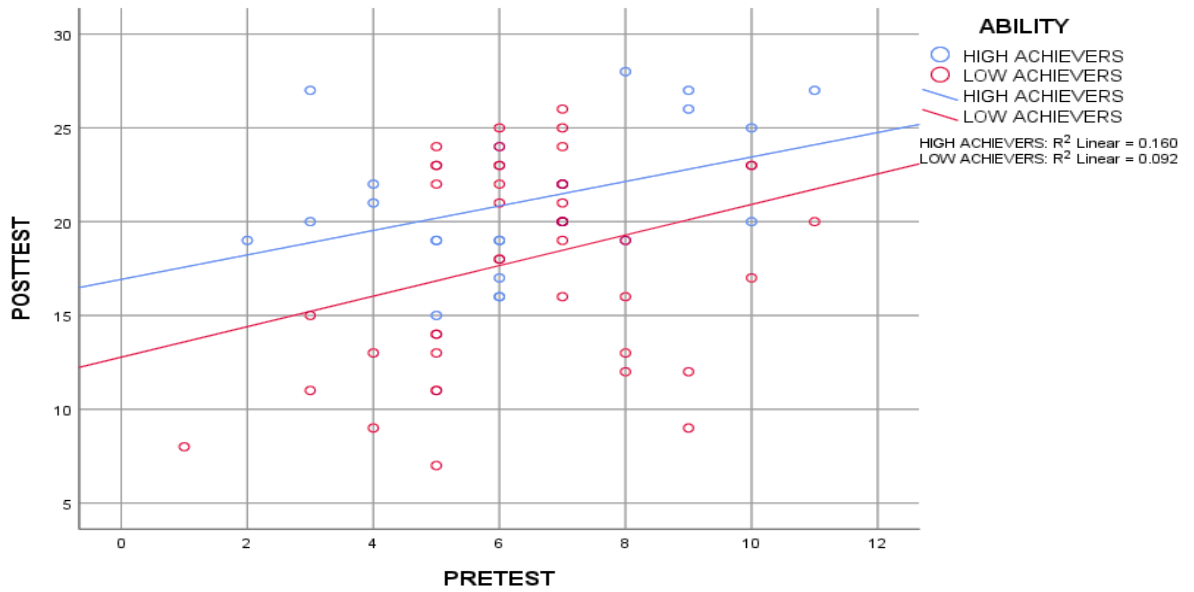


Figure 3.0: linear relationship between the posttest scores and pretest scores for high achievers and low achievers

There is a linear (straight line) association between the pretest and posttest results for the group's high achievers and low achievers, as shown in Figure 3.0. As a result, this assumption was not violated.

4.3.4.4 Results for Assumption of Homogeneity of Variances of Posttest Scores for High Achievers and Low Achievers

This assumption tests the null hypothesis that the variances in the posttest scores between high-achievers and low-achievers are equal. That is, the null hypothesis is rejected if the alpha (p) value is less than 0.05. The results are presented in Table 16.0

Table 16.0: Results for Test of Homogeneity of Variances of Posttest Scores for High Achievers and Low Achievers

		Levene's Test Statistic	
		F	Sig.
Posttest	Equal Variances Assumed	2.814	.103

Levene's test statistic, F, which tests for the assumption of equal variances in the posttest scores between high-achievers and low achievers, revealed that it was not significant ($F = 2.814, p = 0.103 > 0.05$). Therefore, the null hypothesis was accepted. Hence, the variances in posttest scores between high-achievers and low-achievers were equal.

Since all the assumptions were not violated, the one-way analysis of covariance was therefore conducted and the results are presented in Table 17.0

Table 17.0: Results for One-Way Analysis of Covariance of Posttest Scores Between High Achievers and Low Achievers

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10.415 ^a	2	5.208	1.083	.351	.065
Intercept	164.402	1	164.402	34.178	.000	.524
Pretest Group	.240	1	.240	.050	.825	.002
Error	2.305	1	2.305	.479	.494	.015
Total	149.114	67	4.810			
Corrected Total	18330.000	70				
	0					
Corrected Total	159.529	69				

a. R Squared = .065 (Adjusted R Squared = .005)

As observed in Table 17.0, after adjusting for pretest scores for high-achievers and low-achievers, there was no significant difference between high- and low-achievers taught using the Generative Learning Strategy ($F(1, 67) = 0.479, p = 0.494 > 0.05$), with a small effect size (partial eta squared = 0.015).

4.3.4.5 Main Finding for Research Question 2 and Hypothesis 2:

From the results of research questions 2 and hypotheses 2, it can be said that the Generative Learning Strategy helped high- and low-achieving students perform significantly equivalently.

4.3.5 Results for Research Question 3

What are the perceptions of students about the relevance of Generative Learning Strategy in teaching genetic concepts?

This research question sought to determine how low-achieving and high-achieving students taught using the Generative Learning Strategy perceive the effectiveness of the Generative Learning Strategy. Therefore, to answer this research question, a face-to-face, semi-structured interview was conducted with eight students. Students' views were recorded with their permission and transcribed for thematic analysis. It was discovered that students had positive perceptions about the integration of Generative Learning Strategy in teaching genetic concepts. The various themes generated from the interview are presented in Table 18.0, with explanations and representative statements from students (all names are pseudonyms).

Table 18.0: Thematic Presentation of Students' Perceptions on Generative

Learning Strategy

Theme	Topic
Theme 1	Better understanding of genetic concepts
Theme 2	Increased motivation to learn genetics
Theme 3	Retention of genetic concepts
Theme 4	Self-directed learning and more time on learning task

4.3.5.1 Theme 1: Better understanding of genetic concepts

Students pointed out that the use of Generative Learning Strategy helped them to understand genetic concepts better than how they were taught. This is because, according to the students, during the teaching and learning process, lessons were designed in such a way that unfamiliar and abstract concepts were made to become real by connecting new knowledge to previous knowledge. For instance, Eric, an SHS 3 Biology student who was a low-achiever, said:

“Sir, I did not perform well in the first test. That is because how our teacher taught us genetics is totally different from how you taught us. So, in the second test, I saw a better improvement in my performance, to the extent that I was even shocked. I saw you beginning with what we already knew and then ending with the new knowledge that you wanted us to know. In fact, sir, I felt like genetics was a topic I live with every day, instead of previously only reading about it from books and maybe once a while on the radio or television. For example, we used clean water, a mixture of chalk and water, and tomato paste and water during the study of blood compatibility. Through that I learned that, people with blood group AB can receive blood during blood transfusion from other people with blood group A, B and O, but people with blood group O

cannot receive blood from blood group AB. Therefore, it is also good to check and know your blood group.”

Also, Ibrahim, a high-achieving SHS 3 Biology student, added to Eric’s opinion that:

“Sir, I am a very good student. I know myself looking at my performances in Biology. But all this while, how we were being taught, especially for genetics which you came to teach us again, is different from this time how you taught us. When we were taught genetics at first, I felt like I learned on my own, even though our teacher taught us. That is why my scores in the first test were far lower than in the second test. How you taught us made me understand genetics far better than how we were taught at first, especially how you used examples from our daily lives to relate to the new knowledge. For instance, the day we used the fruit juices when studying crossing, I learned that a child can be the shortest among his brothers and sisters, who may all be tall, because there may be characteristics for shortness that are hidden in either their father or mother.”

4.3.5.2 Theme 2: Increased Motivation to learn Genetics

Motivation is associated with academic performance (Amrai, Motlagh, Zalani & Parhon, 2011). and being motivated to learn a particular task helps an individual create an environment to understand every bit of detail regarding that task (Brophy, 2010). Students thus perceived the use of Generative Learning Strategy as an approach to teach genetics which helped them develop deeper intrinsic motivation to learn genetics. In

her own words, Elizabeth, who was a high-achieving SHS 3 Biology student, expressed that:

“Sir, to be frank with you, had it not been you, I said to myself I would not answer genetics questions during my WASSCE examination. Because I did not understand genetics previously, I had no desire and motivation to study, and to find ways to understand. In fact, that topic seemed boring to me. But how you came in and the strategies you used to teach us have ignited a passion and desire within me to the extent that a day will never pass where I have not tried to answer a genetics question on my own. I really love the study of genetics now more than ever”.

In his opinion, Dennis, a low-achieving SHS 3 Biology student, stated that:

“I disliked genetics because I thought it was a very complex topic. Until now, I had no motivation to study the topic and find solutions to sample genetic problems on my own. This is because, our teacher only comes to copy and explain notes to us without any meaningful examples. I only force myself to read it for exams sake. Sometimes I even become worried at myself for studying things I cannot see them. But the way you taught us genetics this time around is very different. I saw myself as fully involved, and also how the examples related to our personal and family life issues made me see genetics as a practical concept that we see in our lives all the time.”

4.3.5.3 Theme 3: Retention of Genetic Concepts

Students moreover saw the use of Generative Learning Strategy in teaching genetics as a method which helps them to retain concepts better. During the interview session, Diana, a low-achieving SHS 3 Biology student, remarked that:

"Oh, sir, honestly, I can remember everything that you taught us from the first day to the last. That even reflected in the second test, which we did. Sir, I always struggled to remember the things that we learned previously in genetics. Sometimes I ask myself, is it only me or is it for everyone? But as you came to teach us, I saw that you used different ways to teach us, which made me see genetics as a topic that is easy to understand and also remember any time somebody asks me a question. Even now, I think it has been about three weeks since you taught us that what we can observe in a person, which is called phenotype, is the result of some internal, unique arrangements of his or her genes, which is called genotype. Before that, I had read and heard genotype and phenotype several times but I did not answer questions correctly in exercises and tests."

Similarly, Abrafi, a high-achieving SHS 3 Biology student, articulated that:

"... I see myself as good in Biology, but I always chew and pour everything I learn. In fact, this is the first time I did not revise my notes for a test but I was able to score high marks. That means I remembered everything you taught us in the classroom. Sir, I could even observe that you did not talk too much in all the lessons that we had. We were doing almost everything, and then you corrected us when we were going

wrong. That really helped me. Because of that, most of the things we learned stuck in my mind, and I was able to remember them. For example, I can remember that though what we see on a person is because of the genotype and the phenotype, but the environment can also affect the outward characteristics we see on the person, which is the phenotype.”

4.3.5.4 Theme 4: Self-directed learning and More Time on Learning Task

By employing the Generative Learning Strategy, students perceived that it helped them seek out relevant genetic information by themselves. For instance, Lydia, a high-achieving SHS 3 Biology student, said:

“This is my first time visiting the school library. Formerly, our Biology teacher would only copy notes and explain everything to us, and then if we had questions, we would ask. But how you taught us always pushed me to look for more information even before coming to class; and I see that as very helpful in my studies. For example, anytime you taught, I saw that you wanted us to explain what we learned by ourselves, and we had to use examples in the explanation. So, I always wanted to learn more by myself so that I could explain things better.”

To add to Lydia’s voice, Seth, a low-achieving SHS 3 Biology student, also asserted that:

“Sir, I did not like further reading. But the way you taught us made the learning of genetics so interesting that, anytime we close from school, I will spend at least one hour at the school library to read further on

genetics topics which we studied in class. This is because I did not want to embarrass myself during the group explanations. And how you did the groupings, I could not hide, so I had to learn more and understand it well before we came to class. And you saw that, after one explanation, I did, they were clapping for me. That always motivated me to learn more after every class. I wish every teacher taught genetics the way you taught us.”

4.3.5.5 Main finding for research question 3:

The responses from students in the interview revealed that students perceived the use of a Generative Learning Strategy as helping them to better understand genetic concepts, increase their motivation to learn genetics, retain genetic concepts, enhance their self-directed learning, and spend more time on genetics learning tasks.

4.4 Discussion of Results

This section discusses the main findings of this study. The findings are discussed based on the specific research questions.

4.4.1 Discussion of Results for Research Question 1

This research question sought to determine the impact of Generative Learning Strategy on students' academic performances in genetics before and after the implementation of the intervention. As a result, the pretest and posttest scores of SHS Biology students taught using Generative Learning Strategy were compared. After comparing the pretest and posttest scores, it was found that, Generative Learning Strategy had a larger effect (effect size = 0.957) on SHS students' performance in genetic concepts, with a

statistically significant difference between the pretest and posttest scores of students (Mean Difference = 13.80, $t_{(105)} = 48.246$, $p = 0.000$).

This finding agrees with the findings of Ogunleye and Babajide (2011), Bot (2018), and Appiah-Twumasi (2018), who found the application of Generative Learning Strategy effective in enhancing students' academic performances. The greater efficacy of the Generative Learning Strategy is due to the fact that, using the Generative Learning Strategy, as Yuliani, Ulfah, Agustina, Al-Huda, & Qamariah (2021) stated, students can expand on prior information in a more original and critical way, where they can actively obtain knowledge that focuses on developing their capacity to evaluate previously learned material in order to draw new conclusions.

It also validates the finding of Grabowski (2004) who reported that it is an environment-based paradigm that allows learners to create their own learning rather than having them solve a pre-defined problem by creating their own issues, and as well resolve the issues. Instead of just memorising the information offered, students who engage in generative learning must create their own meaning by fusing new knowledge with prior knowledge. Additionally, this finding confirms that of Bobby et al (2021) which revealed that it integrates previously learned material with recently acquired ideas thereby improving the students' academic performance.

4.4.2 Implication of Research Question 1

Biology teachers from Sefwi-Wiawso Municipality should ensure that their students are actively involved in the teaching and learning process to enable them to build on their prior knowledge in a more original and comprehensive way. This allows them to

gain knowledge that is centered on strengthening their ability to assess previously studied content in order to make new judgments.

Biology teachers from Sefwi-Wiawso Municipality should plan their lessons to center on the needs of their students rather than the facts per se. This will help the students better understand and organise the material. This would aid in enhancing and expanding their students' prior knowledge.

4.4.3 Discussion of Results for Research Question 2

This research question sought to determine difference in academic performances in pretest and posttest scores between the high-achievers and low-achievers after the use of the Generative Learning Strategy to teach genetic concepts. Therefore, to determine the difference between high and low-achieving SHS 3 Biology students taught using the Generative Learning Strategy, a one-way ANCOVA was conducted on the posttest scores of high and low-achieving students, using their pretest scores as covariates. It was found that, after introducing the Generative Learning Strategy, there was no significant difference between high- and low-achievers taught using Generative Learning Strategy ($F_{(1, 67)} = 0.479$, $p = 0.494 > 0.05$). However, it resulted in mean differences of 16.37 and 13.00 for the low-achievers and high-achievers respectively, favouring the low-achievers.

This finding agrees with Appiah-Twumasi (2018), who also found no significant difference in performance between high achievers and low achievers instructed with Generative Learning Strategy. The relative equivalent levels of performance by high-achieving and low-achieving SHS 3 Biology students instructed with the Generative

Learning Strategy may be explained, at least in part, by the fact that using the Generative Learning Strategy puts all students at the center of the learning process. It also provides equal opportunities for all learners to understand and grasp the meaning of the content as reported by Fiorella and Mayer (2016).

Additionally, the use of a Generative Learning Strategy connected new knowledge to prior understanding, ensuring that the classroom environment was no longer competitive but rather cooperative, where students and the teacher supported and encouraged one another to learn which confirms the finding of Yaduvanshi and Singh (2019). As a result, there was an abundance of empathy, cooperation, and harmony in the classroom, which minimises the likelihood of unpleasant situations and maximises the learning and happiness of all learners with a variety of abilities. The students were also given autonomy as well as personal responsibility for finishing the task. Hence, each student developed an awareness of his or her learning and performance, which helped to raise performance levels.

Moreover, the findings of Fasanya (2022), Appiah-Twumasi (2019), and Carnine and Kinder (1985) corroborate this one, showing that the Generative Learning Strategy can improve the academic performance of low-achievers. Several more students benefit from this as their performance improves, enabling them to advance from the low-achieving to the average or even high-achieving category.

4.4.4 Implication of Research Question 2

Biology teachers from Sefwi-Wiawso Municipality should ensure that their students are given the needed priority during the learning process to guarantee equitable

opportunities for content comprehension and promote cooperative classroom setting where teachers and students of different ability groups can help and support each other.

Biology teachers from Sefwi-Wiawso Municipality should ensure that their classroom environment encourages cooperation, tolerance, and a minimisation in unhealthy coping mechanisms to enhance learning and happiness for all students with varying ability levels. This would help students develop an understanding of their own learning to raise their own performance, which would ultimately close the academic performance disparities among themselves.

4.4.5 Discussion of Results for Research Question 3

To confirm the quantitative findings of this study, a qualitative interview was conducted to find out how SHS 3 Biology students perceived the effectiveness of using a Generative Learning Strategy in teaching genetics. The interview results revealed that SHS 3 Biology students perceived that the Generative Learning Strategy helped them to understand concepts much better, increased their motivation to learn genetics, retained genetic concepts, and also assisted them in self-directed learning. These views are in agreement with Fiorella and Mayer (2016), who also reported similar findings. Also, it supports the findings of Wena (2009), who reported that the Generative Learning Strategy required students to study independently, explore their knowledge from multiple learning sources, concentrate on the issue at hand, execute an experiment to build concepts they had learned, and then apply those concepts to situations they encountered on a daily basis. Similarly, it also validates the finding of Purwo (2016), who reported that learners' opportunities to generate ideas and sharpen their analytical

thinking skills are increased by interchanging their viewpoints, which in turn increases their understanding of concepts.

4.4.6 Implication of Research Question 3

Biology teachers from Sefwi-Wiawso Municipality should support their students' independent study, learning from a variety of sources, problem-solving, research, and application of newly gained knowledge to real life scenarios.

Additionally, Biology teachers from Sefwi-Wiawso Municipality should use the Generative Learning Strategy to help students become more motivated to study, improve their comprehension, retain more information, and encourage self-directed learning.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

5.0 Overview

The study's conclusions have been summarised in this section. In light of the results, conclusions, advice, and recommendations were made for additional study.

5.1 Summary of Findings

The study looked into how SHS Biology students in Sefwi-Wiawso Municipality performed academically when it came to genetic ideas and the Generative Learning Strategy. Through the use of both quantitative and qualitative data, research questions were addressed by implementing a mixed-methods study design. The study employed a sample of 106 SHS 3 Biology students. The instruments used for data collection were an achievement test, thus the Genetics Concept Test (GCT), as well as a semi-structured interview guide. After collecting data and subsequent analysis of the data, it was found that there was a large impact of the Generative Learning Strategy on the academic performance of SHS Biology students in genetics.

Additionally, the study showed that there was no significant difference between low-achieving and high-achieving students after applying the Generative Learning Strategy. SHS 3 Biology students taught using the Generative Learning Strategy expressed in a semi-structured interview that the use of the Generative Learning Strategy helped them to understand genetic concepts better, increased their motivation to learn genetics,

retained genetic concepts, and also assisted them in self-directed learning, hence their improved performances in the Genetics Concept Test.

5.2 Conclusions

Based on the results of this study, it can be concluded that using the Generative Learning Strategy in teaching genetics in SHSs in the Sefwi-Wiawso Municipality helped students improve their academic performances in genetics. Also, the use of the Generative Learning Strategy can help bridge the gap in academic performance between high-achieving and low-achieving Biology students. This is because, the use of Generative Learning Strategy places the Biology students at the center of the teaching and learning process, where their prior knowledge is linked to current knowledge, which consequently results in a deeper understanding of genetic concepts. This was confirmed by SHS 3 Biology students taught using the Generative Learning Strategy in a semi-structured interview who expressed that the use of the Generative Learning Strategy helped them to understand genetic concepts better, increased their motivation to learn genetics, helped them retain genetic concepts, and assisted them in self-directed learning.

5.3 Recommendations

The findings of this study have led to the following recommendations that should be considered when making major educational decisions.

1. It is recommended that Biology teachers in the Sefwi-Wiawso Municipality employ the Generative Learning Strategy in the teaching and learning of genetics as the quest to improve SHS Biology students' academic performances in genetics continues. This means that major education stakeholders in the

Sefwi-Wiawso Municipality must arrange for in-service training in the form of workshops, conferences, and seminars to equip teachers to incorporate the Generative Learning Strategy into the teaching and learning of Biology in senior high school classes.

2. It is also recommended that teachers in the Sefwi-Wiawso Municipality use the Generative Learning Strategy in teaching in order to close the achievement gap between high and low achievers in the classroom. This is possible because the Generative Learning Strategy places students at the center of the teaching and learning process, where their prior knowledge is linked to current knowledge, which consequently results in a deeper understanding of concepts.
3. Again, it is recommended that teachers in the Sefwi-Wiawso Municipality orient their teaching strategies to modern learner-centered methodologies such as the Generative Learning Strategy in order to equip themselves with skills that will enable their learners to understand and retain concepts, increase their motivation to learn, and assist them in self-directed learning.

5.4 Suggestions for Further Research

Following up on the study's conclusions, and recommendations for additional research, it is suggested that further studies be conducted on the impact of Generative Learning Strategy in other subjects or topics and compared with a control group.

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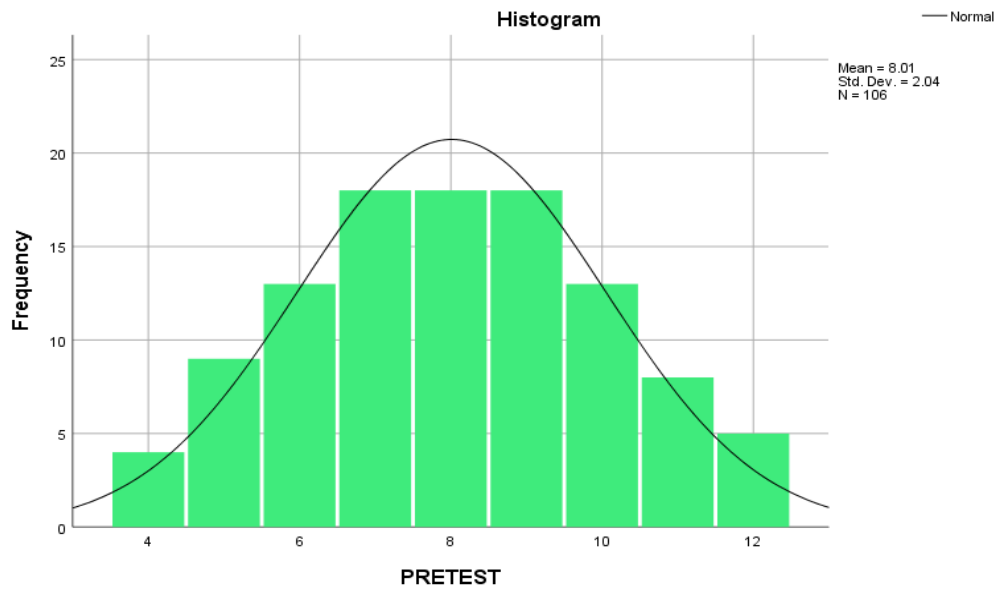
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APPENDICES

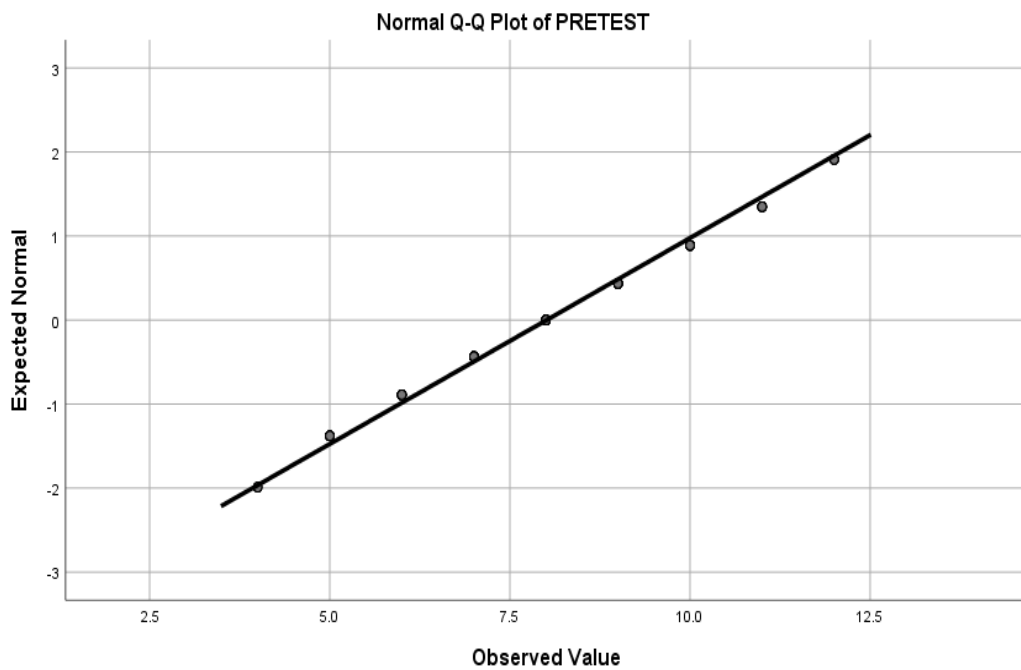
APPENDIX A1

Histogram for Pretest Scores



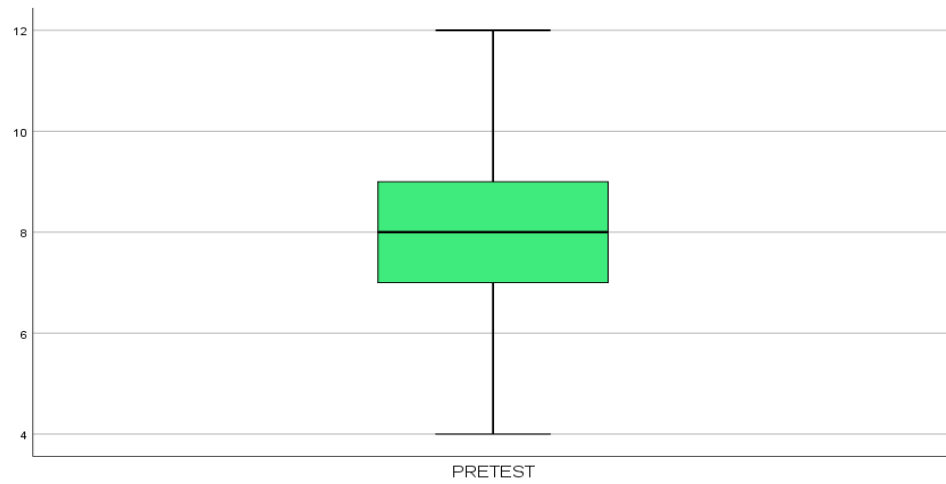
APPENDIX A2

Normal Q-Q Plot for Pretest Scores



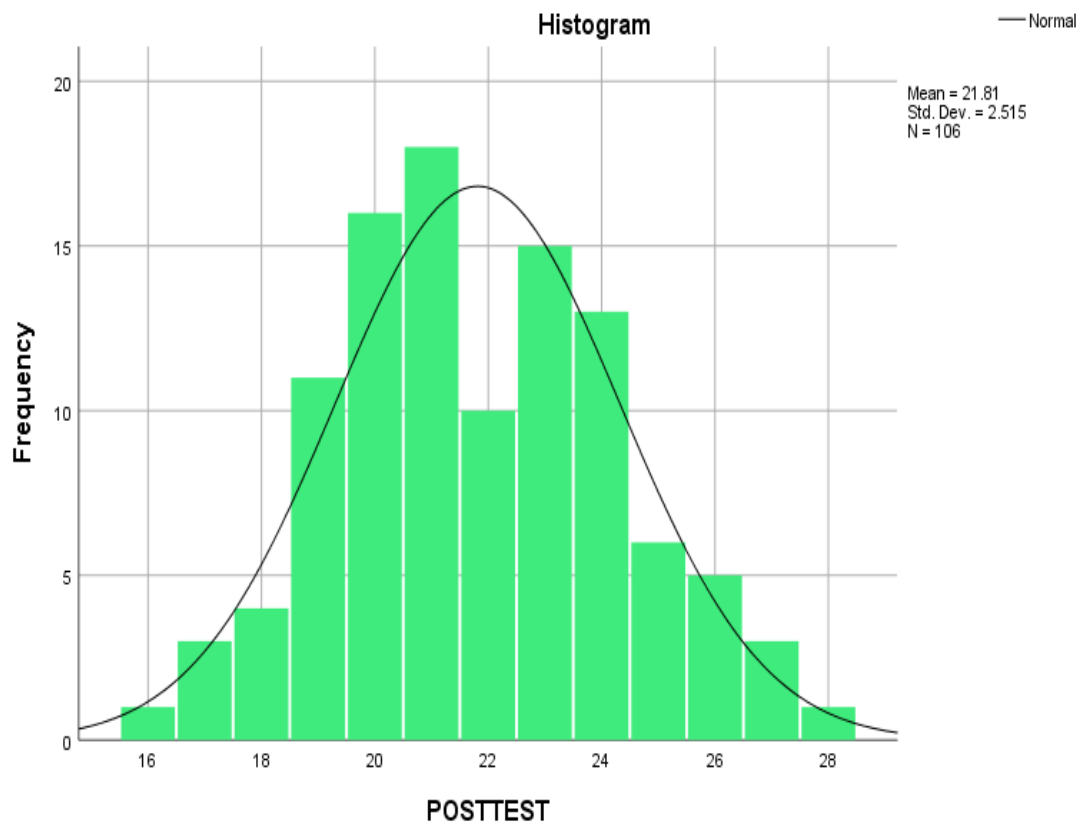
APPENDIX A3

Box Plot for Pretest Scores



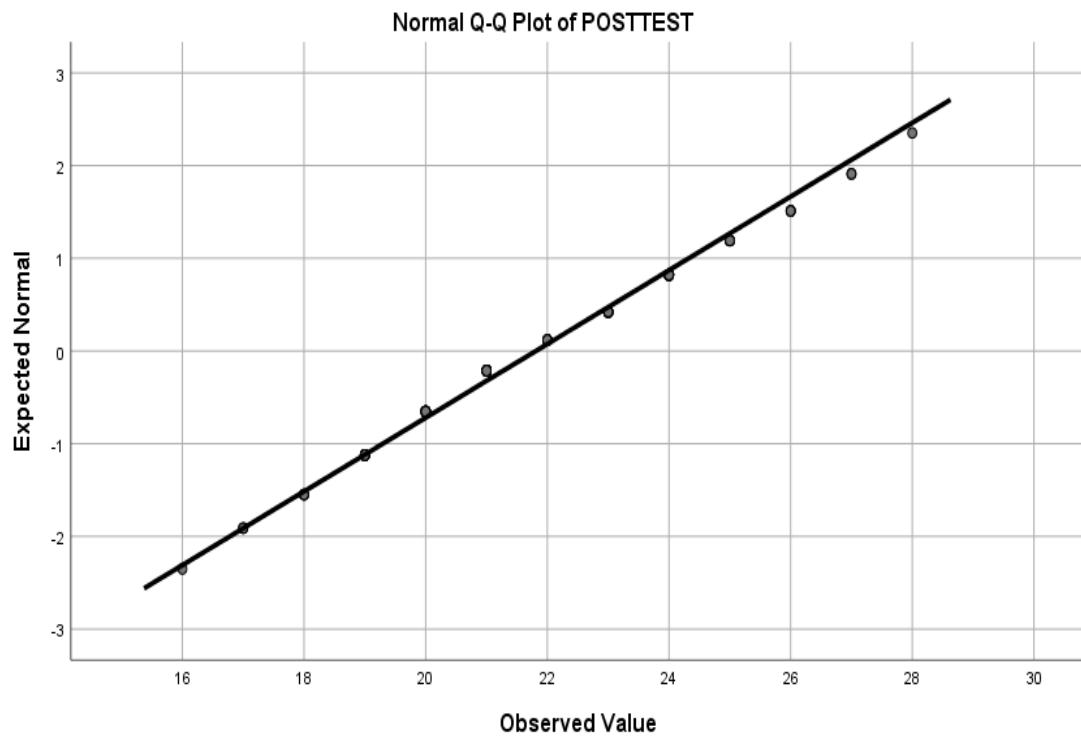
APPENDIX A4

Histogram for Posttest Scores



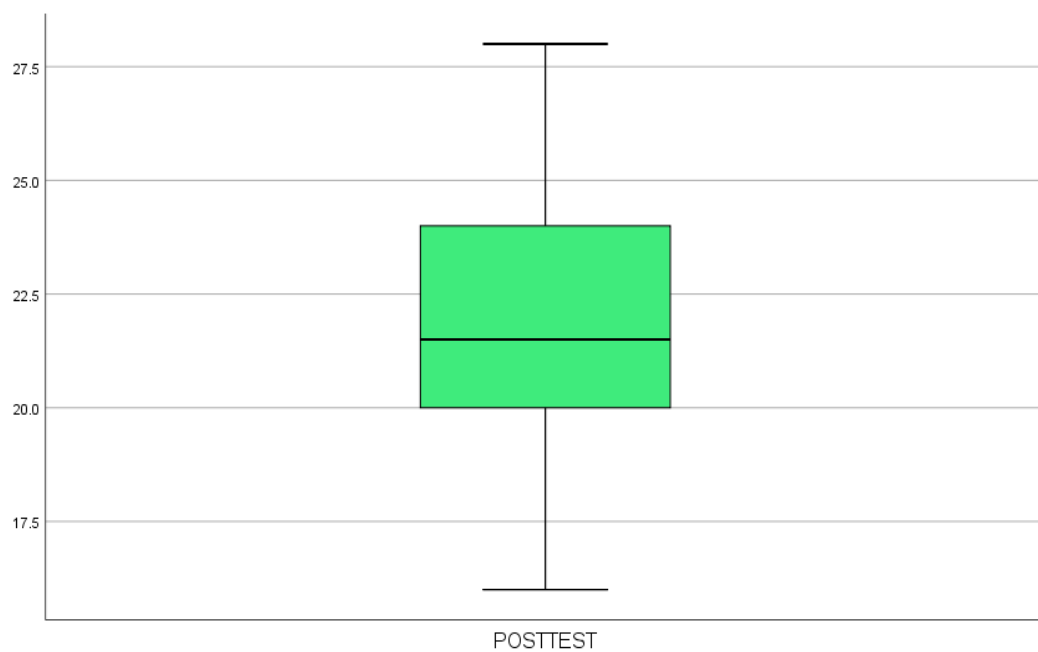
APPENDIX A5

Normal Q-Q Plot for Posttest Scores



APPENDIX A6

Box Plots for Posttest Scores



APPENDIX B

Eta Squared Formula and Interpretation

$$Eta\ Squared = \frac{t^2}{t^2 + (N-1)}$$

where t= calculated t-value

N= Number of Students

Eta Squared Interpretation

Effect size	Interpretation
≤ 0.1	small effect
≤ 0.6	Medium effect
≥ 1.38	Large effect

APPENDIX C

Pretest and Posttest Scores of Students

Student ID	Pretest	Posttest	Difference
5	11	27	16
7	11	27	16
9	10	28	10
11	12	27	15
13	4	23	18
15	10	24	14
17	10	25	15
19	11	23	12
21	7	22	15
23	12	23	11
25	8	19	11
27	9	20	11
29	8	20	12
31	11	20	9
33	9	21	12
35	4	22	17
37	10	24	14
39	8	24	16
41	8	18	10
43	8	19	11
45	8	18	10
47	9	20	11
49	10	21	11
51	10	22	12
53	11	21	11
55	12	23	11
57	7	26	19
59	8	25	17
61	9	20	11
63	7	20	13
65	7	20	13
67	8	19	11
69	9	17	8
71	9	22	13
73	9	24	15
75	10	21	11
77	6	21	15
79	6	23	17
81	6	22	16
83	6	24	18
85	7	22	15
87	8	23	15
89	7	24	17

91	7	20	13
93	7	25	18
95	8	26	18
97	9	23	14
99	9	24	15
101	9	25	14
103	9	26	17
105	4	24	19

APPENDIX D

ACHIEVEMENT TEST ITEMS (FOR BOTH PRE AND POST TESTS)

1. The greatest contribution to genetic studies was made by...
 - A. Charles Darwin.
 - B. Gregor Mendel.
 - C. Robert Hooke.
 - D. Thomas Morgan.

2. An advantage of out-breeding in genetics is...
 - A. more offspring.
 - B. fewer offspring.
 - C. superior hybrid.
 - D. identical individuals.

3. In genetics, test cross is performed to determine...
 - A. crossing over.
 - B. genetic linkage.
 - C. phenotypic composition.
 - D. genotypic composition.

4. The reaction between antibodies and antigens of red blood cells when incompatible blood groups are transfused is called...
 - A. crossing over.
 - B. co-dominance.
 - C. outbreeding.
 - D. agglutination.

5. According to Mendel's first law of inheritance, segregation of genes occurs when...
- A. tall plants and short plants are crossbred.
 - B. tall plants are crossbred.
 - C. short plants are crossbred.
 - D. plants are crossbred.
6. In dihybrid inheritance, Mendel considered...
- A. a pair of contrasting characters.
 - B. two pairs of contrasting characters.
 - C. three pairs of contrasting characters.
 - D. four pairs of contrasting chairs.
7. Two tall plants were crossed and all the F_1 plants were tall. Some of the F_2 plants were tall and others short when the F_1 plants were selfed. The possible genotypes of the original parental plants were
- A. TT and Tt .
 - B. TT and TT .
 - C. Tt and tt .
 - D. Tt and Tt .
8. The following features make fingerprints useful in crime detection except that...
- A. it is unique to an individual person.
 - B. it imprints on objects handled.
 - C. its patterns in individuals are permanent.
 - D. its patterns are more distinct in black people.

Use the diagram below to answer Question 9



9. The type of variation illustrated above is
- A. morphological variation.
 - B. environmental variation.
 - C. continuous variation.
 - D. discontinuous variation.

ESSAY QUESTIONS

10. Define the following terms:

- (i) gene;
- (ii) chiasma;
- (iii) mutation;
- (iv) test cross;

11. monohybrid cross.

[10 marks]

12. Give two examples each of:

- (i) continuous variation;
- (ii) discontinuous variation.

[4 marks]

13. Mr. Abugri who does not have the sickle cell anaemia trait is married to Boaduwa who is a sickler, yet he claims the sickler child born to them is not his child. Determine by aid of a genetic diagram whether his claim is true.

[6 marks]

APPENDIX E

TABLE OF SPECIFICATION FOR BOTH PRETEST AND POSTTEST

OBJECTIVE TEST

Topic: Genetics and Variation

Sub-topic	Number of Questions	Question Items	Depth of Knowledge
Genetics and Applied Genetics	4	1	Level 1 (Recall)
		2	Level 1 (Recall)
		3	Level 1 (Recall)
		4	Level 1 (Recall)
Mendel's Experiments	3	5	Level 1 (Recall)
		6	Level 1 (Recall)
		7	Level 4 (Extended thinking)
Variation	2	8	Level 1 (Recall)
		9	Level 3 (Strategic thinking)

ESSAY QUESTIONS

Topic: Genetics and Variation

Sub-topic	Number of Questions	Question Items	Depth of Knowledge
Genetics and Applied Genetics	1	10 (i)	Level 1 (Recall)
		10 (ii)	Level 1 (Recall)
		10 (iii)	Level 1 (Recall)
Mendel's Experiments	1	10 (iv)	Level 1 (Recall)
		10 (v)	Level 1 (Recall)
		12	Level 4 (Extended thinking)
Variation	1	11 (i)	Level 2 (Skill / Concept)
		11 (ii)	Level 2 (Skill / Concept)

APPENDIX F

Semi-Structured Interview Guide to Determine the Perceptions of SHS Biology

Students on the Use of Generative Learning Strategy

1. How does this teaching strategy used to teach genetics differ from other teaching methods you have experienced in the past?
2. What aspects of these teaching strategy do you find most helpful in understanding difficult concepts?
3. How does this new teaching strategy address your learning style in the classroom?
4. Which stage in this teaching strategy used in the teaching and learning of genetics do you think benefited you most in the understanding of genetic concepts, and why?
5. Will you suggest that Biology teachers should continually use this teaching strategy in teaching genetic concepts, and why?

APPENDIX G1

Learning Plan							
Subject	<i>Biology</i>	Week	<i>1</i>	Duration	<i>120 min</i>	Form	<i>SHS 3</i>
Strand	<i>GENETICS AND VARIATION</i>	Sub-Strand	<i>GENETICS AND APPLIED GENETICS</i>				
Content Standard	<ol style="list-style-type: none"> 1. Appreciate inheritance as a characteristic of variation and evolution. 2. Appreciate the use of techniques of genetics in the improvement of varieties of animals and plants to suit human needs. 3. Understand the basis for the similarities and differences in function among living things. 						
Learning Outcome(s)	<ol style="list-style-type: none"> 1. Explain the term genetics. 2. Explain and define some terms used in genetics with examples. 						
Essential Question(s)	<ul style="list-style-type: none"> • How can the knowledge and understanding of genetics enable us to appreciate the fact that our genetic makeup influences our physical traits, behaviors, and susceptibility to certain conditions? • To what extent can the knowledge acquired from the learning of genetics be used to solve crimes and ensure justice in the legal system? • How can the knowledge variation aid in understanding how physical traits and behaviors among individuals impact social interactions and societal norms? • In what ways can understanding genetics and variation help in the prevention and treatment of diseases? • To what extent can the knowledge and understanding of genetics and variation be utilised to improve agriculture to improve crop and livestock production? 						
Pedagogical Strategies	<ul style="list-style-type: none"> • <i>Talk for learning approach, Inquiry-based method</i> • <i>Think pair share</i> • <i>Demonstration/ practical activity</i> • <i>Collaborative learning, discussion method</i> 						
Teaching & Learning Resources	<ul style="list-style-type: none"> • Coloured beads • Word cards • Projector • Video and • Internet 						

<p style="text-align: center;"><i>Organisation</i> <u>Activity 2 (15 minutes)</u></p> <p>I. Guide students to explore and illustrate connections between the previously learned concepts / knowledge and the new one.</p> <p style="text-align: center;"><i>Elaboration</i></p> <p><u>Activity 3 (30 minutes)</u></p> <p>I. Explains to learners on the applications genetics with an emphasising that each of us carries genetic information that determines everything from our eye colour to our risk of certain diseases.</p>	<p style="text-align: center;"><u>Activity 2</u></p> <p>I. Explore using their textbooks and notes to create connections between the previously learned concepts / terminologies / knowledge with the newly learned.</p> <p style="text-align: center;"><u>Activity 3</u></p> <p>I. In their mixed-gender and proficiency groups discuss, think-ink pair and share with the larger class situations in everyday life that illustrate the application of genetics.</p>
Lesson closure	
<p><u>Activity (15 minutes)</u></p> <p><i>Teacher summarises the lesson by laying emphasis on the main concepts of the lesson using reflective activities where students articulate their understanding of genetic concepts and connecting them to their own lives.</i></p>	
Evaluation	
<p>Briefly explain the following terminologies as used in the study of genetics:</p> <ul style="list-style-type: none"> (a) gene; (b) genotype; (c) allele; (d) dominant allele; (e) recessive allele; (f) test cross. 	
Reflection & Remarks	

APPENDIX G2

Learning Plan							
Subject	<i>Biology</i>	Week	2	Duration	<i>120 min</i>	Form	<i>SHS 3</i>
Strand	<i>GENETICS AND VARIATION</i>	Sub-Strand	<i>GENETICS AND APPLIED GENETICS</i>				
Content Standard	<ol style="list-style-type: none"> 1. Appreciate inheritance as a characteristic of variation and evolution. 2. Appreciate the use of techniques of genetics in the improvement of varieties of animals and plants to suit human needs. 3. Understand the basis for the similarities and differences in function among living things. 						
Learning Outcome(s)	<ol style="list-style-type: none"> 3. Explain that chromosomes form the basis of heredity. 4. Explain the concept of inheritance 						
Essential Question(s)	<ul style="list-style-type: none"> • How can the knowledge and understanding of genetics enable us to appreciate the fact that our genetic makeup influences our physical traits, behaviors, and susceptibility to certain conditions? • To what extent can the knowledge acquired from the learning of genetics be used to solve crimes and ensure justice in the legal system? • How can the knowledge variation aid in understanding how physical traits and behaviors among individuals impact social interactions and societal norms? • In what ways can understanding genetics and variation help in the prevention and treatment of diseases? • To what extent can the knowledge and understanding of genetics and variation be utilised to improve agriculture to improve crop and livestock production? 						
Pedagogical Strategies	<ul style="list-style-type: none"> • <i>Talk for learning approach, Inquiry-based method</i> • <i>Think pair share</i> • <i>Demonstration/ practical activity</i> • <i>Collaborative learning, discussion method</i> 						
Teaching & Learning Resources	<ul style="list-style-type: none"> • Coloured beads • Word cards • Projector • Video and • Internet 						

Keywords	<i>Selection, artificial selection, inbreeding, outbreeding, hybrid vigour</i>

Lesson Activities	
<i>Teacher Activity</i>	<i>Learner Activity</i>
<p><u>Introduction (10 minutes)</u></p> <p style="text-align: center;"><i>Recall</i></p> <p>I. Introduces the lesson through questioning and answering on some of the key concepts learned in the previous lesson.</p> <p><i>Expected answers:</i> <i>Genetics, genes, heredity, chromosomes, chiasma, locus, alleles, trait, genotype, phenotype etc.</i></p> <p><u>Development</u></p> <p style="text-align: center;"><i>Integration</i></p> <p><u>Activity 1 (40 minutes)</u></p> <p>I. Assigns students into mixed-gender and proficiency groups and guide them to explore and research through their Biology textbooks to and find the meanings of some of the keywords listed in the ‘keywords section’ such as artificial selection, inbreeding, outbreeding etc.</p> <p style="text-align: center;"><i>Organisation</i></p> <p><u>Activity 2 (15 minutes)</u></p> <p>I. Guide students to explore and illustrate connections between the previously learned concepts / knowledge and the newly learned ones.</p>	<p><u>Introductory Activity</u></p> <p>I. Reflect and brainstorm to bring out some of the concepts / terminologies learned in the previous lesson.</p> <p><u>Activity 1</u></p> <p>I. In their mixed-gender and proficiency groups explore and research using their Biology textbooks to discuss, think-ink pair and share with the larger class, the meaning of the keywords listed in the ‘keywords section’.</p> <p><u>Activity 2</u></p> <p>I. Explore using their textbooks and notes to create connections between the previously learned concepts / terminologies / knowledge with the newly learned content.</p>

<i>Elaboration</i>	
<p><u>Activity 3 (30 minutes)</u></p> <p>I. Plays a video on the application of genetics in various fields such as agriculture, medicine, biotechnology, forensics etc. by pre-informing them to note down their observations and findings.</p> <p>II. Tasks students in their mixed-gender and proficiency groups to present their respective findings from the video to the whole class.</p>	<p><u>Activity 3</u></p> <p>I. In their mixed-gender and proficiency groups watch the video, think-ink-pair and share their observations and note down their findings.</p> <p>II. In their mixed-gender and proficiency groups, present to the whole class their findings.</p>
Lesson closure	
<p><u>Activity (15 minutes)</u></p> <p><i>Teacher summarises the lesson by making additional emphases on the findings of the group presentations.</i></p>	
Evaluation	
<ol style="list-style-type: none"> 1. What is meant by artificial selection? 2. Distinguish between inbreeding and outbreeding. 3. Give two advantages and disadvantages each of inbreeding and outbreeding. 4. Give two applications of genetics each in: <ol style="list-style-type: none"> (i) medicine; (ii) agriculture; (iii) biotechnology. 	
Reflection & Remarks	

APPENDIX G3

Learning Plan							
Subject	<i>Biology</i>	Week	3	Duration	<i>120 min</i>	Form	<i>SHS 3</i>
Strand	<i>GENETICS AND VARIATION</i>	Sub-Strand	<i>MENDEL'S EXPERIMENTS</i>				
Content Standard	<ol style="list-style-type: none"> 1. Appreciate inheritance as a characteristic of variation and evolution. 2. Appreciate the use of techniques of genetics in the improvement of varieties of animals and plants to suit human needs. 3. Understand the basis for the similarities and differences in function among living things. 						
Learning Outcome(s)	<ol style="list-style-type: none"> 1. Explain that chromosomes form the basis of heredity. 2. Explain the concept of inheritance 						
Essential Question(s)	<ul style="list-style-type: none"> • How can the knowledge and understanding of genetics enable us to appreciate the fact that our genetic makeup influences our physical traits, behaviors, and susceptibility to certain conditions? • To what extent can the knowledge acquired from the learning of genetics be used to solve crimes and ensure justice in the legal system? • How can the knowledge variation aid in understanding how physical traits and behaviors among individuals impact social interactions and societal norms? • In what ways can understanding genetics and variation help in the prevention and treatment of diseases? • To what extent can the knowledge and understanding of genetics and variation be utilised to improve agriculture to improve crop and livestock production? 						
Pedagogical Strategies	<ul style="list-style-type: none"> • <i>Talk for learning approach, Inquiry-based method</i> • <i>Think pair share</i> • <i>Demonstration/ practical activity</i> • <i>Collaborative learning, discussion method</i> 						
Teaching & Learning Resources	<ul style="list-style-type: none"> • Coloured beads • Word cards • Projector • Video and • Internet 						

Keywords	<i>Monohybrid cross, dihybrid inheritance, independent assortment, segregation, crossing over, sex-linked characters, blood groups, blood transfusion, agglutination, rhesus factor, genetic engineering etc.</i>

Lesson Activities	
<i>Teacher Activity</i>	<i>Learner Activity</i>
<p><u>Introduction (10 minutes)</u></p> <p style="text-align: center;"><i>Recall</i></p> <p>I. Tasks students to reflect on the key concepts or terminologies learned in previous lessons and write down at least three of them in their note books or jotters.</p> <p><i>Expected answers:</i> <i>Genetics, genes, heredity, chromosomes, chiasma, locus, alleles, trait, genotype, phenotype, selection, artificial selection, inbreeding, outbreeding, hybrid vigour etc.</i></p> <p><u>Development</u></p> <p style="text-align: center;"><i>Integration</i></p> <p><u>Activity 1 (40 minutes)</u></p> <p>I. Builds on students' answers to brainstorm learners on some of the new concepts or terminologies to be learned in the content of the lesson such as monohybrid cross, dihybrid inheritance, independent assortment etc. using word cards.</p>	<p><u>Introductory Activity</u></p> <p>I. Individually reflect and write down at least three of the key concepts / terminologies learned from previous lessons in their note books / jotters for inspection.</p> <p><u>Activity 1</u></p> <p>I. Individually, and in turns, randomly pick or select a word card and loudly pronounce the printed word on it to the hearing of the whole class.</p>

<p style="text-align: center;">Organisation</p> <p><u>Activity 2 (15 minutes)</u></p> <p>I. Assigns students into mixed-gender and proficiency groups to collaboratively connect previously learned knowledge with the newly learned knowledge on genetic concepts through hands-on activities using coloured beads as physical representation of alleles to model genetic crosses by applying Punnett squares.</p> <p style="text-align: center;">Elaboration</p> <p><u>Activity 3 (30 minutes)</u></p> <p>I. Tasks students in their respective mixed-gender and proficiency groups to collaboratively relate what is learned in the lesson into real-life situations such as using haemophilia as a case study. (thus, using genetic cross to determine the possible offspring based on the Punnett squares model).</p>	<p><u>Activity 2</u></p> <p>I. In their mixed-gender and proficiency groups collaboratively connect previously learned knowledge with the newly learned knowledge on genetic concepts by undertaking hands-on activities using coloured beads as physical representation of alleles to model genetic crosses by applying Punnett squares.</p> <p><u>Activity 3</u></p> <p>I. In their respective mixed-gender and proficiency groups to collaboratively think-ink-pair-share and relate what is learned in the lesson into real-life situations such as using haemophilia as a case study.</p>
Lesson closure	
<p><u>Activity (15 minutes)</u></p> <p><i>Teacher summarises the lesson by giving brief explanations to some of the key concepts or terminologies of the lesson as well as the significance the Mendel's Experiments.</i></p>	
Evaluation	
<ol style="list-style-type: none"> 1. State the law of: <ol style="list-style-type: none"> (α) segregation; (β) independent assortment. 2. If a man with blood group AB marries a woman with blood group B. Use genetic diagram to show the blood group of the children of the couple. 	
Reflection & Remarks	

APPENDIX G4

Learning Plan							
Subject	<i>Biology</i>	Week	4	Duration	<i>120 min</i>	Form	<i>SHS 3</i>
Strand	<i>GENETICS AND VARIATION</i>	Sub-Strand	<i>VARIATION</i>				
Content Standard	<ol style="list-style-type: none"> 1. Appreciate inheritance as a characteristic of variation and evolution. 2. Appreciate the use of techniques of genetics in the improvement of varieties of animals and plants to suit human needs. 3. Understand the basis for the similarities and differences in function among living things. 						
Learning Outcome(s)	<ol style="list-style-type: none"> 1. Explain what variation is. 2. Distinguish between continuous and discontinuous variation. 3. Distinguish between heritable and non-heritable variations. 4. Describe the sources of variation. 5. Explain the causes of variation and classify them. 6. Explain the consequences of variation. 						
Essential Question(s)	<ul style="list-style-type: none"> • How can the knowledge and understanding of genetics enable us to appreciate the fact that our genetic makeup influences our physical traits, behaviors, and susceptibility to certain conditions? • To what extent can the knowledge acquired from the learning of genetics be used to solve crimes and ensure justice in the legal system? • How can the knowledge variation aid in understanding how physical traits and behaviors among individuals impact social interactions and societal norms? • In what ways can understanding genetics and variation help in the prevention and treatment of diseases? • To what extent can the knowledge and understanding of genetics and variation be utilised to improve agriculture to improve crop and livestock production? 						
Pedagogical Strategies	<ul style="list-style-type: none"> • <i>Talk for learning approach, Inquiry-based method</i> • <i>Think pair share</i> • <i>Demonstration/practical activity</i> • <i>Collaborative learning, discussion method</i> 						
Teaching & Learning Resources	<ul style="list-style-type: none"> • Coloured beads • Word cards • Projector 						

	<ul style="list-style-type: none"> • Video and • Internet
Keywords	<i>Variation, continuous variation, discontinuous variation, polygenic inheritance, heritable variation, non-heritable variation, mutation, co-dominance</i>

Lesson Activities	
<i>Teacher Activity</i>	<i>Learner Activity</i>
<p><u>Introduction (10 minutes)</u></p> <p style="text-align: center;"><i>Recall</i></p> <p>I. Introduces the lesson by tasking and guiding students to look around their classmates and write down in their note books or jotters the different physical traits in them such as hair colour, eye colour, height, skin colour etc.</p> <p>II. Tasks some of the students to read out their written traits to the whole class.</p> <p><u>Development</u></p> <p style="text-align: center;"><i>Integration</i></p> <p><u>Activity 1 (40 minutes)</u></p> <p>I. Base on students' read-out answers to brainstorm the new concepts or terminologies to be learned in the lesson such as variation, continuous variation, discontinuous variation, mutation etc. using word cards.</p> <p>II. Tasks students to randomly pick or select a word card and pronounce the word printed on it to the whole class. Further provide</p>	<p><u>Introductory Activity</u></p> <p>I. Individually look around each other and write down the different traits observed in their classmates in their note books or jotters.</p> <p>II. Respond by reading out the written traits in their notes or jotters to the whole class.</p> <p><u>Activity 1</u></p> <p>I. Pay attention and listen to the delivery.</p> <p>II. Individually, and in turns, randomly pick or select a word card and loudly pronounce the printed word on it to the hearing of the whole class</p>

<p>assistance to students to who find it difficult pronouncing their chosen word on word card.</p> <p style="text-align: center;"><i>Organisation</i></p> <p><u>Activity 2 (15 minutes)</u></p> <p>I. Assigns students into mixed-gender and proficiency groups to collaboratively use concept mapping to create connections between previously learned knowledge with the newly learned concepts / knowledge with the newly acquired knowledge.</p> <p style="text-align: center;"><i>Elaboration</i></p> <p><u>Activity 3 (30 minutes)</u></p> <p>I. Tasks students in their respective mixed-gender and proficiency groups to collaboratively relate the knowledge acquired in the lesson into real-life situations such as why certain organisms adapt more readily to changes in the environment while others do not survive.</p>	<p style="text-align: center;"><u>Activity 2</u></p> <p>I. In their mixed-gender and proficiency groups, collaboratively use concept mapping to create connections between previous acquired knowledge and the newly learned.</p> <p style="text-align: center;"><u>Activity 3</u></p> <p>I. In their mixed-gender and proficiency groups, collaboratively think-ink-pair-share, discuss and relate what the newly acquired knowledge into everyday life.</p>
Lesson closure	
<p><u>Activity (15 minutes)</u></p> <p><i>Teacher ends the lesson by summarising the main concepts using reflective activities where students partake by articulating their understanding of the concepts of the lesson through answering of questions.</i></p>	

Evaluation
<ol style="list-style-type: none">1. Define variation.2. Distinguish between continuous and discontinuous variation.3. Give two examples each of:<ol style="list-style-type: none">(α) continuous variation;(β) discontinuous variation.4. Give a brief account of the consequences of variation.
Reflection & Remarks