AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

EFFECT OF THINKING FRAMES APPROACH ON STUDENTS' ACADEMIC PERFORMANCE IN GENETICS IN SENIOR HIGH SCHOOLS

MAXWELL GYAMFI

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BY

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

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DECLARATION

Candidate's Declaration

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

Maxwell Gyamfi

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

Supervisors' Declaration

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

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DEDICATION

I dedicate this work to my father, Papa Alex Fosu Mensah, my mother, Patience Fosu Mensah, my siblings, and all of the Gyamfi's.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This study examined the effect of the Thinking Frames Approach (TFA) on Senior High School (SHS) students' academic performance in genetics in the Ashanti Region of Ghana. Using a quasi-experimental design, the study involved 200 SHS 3 Biology students, divided into an experimental group (n=104) taught using TFA and a control group (n=96) taught using conventional teaching methods. A sequential explanatory mixed-method approach was employed, with quantitative data collected through pretest and posttest assessments, and qualitative data obtained via semi-structured interviews to explore students' views on the TFA. Quantitative data were analysed using non-parametric statistical tests, including the Mann-Whitney U test and Wilcoxon Signed Rank Test, due to violations of normality assumptions. Results revealed that students exposed to the TFA significantly outperformed those in the control group in genetics. Additionally, gender-based comparisons indicated no significant difference in performance, suggesting TFA's effectiveness across genders. Qualitative data were analysed using reflexive thematic analysis, which identified key themes such as enhanced understanding, increased engagement, and improved ability to explain genetic concepts. The study concludes that the TFA is an effective pedagogical strategy for improving conceptual understanding in genetics and recommends its integration into biology teaching practices.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter contains the background to the study and problem statement. The study's purpose, and research questions are also included in this chapter. This chapter also highlights the importance of the study, along with its limitations and delimitations. The organizational framework of the research and the operational definitions of the terms utilized in the study round up this chapter**.**

1.1 Background to the Study

The role of genetics in human health and reproduction has made it a fundamental concept in Biology that everyone needs to understand (Ahmed & Opatola, 2018). According to Duncan, Freidenrich, Chinn and Bausch (2009), genetics is the cornerstone of modern Biology and understanding genetics is a critical aspect of scientific literacy. The application of the knowledge of genetics is gradually crossing over into more diverse fields of society, such as, human reproductive technology, agriculture, health care, and crime detection and resolution, therefore, fostering the teaching and learning of genetics in our world. Again, the outbreak of Covid -19 and the production of vaccines using the concept of messenger ribonucleic acid (RNA) has piqued people's curiosity over the study of genetics. It can therefore, be concluded that, the significance of genetics in the world cannot be underestimated.

Despite the significance of genetics in this modern world, students continue to have difficulties in understanding the genetics concept taught in the classroom (Machová &

Ehler, 2021; Ahmed, Opatola, Yahaya & Sulaiman, 2018; Fauzi 2018; Danso, 2016; Langheinrich, & Bogner, 2015; Ekong, Akpan, Anongo & Okrikata, 2015; Lewis & Wood-Robinson 2000). For example, Machová and Ehler, (2021) conducted a study on secondary school students' views and perceptions in genetics in Czech Republic,the study showed that, secondary school students have difficulties in genetic concepts and students also struggle to synthesize the knowledge obtained in classroom on genetics into a deeper understanding of functions in the living body. Chu (2008), opined in his study on students learning difficulties in Genetics in United Kingdom that, the essential foundational concepts, such as structure and function of cells and its organelles, cell divisions (mitosis and meiosis), reproduction, and basic mathematical requirements and the concept of probability, are generally vague and misconceptions are widespread. Langheinrich, and Bogner (2015), revealed in their study on students' conceptions about the deoxyribonucleic acid (DNA) structure that, students have low conceptions in DNA.

Ahmed, and Opatola (2018), conducted a study on secondary school students' alternate conceptions in Nigeria and found out that when it comes to genetics, science students have a great challenge especially, the conceptualization of DNA and RNA. Ekong *et al.,* (2015) also found in their study on influence of selected variables on students 'academic performance in genetics that, students have challenges in answering questions related to genetics which affect their general performance in biology. Kılıç, Taber and Winterbottom (2016) have revealed that the difficulties of students in genetics are responsible for their inability to apply the concepts in their daily lives and in making informed decisions.

Moreover, it is established in the literature (Dzidzinyo, 2020; Hadiprayitno, Muhlis, & Kusmiyati, 2019; Etobro & Fabinu, 2017) that the majority of SHS Biology students have conceptual difficulties in genetics. For instance, in Ghana, Dzidzinyo (2020) conducted a study and found that the majority of SHS Biology students have conceptual difficulties in DNA, chromosomes and genes. The ensuing consequence is that students will register low academic performance in the area of genetics.

Similarly, empirical studies in Ghana points out that, most students have problems in understanding genetics (WAEC, 2022, 2021, 2020, 2019 and 2018). The questions that need to be asked is why students continue to demonstrate weakness in answering questions related to genetics almost every year although there are teachers teaching them? Could these problems faced by students be due to teaching approaches of teachers? Whittle, Telford and Benson (2018), accentuated that, one area in education that has significant relationship with the conceptual understanding of scientific concepts is the type of teaching methods employed by teachers in the classroom. Empirical evidence affirms that, teaching methods employed by teacher in the classroom greatly influence how students learn science concepts such as genetics (Crimer, 2019) which invariably affect their performance. A review of literature reveals that; there are numerous teaching methods a teacher can utilize in teaching a science concept in the classroom. These teaching approaches generally are categorized as teacher centered and student centered.

Teacher-centered approaches refer to traditional systems that place a strong emphasis on the teacher as an educator. Also called expository teaching, deductive teaching, and direct instruction. They are distinguished by the lecture-style presentation (Hill, 2002). In other words, while students work to achieve the teacher's objectives, the teacher adopts a directive role, plans activities for them to complete to meet the goals, manages student interaction, and uses extrinsic motivators to encourage learning, such as grades and marks through assessments (Thomas, 2013). Students only contribute to the learning process when asked to ask or respond to questions (Mackatiani, 2018). With this teaching approach, the teacher decides what is to be taught and how the material is delivered to the students (Hill, 2002). In the classroom, the instructor assumes the well-known role of the lecturer, delivering content to the students with the understanding that they will absorb it without question. This indicates that the teacher is in charge of the teaching-learning process. This, according to Thomas (2013), leads to cramming of information and rote learning. Students in this environment are sometimes referred to as "empty vessels," listening to and taking in information, which does not improve their memory (Lee, 2017), hence affecting their academic performances negatively.

On the other hand, student-centered teaching methods puts the student at the center stage of the lesson (Ampiah, 2004) with the teacher only playing the role of a guide, coach or a facilitator. The teacher provides materials, give directions, ask questions and encourage students’ discovery in the classroom (Fernando & Marikar, 2017; Woolfolk, 2010; Eisenkraft, 2003). In other words, the teacher guides the learning process as he/she works with the students to organize data, look for patterns, make comparisons, and identify problems.

Student-centered approach put the student at the center of the educational process. With each student contributing to the learning process, the student-centered teaching style fosters more harmony between the teacher and student (Mackatiani *et al.,* 2018). Thus, students decide what they need to know and do to respond to a central question, but under the guidance of the teacher. Because of this, the instructor in this instance acts as a guide or facilitator for the students' learning, assisting them in taking ownership of their education. According to Thomas (2013), the teacher who is still the authority figure in the classroom becomes more of a coach or facilitator as students take on an increasingly active and collaborative role in their learning. By employing this approach, students become more creative, seeing themselves as responsible for knowledge construction, which consequently leads to permanent learning, helping them apply the concepts being taught, thus affecting their academic work positively.

Although student centered teaching methods have numerous benefits, it comes with its associated challenges (Oinam, 2017; Sumarni, 2015; Chika, 2012). One of such challenge is that student centered teaching methods are time consuming and becomes difficult in covering the stipulated contents in the syllabus (Sumarni, 2015). But the benefits far outweigh the shortfalls associated with the student-centered teaching methods. Therefore, many curricula have recommended the utilization of teaching methods that are student centered to increase student's achievements.

In biology education, gender equality is a major concern, especially given the increasing attention being paid to methods of increasing the proportion of women employed in science and technology fields as well as the workforce required to drive technological progress. In the past, certain professions and careers (such as engineering, medicine, and architecture) have been associated with men, while other professions and vocations such as nursing, catering etc. have been associated with women (Tambaya *et al.,* 2016).

There is evidence of mixed reports with regard to gender differences having an impact on academic performances on students. The effects of gender on the academic performance of biology students who attend extra-mural classes (EMCs) in public senior secondary schools, for instance, were the subject of a study conducted in Nigeria by Eseine (2021). Based on the study by Eseine (2021), he found a statistically significant gender gap in the academic performance of biology students attending extra-mural classes. Male students demonstrated a higher level of performance, achieving a mean score of 47.70, which was notably greater than the mean score of 40.15 achieved by female students.

According to Ekong et al. (2015), these genetic ideas such as gene as the unit of inheritance, DNA structure and function and central dogma of molecular Biology are critical to comprehending a wide range of fields, including molecular biology, cell biology, evolution, physiology, ecology, systematics, and even behavior. The use of genetic principles in engineering, biotechnology, transgenic organisms, gene therapy, crop and animal breeding, and medicine today has improved human welfare. This means that, even in this rapidly advancing technological world, the study of genetics in modern science cannot be taken for granted. Students' interest in pursuing post-secondary courses in genetic engineering, medical genetics, and molecular and cell biology will decrease due to their poor academic performance in genetics, and this will have an impact on our economy, agricultural, engineering, and health sectors. The Ghanaian Senior High School Biology syllabus recommends teachers to use constructivist teaching methodologies to teach Biology concepts for maximum conceptual understanding (CRDD, 2012) because the type of instructional approach a teacher uses in teaching greatly affects learners' academic achievement

(Westwood, 2017; Chifwa, 2015; Ekong *et al.,* 2015; Topçu & Sahin-Pekmez, 2009; Dogru-Atay &Tekkaya, 2008). Therefore, in tackling the issue of students 'low achievement in Biology, one can reason that effective constructivist teaching approaches that are being employed in other countries should be considered in teaching Biology concepts which will help in improving students' performance in the subject.

According to research on science education, student performance in science increases when they are taught using constructivist teaching methods that are student-centered (Adak, 2017; Kim, 2005; Magak, 2016). One of these student-centered approaches that has been found to improve students' performance is the Thinking Frames Approach (TFA).

The TFA is a multidimensional conceptual change approach that engages students' interest and cognition through presentation of discrepant ideas, scaffolds explanation development through production of multiple representations of explanations in verbal, pictorial, written modes, supports co-construction of understanding through small group interactions and careful questioning strategies used by the teacher. TFA also gives opportunity for self-reflection and evaluation of explanations (McLure *et al.,* 2020). Since Ghanaian SHS biology students are performing poorly in genetic concepts, this study therefore is to assess the effect of thinking frames approach on senior high school students' performance in genetics in selected senior high schools (SHS) in the Ashanti Region of Ghana.

1.3 Statement of the Problem

Genetics is a cornerstone of modern scientific advancement, with applications critical to fields like medicine, agriculture, and biotechnology. However, in Ghanaian Senior High Schools, genetics is especially one of the most challenging topics for students to master. Despite its importance, consistent data from the West African Examinations Council (WAEC) Chief Examiners' Reports, from 2018 through 2022, highlights a persistent and alarming trend of student underperformance. Year after year, students struggle with fundamental tasks such as constructing genetic diagrams, distinguishing between key terms, and explaining basic molecular concepts, indicating a systemic failure to achieve core curriculum objectives.

This long-lasting difficulty is not merely an examination issue but a profound gap in conceptual understanding (Dzidzinyo, 2020; Hadiprayitno, 2019). Students often perceive genetics as highly abstract, struggling to visualize processes like gene expression and chromosomal behavior (Dzidzinyo, 2020; Etobro & Fabinu, 2017; Hadiprayitno, 2019). This challenge is compounded by instructional limitations, including a prevalent use of teacher-centered, lecture-based methods that prioritize rote memorization over deep comprehension (Westwood, 2017). Furthermore, a frequent lack of practical resources and hands-on learning opportunities prevents students from moving beyond the abstract to engage with the material in a tangible way, leaving them unable to apply genetic principles effectively (Whittle, Telford and Benson, 2018; Westwood, 2017; Chifwa, 2015).

While the root of this problem is multifaceted, research consistently points to teaching methodology as a primary contributing factor (Amoako & Ameyaw, 2022). Although, the Ghanaian Biology syllabus advocates for student-centered, constructivist approaches, classroom practice often defaults to traditional techniques that fail to address the unique challenges of the subject matter. This misalignment between pedagogical recommendation and actual classroom practice means students are passive recipients of information rather than active constructors of their own knowledge, leading to widespread misconceptions and a lack of critical thinking skills necessary to solve genetics problems (Umida, 2020). Therefore, there is an urgent need for pedagogical reform. To improve student outcomes and foster a genuine understanding of genetics, there must be a shift towards evidence-based instructional strategies that are specifically designed to make abstract concepts concrete. This study sought to investigate the effectiveness of one such approach, the Thinking Frames Approach, as a potential means to providing the structured, conceptual scaffolding students need to overcome their learning difficulties and achieve academic success in genetics.

1.4 Purpose of the Study

The purpose of this study was to assess the effect of thinking frames approach on senior high school students' performance in genetics in Mampong municipal.

1.5 Specific Objectives of the Study

The specific objectives of the study were to:

1. evaluate the effect of the TFA on students' academic performance in genetics.
2. analyse the differences in academic performance between male and female students instructed using the Thinking Frames Approach in genetics.

3. analyse the difference in academic performance of students taught genetics using TFA and those taught using conventional approach in genetics.
4. explore SHS Biology students' views on the use of TFA in teaching and learning of genetics.

1.6 Research Questions of the Study

The following research questions guided the study.

1. What is the effect of thinking frames approach on students’ performance in genetics?
2. What difference exists between the academic performance of male and female biology students instructed with the thinking frames approach in genetics?
3. What is the difference in academic performance of students taught genetics using TFA and those taught using conventional approach in genetics?
4. What are the views of SHS biology students on the use of TFA in teaching and learning of genetics?

1.7 Significance of the Study

First and foremost, the results of this study, such as the impact of the TFA on students' genetics performance, may assist biology instructors in Mampong municipal in choosing instructional strategies that will improve their students' genetics comprehension.

In addition, it would also result in more students enrolling in science programs at Mampong SHS 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.

1.8 Justification of the Study

The teaching and learning of genetics in Ghanaian Senior High Schools (SHS) are confronted with a persistent and critical challenge, as consistently documented by the West African Examinations Council (WAEC) Chief Examiners’ Reports from 2018 to 2022.

The root of this problem is multifaceted, but empirical evidence consistently identifies the predominant reliance on teacher-centered, lecture-based instructional methods as a primary cause (Amoako & Ameyaw, 2022). While the Ghanaian Biology syllabus advocates for student-centered, constructivist pedagogies, a significant gap exists between this recommendation and actual classroom practice. There is, therefore, a compelling and urgent need for pedagogical reform through the introduction of evidence-based, innovative teaching strategies specifically designed to address the abstract nature of genetics. The Thinking Frames Approach (TFA) presents a prevailing, multidimensional solution to this problem. Grounded in constructivist and metacognitive learning theories, TFA provides a structured scaffold that guides students to visualize, articulate, and reason through complex scientific explanations.

Although the efficacy of TFA has been demonstrated in international studies to improve science learning, its impact remains largely unexplored within the Ghanaian context and specifically in the domain of genetics. This study is not just the adoption of an international method; it serves as a direct response to a recognized national educational challenge. Rather than merely comparing teaching approaches, it focuses on examining a purposeful intervention designed to address a specific problem.

Furthermore, by examining the approach's effectiveness across genders and capturing students' perspectives, this research provides a comprehensive evaluation of TFA's potential as an equitable and practical pedagogical tool for Ghanaian classrooms. Therefore, this study is rigorously justified by the imperative to address a persistent national challenge in science education. It seeks to provide empirical, context-specific evidence on the effectiveness of a promising pedagogical innovation, the Thinking Frames Approach, to improve conceptual understanding and academic performance in genetics, ultimately contributing to the broader goals of educational quality and scientific advancement in Ghana.

1.9 Delimitations of the Study

This research focused on genetic concepts which include nucleic acids, DNA replication, transcription, and protein synthesis. These concepts were considered because they were the major concepts identified by researchers, as well as the chief examiners for WAEC, where SHS Biology students encounter difficulty.

Secondly, because a quasi-experimental design was employed in this study, not all schools in Mampong Municipality participated in this study. Therefore, only two Senior High Schools from Mampong Municipality was selected to participate in this study. Moreover, the study focused on SHS 3 Biology students because as outlined in the Ghanaian Biology syllabus, Genetics is taught in year 3 at the SHS level.

1.10 Limitations of the Study

First of all, while non-parametric tests like the Mann-Whitney U and Wilcoxon Signed Rank Test are appropriate given the violation of normality assumptions, they tend to be less powerful than parametric tests. This means they may be less sensitive to detecting true differences or effects, potentially not generalizing results of the study. Moreover, the study was conducted with only two senior high schools in the Mampong Municipality, which may limit the generalizability of the findings to other regions or populations with different educational contexts.

1.11 Definition of Key Terms

Performance: refers to how well someone or something accomplishes a task or fulfills a role. In the context of education, student performance typically refers to how well a student meets learning objectives or achieves academic success, often measured through assessments such as tests, assignments, or projects.

Teaching methods: The word "teaching method" refers to the fundamental principles, pedagogy, and classroom management strategies that are used in the classroom.

Genetics: Genetics refers to the structures and functions of nucleic acids, deoxyribonucleic acid replication, transcription, and protein synthesis.

Thinking frames approach: The TFA is a multidimensional conceptual change approach that engages students 'interest and cognition through presentation of conflicting events, scaffolds explanation development through production of multiple representations of explanations in verbal, pictorial, and written modes, supports co-

construction of understanding through small group interactions and careful questioning strategies used by the teacher, and gives opportunity for self-reflection and evaluation of explanations.

1.12 Organization of the Study

The study was categorized into five chapters. The first chapter focused on the background to the study, statement of the problem, purpose of the study, research objectives, research questions, significance of the study, delimitations, limitations, definition of key terms and organization of the study. The second chapter reviewed relevant literature under headings clearly marked. Chapter three indicated the methodology used in the study. It highlighted the research design, population, sample and sampling procedures, research instrument, data collection procedures as well as data analysis procedures. The fourth chapter was devoted to the results and discussions. Finally, the fifth chapter provided summary of the key findings of the study, conclusions and recommendations based on the findings as well as areas for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

A review of the literature that is relevant to this topic is presented in this chapter. The theoretical review is presented in this chapter. This chapter also highlighted the empirical review of the study, which analyzed earlier research that was relevant to the current investigation. A summary of the reviewed literature closes the chapter.

2.1 Theoretical Review of the Study

Constructivism theory forms the basis of this investigation. Constructivist theory, commonly known as constructivism, is a theory of learning that maintains that learners combine newly acquired information with previously learned knowledge to produce new meanings and understandings (Gupta, 2013). Even physical laws, according to a constructivist, exist because they have been created by individuals based on data, observation, and logical or intuitive reasoning. More essential, however, is the fact that specific communities of individuals (in this example, scientists) have mutually agreed upon what constitutes valid knowledge. Therefore, the constructivist perspective asserts that knowledge is created by people or groups making meaning of their experiential realities rather than passively being acquired from the outside world or from reliable sources (Gupta, 2013).

Students actively participate in the learning process and the teacher functions more as a facilitator in a constructivist classroom. According to this concept, a teacher who serves as a "facilitator" who mentors, directs, and coaches students to interpret the course material independently (Umida *et al.,* 2020). In order to work together to create new information, students are encouraged to interact and share their thoughts.(Herlina & Ilmadi, 2022), as it occurs in the “Setting the scene” stage of the TFA teaching strategies. This means that the students are increasingly becoming or assuming the center of instruction instead of the teacher. Today’s learners, according to Umida et al. (2020), are not passive sponges waiting to be filled with knowledge by their knowledgeable teacher in the classroom. Constructivism, according to Gupta (2013) is not a unitary theoretical position; rather, it is a continuum. However, the two most well-known constructivist approaches are cognitive constructivism (propounded by Jean Piaget) and sociocultural constructivism, which was propounded by Lev Vygotsky (Efgivia *et al.,* 2021; Begg, 2015).

In opposition to conventional behaviorist ideas, Piaget created his cognitive constructivist theory. The basic tenet of his theory is that children’s intellect varies as they mature and that environmental factors and biological maturation are responsible for cognitive growth (Schunk, 2012). Piaget believed that the human mind developed through interaction with its surroundings, but in sequentially essential physiological stages that resulted in knowledge and abilities that were adaptively structured. These cognitive phases evolve in a complex, natural way that is important for adaptive functionality, along with other changing behavioral and emotional traits (Hruby & Roegiers, 2013). These developmental stages, according to Piaget (1976), are attained by the acquisition of specific schemas, also defined by Hruby & Roegiers (2013) as "regimens, skill sets, or procedures," which initially address the needs of present development but can thereafter be analogously applied to new experiences, circumstances, or scenarios. Significant structural alterations to the knowledge base of the type that denote a behavioral stage-shift are necessary when previously adaptable schemas prove to be inadequate for a child's needs. The cognitive dissonance brought on by this inadequacy facilitates the next stage in the developmental process by motivating the kid to explore in order to have a more satisfying engagement with the world. However, for an individual to develop cognitively, Piaget assumed that one must “adapt” to an evolving body of knowledge (Piaget, 1976). The process of adapting or resolving the conflict which the individual experiences in the face to this new knowledge is called “equilibration”. The biological desire to create the best possible condition of equilibrium (or adaptation) between cognitive structures and the environment is known as equilibration (Schunk, 2012).

Therefore, youngsters use the adaption processes of "assimilation" to increase their knowledge of the environment and help them make sense of it. “Assimilation” means fitting new information to match current knowledge; and “accommodation”, which means changing preconceived notions in response to new information. Put another way, the integration of less complex knowledge concepts with more complex ones is the means by which cognitive mental progress is attained at every developmental stage. In light of this, Piaget believed that growth would occur organically as a result of repeated interactions with the natural and social contexts. There are internal variables that trigger developmental change. Environment and other extrinsic factors can influence growth, but they cannot direct it. As a result, Schunk (2012) emphasized the significance of providing children with rich environments that support active learning and hands-on activities. Knowledge construction that is active is made easier by this design. Furthermore, the content should be neither too easy nor too hard to accommodate. Even though Piaget's theory maintains that social interaction is necessary for development to progress. (Schunk, 2012), Nonetheless, Vygotsky (1994) asserts that the social environment is a crucial source for cognitive growth. Thus, Vygotsky highlighted that the key to human development in the learning process is the combination of interpersonal (social), cultural–historical, and individual elements. He denied Piaget's assertion that learning can be separated from context and claimed that culture had a major influence on the development of cognitive ability. In other words, learners' interactions with the people, things, and institutions in their environments change the way they think. The social environment's "tools," or cultural artifacts (such vehicles and machinery), language, and social structures, have an impact on cognition (e.g., schools, churches). Therefore, applying cultural skills in social interactions and internalizing and cognitively changing these encounters lead to cognitive transformation. Concepts get new meanings as they become connected to the outside world. For instance, according to Schunk (2012), "School" is an institution that aims to advance citizenship and learning, not just a term or a physical building. Accordingly, first stage of the TFA strategies assumes that the subject matter should be linked with the context of the learner for the learner to make a concrete meaning of the content.

Also, the social constructivism theory gives relationships and small groupings a lot of attention. According to Vygotsky, learning is limited to what a person already knows without interactions with others. While teachers encourage and assist talk by utilizing the organic flow of discourse in the classroom, students learn largely via interactions with their peers, teachers, and parents. According to Vygotsky, social interactions produce language, writing, and concepts that stimulate higher order cognitive processes.

The zone of proximal development, or ZPD, is a central idea in Vygotsky's theory of social constructivism. It highlights the importance of the teacher in a student's education. The ZPD outlines the tasks that a pupil can complete on their own and those that they require assistance from a teacher or more experienced classmates to complete. According to the ZPD, pupils can comprehend and acquire knowledge and abilities that they would not be able to do on their own with the assistance of an instructor. Students are capable of finishing a task on their own once they have mastered it (Schunk, 2012). As a result, rather than acting as a passive figure, the instructor actively contributes to the learners' knowledge gain. Cognitive development in the ZPD is brought about by the instructor and learner sharing cultural tools, and when this culturally mediated interaction is internalized by the learner, it also brings about cognitive change. Although there is a lot of focused engagement required for ZPD work, Schunk (2012) asserts that children do not automatically or accurately reflect events when they learn about culture through these encounters. As an alternative, students approach social interactions with their own conceptual frameworks and give them significance by combining them with their personal experiences. In contrast to representing a gradual accumulation of information, learning typically happens all at once in the sense of gestalt comprehension.

There are various approaches to assist learners in developing cognitive mediators through their social environment. The idea of instructional scaffolding, as defined by Schunk (2012), is frequently used in applications. It is the practice of limiting task aspects that are difficult for learners to complete so they may concentrate on and become proficient in the task's easier components. In an instructional setting, the majority of the work may first be completed by the teacher, and then the learners and the teacher will share responsibilities. The teacher progressively removes the scaffolding as students gain proficiency so they can work on their own. Making sure the scaffolding keeps students in the Zone of Proximal Development (ZPD), which rises as students gain skills, is crucial. It is a struggle for the students to learn inside the ZPD. Peer collaboration is a significant application area that embodies the concept of collaborative activity. The shared social interactions that occur when peers collaborate on projects might have an educational purpose. As a result, the TFA teaching strategies houses in themselves the "Setting the stage" to help learners interact among themselves and the teacher during the instructional process.

2.1.1 Constructivism as a Foundation of the Thinking Frames Approach (TFA)

Constructivism is a well-established learning theory that posits learners construct their own understanding and knowledge of the world through experiences and reflection. It emphasizes active engagement, personal interpretation, and the integration of prior knowledge in the learning process (Piaget, 1952; Bruner, 1960). The Thinking Frames Approach (TFA) aligns strongly with these principles by providing students with a structured means to process new information, link it to existing cognitive structures, and build meaningful understanding through visual and verbal scaffolds.

Jean Piaget's cognitive constructivism focuses on how learners move through stages of development by interacting with their environment, accommodating and assimilating new information to form complex cognitive schemas (Piaget, 1970). In the context of genetics education, students often encounter abstract concepts like gene expression, codominance, or Punnett squares, which can be difficult to grasp through traditional instruction. TFA supports learners in this constructive process by guiding them to organize their thoughts visually and sequentially. This helps them to internalize difficult concepts and build accurate mental models of genetic mechanisms.

In addition to Piaget, Jerome Bruner contributed significantly to constructivist thought with his notion of discovery learning. Bruner emphasized that learners should be encouraged to discover principles by themselves through guided inquiry and scaffolded learning experiences (Bruner, 1960). TFA incorporates this idea by allowing students to explore genetic scenarios within structured thinking frames. These frames do not give away answers but prompt learners to construct explanations, draw conclusions, and make predictions based on evidence core practices in discovery learning.

Lev Vygotsky's social constructivism further enriches the foundation of TFA. Vygotsky highlighted the importance of social interaction, cultural context, and language in learning. His concept of the Zone of Proximal Development (ZPD) suggests that learners can achieve higher understanding with appropriate scaffolding from teachers or peers (Vygotsky, 1978). Thinking frames act as a form of cognitive scaffolding within this zone, guiding students' thought processes while gradually encouraging autonomy (Newberry, 2011). The verbal elements of TFA such as sentence starters and explanation prompt mirror Vygotsky's emphasis on language as a tool for cognitive development, especially in abstract disciplines like genetics. Constructivism also underscores the importance of prior knowledge in learning. Students do not come to class as blank slates; they bring preconceptions that can either aid or hinder new learning. In genetics, students may hold misconceptions such as “dominant traits are stronger” or “only one gene controls a trait.” Thinking frames allow learners to make their reasoning visible, making it easier for educators to identify and address these misconceptions (Driver et. al., 1994). The structured thinking process helps learners revise incorrect notions as they build more scientifically accurate understandings.

The constructivist approach inherent in TFA fosters higher-order thinking and inquiry. Rather than relying on rote memorization, students engage in reasoning, problem-solving, and justifying their answers. This aligns with Bloom (2013) revised taxonomy, where students move from understanding to applying, analyzing, and evaluating information. In genetics, this might involve analyzing genetic crosses, interpreting phenotypic ratios, or constructing coherent explanations for genetic disorders. By encouraging learners to explain their reasoning, TFA operationalizes the constructivist goal of deep, conceptual learning.

Furthermore, constructivism supports differentiated learning and inclusivity. Students have diverse cognitive styles and learning paces, and constructivist-based approaches like TFA accommodate these differences by allowing for individualized exploration and expression of ideas. Visual thinkers, for example, benefit greatly from the graphical structure of thinking frames, while verbal learners gain from the written components (Piaget, 1970). This makes TFA a flexible tool for promoting equity in science classrooms, particularly in diverse settings where learners may have varied backgrounds in science education.

Finally, constructivist learning environments encourage continuous assessment and feedback, not just summative testing. TFA naturally embeds formative assessment by making student thinking visible and assessable. Teachers can provide targeted feedback, adjust instruction, and support conceptual growth in real-time, rather than waiting until a test exposes misunderstanding. This aligns with Black and Wiliam's (1998) principles of formative assessment, which emphasize its role in improving learning outcomes through timely, constructive interventions.

2.2 Conceptual Framework of the Study

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 and Chhapra (2013). This aids learners in deepening their conceptual comprehension through experiences, ultimately improving their academic achievement. This theory served as the foundation for conceptualizing how the research variables interacted, as shown in Figure 2.1.

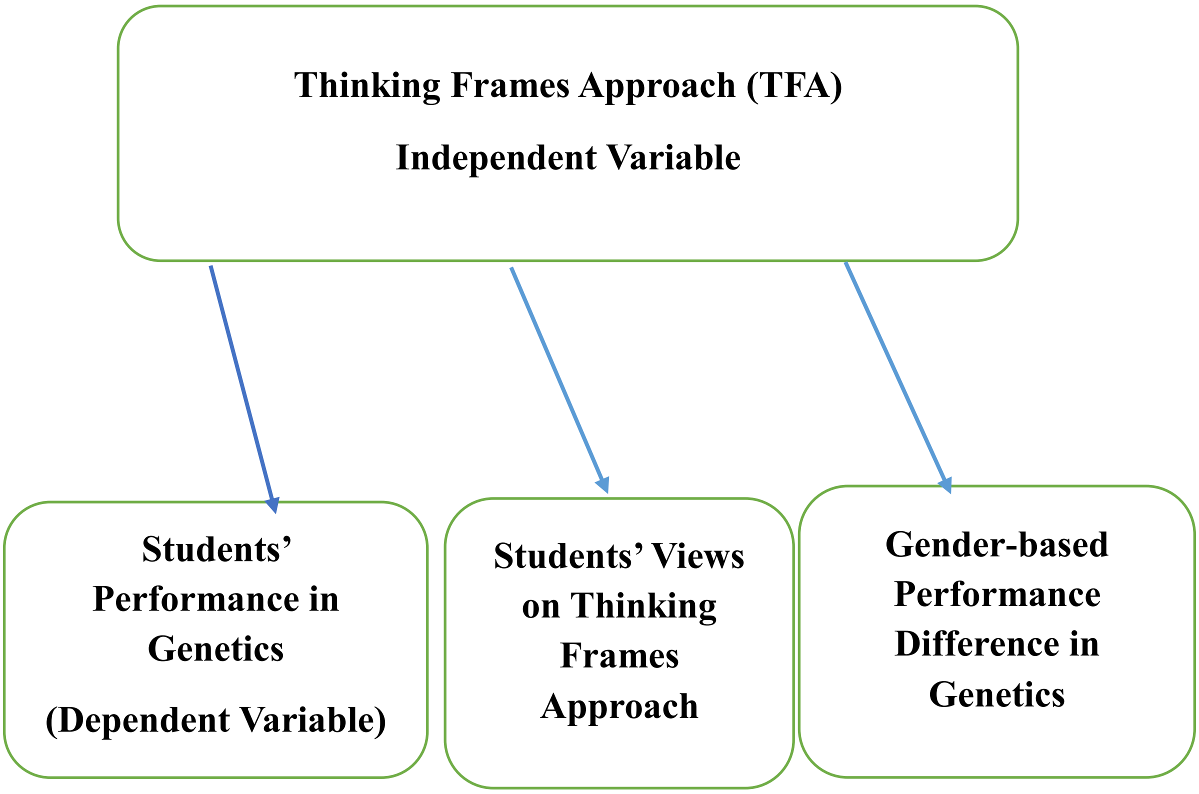


Figure 2.1: Conceptual framework of the study

The conceptual framework for this study is built around the central premise that the Thinking Frames Approach (TFA) serves as the core instructional strategy designed to improve students' understanding of genetics. TFA, as an innovative teaching method, uses visual organizers, structured sentence starters, and reflective thinking prompts to guide learners through the scientific explanation process. The approach is grounded in constructivist and metacognitive learning theories, which emphasize the active construction of knowledge and awareness of one's own thinking processes (Mclure, 2020). In the context of genetics which involves abstract concepts, multi-level reasoning, and symbolic representation TFA provides a structured scaffold for students to grasp difficult ideas more effectively.

From this central intervention, the framework shows three primary outcome variables (dependent variables) that the study seeks to investigate. The first is students' academic performance in genetics, which reflects their conceptual understanding and achievement after being taught using TFA. This performance was quantitatively measured through pretests and posttests. The assumption is that the structured and guided nature of TFA enhances comprehension, retention, and application of genetics content.

The second outcome is students' views of the TFA. This dimension recognizes that how students feel about and engage with the instructional method can influence its effectiveness. Their views may include whether they found the approach helpful, easy to follow, engaging, or supportive of their learning. These perceptions were gathered through qualitative methods using interviews. The third outcome focused on gender-based differences in performance, aiming to explore whether male and female students benefit equally from the Thinking Frames Approach. This component is important for addressing issues of equity and inclusion in science education. Numerous studies have shown that gender may influence learning preferences, confidence levels, and achievement in science subjects. By comparing the genetics test scores of males and females taught with TFA, the study investigates whether the approach helps close existing performance gaps or if differential impacts exist.

2.3 The Concept of Teaching Strategies

According to Dorgu (2015), phrase "teaching strategies" describes a range of methods that educators use to introduce their material to students in a way that aligns with a set of learning objectives and fosters understanding. But a teacher will have an affiliation for a teaching method based on their philosophy of imparting knowledge. It is by this philosophy that will make a particular teaching strategy effective to the teacher. The use of effective teaching strategies helps pupils learn and receive information and acquire new skills. In the classrooms, there are a variety of teaching techniques that can be applied; it is up to the instructor to choose those that are most suited for the lesson.

When effectively applied, these techniques will improve instruction and learning while also affecting pupils in the way that is intended. Different teaching methods can be used in combination with each other or in different combinations throughout a lesson or course. Selecting the best teaching method for the unique learning objectives and student demands is crucial. The method a teacher uses to teach a subject can either make it engaging or tedious (Hargrove, 2023).

2.3.1 Learner-Centered Teaching

Montessori education in 1917, Dewey's progressive education in 1938, and Carroll and Bloom's mastery learning in 1963 and 1968 are some of the early educational movements that paved the way for learner-centered education (An & Mindrila, 2020). Instruction that centers on the student and their actions is known as learner-centered instruction. In other words, it sees learners as active agents. The knowledge, experiences, culture, and beliefs that each student brings to the classroom have an impact on how they learn and assimilate new material (Olugbenga, 2021). The instructor's job is to create conducive learning environments, push students to collaborate and learn from one another, and create engaging real-world assignments that stimulate engagement (Ochieng, 2020). Students build knowledge in a learner-centered classroom by acquiring and synthesizing information, which includes explicit skill instruction. As a result, students develop the critical thinking, problem-solving, decision-making, teamwork, evidence-evaluation, argument analysis, and hypothesis-development skills that are essential for mastering the curriculum of the discipline (Olugbenga, 2021). An and Mindrila (2020) noted five characteristics of learner-centered teaching that can be commonly seen in classrooms. Personalized learning activities and support, social and emotional support, self-regulation, collaborative learning, and real-world learning experiences are a few of these qualities. According to McCombs (2015), there is also a benefit to fostering a pleasant learning environment and relationships, adjusting to the demands of the class, supporting the learning process, promoting personal accountability and challenge, and meeting social and individual learning needs.

2.3.2 Teacher-Centered Teaching

Conventional teaching, another name for teacher-centered instruction, describes established methods that have been used in classrooms throughout history (Shuchi, 2017). According to Dimitrios et al. (2013), the syllabus, the teaching materials, and the student assessments are decided by the teacher and communicated to students in numerous lectures, complimented by standard text books and notebooks, which are the main media for learning content (Li, 2016; Dutta, 2010) . Thus, this teaching method uses didactic lectures and discussions while the problem-solving component is delivered by and discussed with the instructor.

The characteristics of conventional curriculum are subject-matter expert providing learning objectives and assignments, lectures, structured laboratory experiments. In conventional schools, individual department decides about the content coverage of that subject (Dutta, 2010). This means that, in a conventional classroom, instruction is more regimented and monotonous, which does not involve students much, as a result it is more teacher-centered. That is, when the instructor is speaking and writing on the board, some of the pupils will be fidgeting and taking naps, and others will be transcribing what they see into their notebooks.

For a large class of students, the traditional method of teaching is typically used. However, the teacher might not be able to comprehend each student's perspective on their understanding of the material (Bloomfield *et al.,* 2010). As a result, the diverse learning needs of students are not accommodated. According to Dutta (2010), this teaching method is important for learners who lack self-awareness since it offers a more structured method of instruction. Begum (2018) further argues that it may be used to introduce students to new ideas, and that the instructor can guide the class in an efficient manner by summarizing the main ideas of a chapter or lesson and emphasizing some of the most important and remarkable components. Furthermore, a lot of material can be covered in a short amount of time (Sobirova & Karimova, 2021). As a result, teachers cling to this method of teaching.

But Shuchi (2017) argues that, as knowledge is presented in traditional teaching, it is uncertain if the right information is getting to every student or not. This results from the teacher controlling the majority of the teaching and learning activities without the students' active involvement. As a result, it will be difficult to ascertain whether students grasp the main concepts or not. This can only be known when students have undertaken a “paper-and-pencil test”, since Dutta (2010) explains that the conventional teaching method’s most important component is holding frequent exams. This implies that the students absorb the information passively before reviewing it in preparation for the test.

2.4 Nature of Science Learning and Cognitive Development in Genetics

Science learning, particularly in biology education, demands more than the memorization of facts, it requires the development of conceptual understanding, reasoning, and problem-solving skills (Kampourakis, 2017). In the domain of genetics, students are often challenged by the abstract nature of core concepts such as gene interactions, dominance, and molecular inheritance. These concepts require learners to operate across different levels of biological organization molecular, cellular, organismal, and population levels thereby demanding a high degree of cognitive flexibility (Stern & Kampourakis, 2017).

Genetics learning poses a significant cognitive load because many of its processes such as gene expression or meiosis are not directly observable. Instead, students must rely on models, analogies, and symbolic representations to make sense of invisible mechanisms (Treagust & Tsui, 2013). This makes the development of mental models and reasoning strategies essential for conceptual change and scientific understanding. However, research has shown that many students hold persistent misconceptions, such as believing that dominant traits are “stronger” or that each trait is controlled by a single gene, which can hinder deep learning (Chapman & Martin, 2021; Gericke & Wahlberg, 2013).

From a cognitive development perspective, genetics education intersects with students' readiness for abstract reasoning. According to more recent applications of Piagetian and neo-Piagetian theory, many senior high school students are transitioning from concrete to formal operational thinking, but may still struggle with hypothetico-deductive reasoning (Shin, Sutherland, & Shin, 2021). This becomes a barrier in genetics, where students are expected to hypothesize genetic crosses, interpret phenotypic ratios, and predict genotypic outcomes using abstract symbolic tools like Punnett squares.

Moreover, contemporary research highlights the importance of scientific practices and epistemic cognition how students understand the nature and purpose of scientific knowledge in mastering genetics. Students need opportunities to engage in evidence-based argumentation, explanation, and model construction, which are central to science learning (Berland *et al.,* 2016; National Research Council [NRC], 2012). Genetics instruction that incorporates these practices helps students understand not only "what" happens during inheritance, but "how" and "why," thus promoting deeper conceptual understanding. Recent neuroscience and educational psychology studies also emphasize the role of executive functions working memory, inhibitory control, and cognitive flexibility in learning complex science topics like genetics (Diamond, 2013). These functions enable students to manipulate information, suppress misconceptions, and shift between genetic mechanisms and observed phenotypes. Effective instructional methods, such as the Thinking Frames Approach (TFA), can scaffold these processes by externalizing students' reasoning and reducing cognitive overload (Mclure, 2020).

Furthermore, the sociocultural context of science learning also plays a role in genetics understanding. Students construct knowledge through interaction with teachers, peers, and instructional tools. Language is especially important in genetics, where terms like “recessive,” “carrier,” or “mutation” carry specific meanings that differ from everyday usage (Tibell & Rundgren, 2010). Providing students with structured thinking tools that incorporate visual and verbal supports can help clarify these meanings and promote accurate conceptual development.

In effect, the nature of science learning in genetics requires targeted instructional strategies that account for students’ cognitive development, epistemological beliefs, and conceptual difficulties (Dzidzinyo, 2020). Interventions like the Thinking Frames Approach, which combines visual thinking with reflective scaffolding, are grounded in current understanding of how students learn science. Such approaches can significantly support the development of coherent, transferable understanding in genetics by aligning with students' cognitive needs and the complex nature of biological knowledge.

2.5 The Thinking Frames Approach

The TFA was established in the UK to support gifted students in Key Stages 2 and 3 (primary and middle school) by the Cams Hill Science Consortium (CHSC), which is made up of researchers and educators (Newberry & Gilbert, 2007). While doing action research in their classrooms, this group concentrated on modeling and the usage of models. The only published works that describe the effects of the TFA on student learning are student written explanation examples (Newberry et al., 2011) and a paper on the use of the Levels Mountain as a rubric for students to self-evaluate their writing (Newberry et al., 2005). However, educators have carried out action research in their classrooms to determine the impact of the TFA (Mclure, 2016; Newberry et al., 2011; Newberry & Gilbert, 2007). I came to the realization that the TFA might be used as a framework for teaching any science subject in a way that systematically addressed all aspects of multidimensional conceptual change theory. According to the AstraZeneca scientific Teaching Trust website, they adapted the TFA's principles to teach scientific courses in middle and high school mixed ability classes from a multidimensional conceptual shift approach (Newberry et al., 2011).

The TFA is a methodical strategy that challenges students' epistemic assumptions and makes their alternative ideas visible by utilizing cognitive conflict strategies. Through interaction between students and teachers, it integrates this tactic with the social formation of conceptual knowledge in diverse small groups. In their small groups, students make predictions about the results of meticulously planned demonstrations, which they subsequently explain to the class. They go back to their little group to rework their explanations after seeing how the demonstration turned out.

Students are encouraged to apply the scientific ontological paradigm to the observed phenomenon by their teachers' probing questions. After that, the students collaborate to provide various written, visual, and spoken explanations of what they have learned. In addition to the teacher giving quick, helpful comments, students assess their written explanations using a rubric known as the Levels Mountain (Newberry *et al.,* 2005). Understanding of the ontological paradigm that underlies epistemological ideas is developed through a sequence of TFA courses. In order to address problems regarding students' scientific writing, the TFA may also serve as a "writing-to-learn by learning-to-write" technique (Carter, Ferzli, & Wiebe, 2007). By assigning students meaningful writing assignments that encourage them to use the language of science as they formulate explanations, support their arguments with evidence, and edit their claims, this method enhances students' conceptual comprehension while fostering their scientific writing abilities (Sampson, et. al., 2013). Students are assisted in scaffolding, developing, and refining their final written explanations by the various representations they generate during a TFA class, keywords, verbal and visual explanations, and dot-points.

The TFA is a multifaceted approach to conceptual change that supports co-construction of understanding through small group interactions and the teacher's careful questioning techniques, engages students' interest and cognition by presenting disparate events, scaffolds explanation development by producing multiple representations of explanations in verbal, pictorial, and written modes, and provides opportunities for self-reflection and explanation evaluation (McLure *et al.,* 2020c). The following components make up TFA lessons:

1. *Setting the scene (PDEODE and group/whole-class discussion):* Students are divided into small groups and given a scenario that aims to refute other ideas about the subject. They discuss their predictions and the reasons behind them in small groups before presenting their ideas to the class. Following the teacher's demonstration (or description of a scenario's outcome), the students provide an explanation that aligns with their observations. The class is then given these updated explanations.

2. *Brainstorming*: Thought provoking questions by the teacher supports students in elaborating explanations, linking explanations to observations and the ontological model.
3. *Written and visual explanations:* Students choose the keywords they want to use while writing explanations. Individual diagrammatic explanations are constructed by the small groups. A detailed written description of the phenomenon is then created when understanding has been converted into a logical series of brief dot points (Treagust *et al.,* 2018). It has been demonstrated that producing student-generated multiple representations encourages students to participate more thoroughly in the construction of explanations and supports their adoption of higher levels of explanation, such as the more frequent use of causal statements and non-visible entities (McLure *et al.,* 2021; Chang *et al.,* 2016). The teacher walks between groups and uses questioning to stimulate further elaboration of ideas while students produce numerous representations of their understanding.
4. *Thinking Sequence and Paragraphing:* Students create dot points for "what happens" and "why" based on the visual depiction of concepts and important words. Students next write a paragraph explaining the phenomenon and responding to the initial questions using the keywords that were thus generated.
5. *Feedback from the teacher*: The instructor assesses the students’ explanations, offers detailed, helpful criticism on how the student can enhance their explanation in studying.

6. *Progressive development of conceptual knowledge over time:* Each topic is covered by a set of TFA lessons that help students enhance their knowledge of various facets of the theoretical scientific model.

2.6 Thinking Frames Approach in Science Classrooms: A Review of Empirical Studies

The Thinking Frames Approach (TFA) is a structured, visual, and metacognitive teaching strategy developed to help learners make their thinking visible and coherent, particularly in science education where abstract concepts and complex reasoning are required. TFA provides visual scaffolds such as cause-effect diagrams, compare-contrast charts, and sequencing templates coupled with sentence stems and reflective prompts to support students in constructing, organizing, and communicating scientific explanations (Mclure, 2020). The approach is grounded in constructivist and metacognitive theories, emphasizing the importance of students actively processing and monitoring their understanding during learning (Zohar, 2018; Tanner & Jones, 2007).

TFA was first widely applied in the United Kingdom through the *Learning to Learn* project led by McClure, Newbery, and Bird (2007), where schools implemented thinking frames across subjects, including science, to promote structured reasoning and independent thought. Their findings demonstrated that students using TFA developed more coherent explanations, improved their scientific vocabulary, and were better able to justify their ideas. Teachers involved in the project noted that TFA supported inclusive teaching by offering a consistent structure for students of all ability levels to express their understanding. Additionally, the project highlighted that when teachers explicitly modeled how to use thinking frames, students internalized the strategy and transferred it across scientific contexts.

Subsequent empirical studies have confirmed and extended these findings. For instance, Higgins and Baumfield (2004) documented the use of thinking frames in both primary and secondary science classrooms and found substantial gains in students' ability to explain and reason scientifically. Their research showed that TFA enhanced assessment for learning practices, as the visible structure of student thinking allowed teachers to diagnose misconceptions, provide timely feedback, and differentiate instruction effectively. Similarly, Fensham and Bellocchi, (2013) applied TFA in classes and reported a statistically significant improvement in students' academic achievement, especially in abstract topics such as chemical bonding. The researchers concluded that TFA's structured scaffolding helped students organize their reasoning and reduced cognitive overload, particularly for lower-achieving learners.

In another study, Duit and Treagust, (2012) used TFA to foster systems thinking in environmental science topics such as biodiversity, pollution, and climate change. Their results indicated that students who used cause-effect and systems-thinking frames developed a deeper understanding of dynamic environmental relationships and were better able to explain interdependencies within ecosystems. This aligns with findings by Andrade (2019), who demonstrated that metacognitive interventions like TFA improve students' ability to reflect on and regulate their thinking, particularly in tasks requiring explanation, evaluation, and argumentation.

Moreover, research by Tang (2016) on generative learning strategies supports the integration of structured tools like thinking frames to enhance student learning.

Generative tasks such as drawing, summarizing, and explaining key components of TFA are known to foster deeper processing and durable learning. Alvermann and Moore (2022) further argue that graphic organizers and visual scaffolds promote scientific literacy by helping students shift from descriptive to explanatory and argumentative writing, which is essential for meeting modern science education goals. Recent classroom-based action research by Karamustafaoğlu and Kandaz (2022) examined teachers' perceptions of using visual thinking tools like TFA in Turkish science classrooms. The study found that teachers valued TFA for its ability to simplify complex concepts, encourage classroom discussion, and support all learners especially those with limited prior knowledge. Similarly, Treagust *et al.,* (2018) examined the impact of thinking frames in teaching cell biology and found a significant improvement in students' conceptual understanding and retention. The study emphasized that the structured nature of TFA allowed students to sequentially build on prior knowledge and connect abstract ideas to real-world examples.

Students' confidence increased as a result of this technique, according to Cams Hill Science Consortium (CHSC) teachers who used the TFA in their classrooms (Newberry et al., 2011). Additionally, they demonstrated increased motivation to solve problems and provide answers (Newberry et al., 2011). As a result, the TFA is a method that can serve as a scaffold for students and teachers to address the ontological, social/affective, and epistemological facets of conceptual transformation. The effectiveness of TFA is also evident in research on teaching genetics a topic often described as cognitively demanding due to its abstract and multi-layered concepts. In a study by Chapman and Martin (2021), students exhibited persistent misconceptions about gene dominance, allele segregation, and phenotype expression. The authors recommended structured visual and verbal scaffolds akin to TFA to help students navigate these abstract relationships. While the study did not directly apply TFA, it provided strong theoretical support for its integration in genetics education. Despite its growing empirical support, the implementation of TFA is not without challenges. Teachers must be adequately trained to use the frames not as mere worksheets but as cognitive tools for fostering inquiry and reflection. As McClure *et al.* (2020) noted, the most significant learning gains occurred when teachers deliberately integrated thinking frames into inquiry-based instruction, modeled their use, and facilitated reflective dialogue around them. There is also a call for more longitudinal research to assess the sustained impact of TFA on knowledge retention, transfer, and performance in standardized assessments.

The Thinking Frames Approach has demonstrated consistent and positive outcomes across multiple empirical studies in science education. It has been shown to improve students' conceptual understanding, reasoning, metacognition, and performance in subjects like chemistry, biology, and environmental science. By externalizing cognitive processes and supporting structured reflection, TFA equips students with the tools needed to engage deeply with scientific content. Its applicability across topics and educational contexts underscores its value as an innovative, equity-promoting instructional strategy in modern science classrooms.

The integration of the Thinking Frames Approach (TFA) into science instruction represents a growing pedagogical trend aimed at enhancing conceptual understanding and problem-solving skills among students. In the context of genetics education, this study found a statistically significant improvement in student performance following the use of TFA, as evidenced by a Wilcoxon Signed Rank Test result (p = .001, r = 0.87). These findings align with recent literature emphasizing the importance of structured thinking tools in improving student outcomes in science (Ng & Chan, 2021; Cooper *et al.,* 2019). TFA encourages students to organize, analyze, and represent their thoughts systematically, thus fostering deeper cognitive engagement. Research suggests that when students are provided with visual and linguistic scaffolds, such as diagrams, sentence starters, and structured thinking prompts, they are better able to internalize complex scientific concepts (Schnepps & Sadler, 2018). This is particularly vital in genetics, which involves abstract ideas like gene expression, inheritance patterns, and molecular processes that are often difficult for students to visualize and relate to real-life experiences. The marked improvement from a mean rank of 9.2 in the pretest to 35.9 in the posttest underlines the effectiveness of TFA in bridging this conceptual gap. According to Ainsworth and Loizou (2020), visual-based learning frameworks not only aid in retention but also enhance students' ability to apply knowledge in problem-solving contexts. The TFA serves as a cognitive scaffold, enabling learners to transfer knowledge across different genetic phenomena, thereby improving their overall academic performance. Moreover, this significant effect size (r = 0.87) indicates a large and meaningful impact of TFA on learning, reinforcing the notion that instructional design plays a critical role in shaping learning outcomes. Contemporary studies have highlighted how guided-inquiry methods, such as TFA, promote self-regulated learning and metacognitive awareness (Gilbert & Justi, 2016; Grevatt, Gilbert, & Newberry, 2007). These skills are essential in complex domains like genetics, where students are expected to make logical inferences and predict genetic outcomes.

Importantly, TFA aligns with constructivist learning theories, where knowledge is actively constructed rather than passively received. The approach empowers learners to make sense of genetic content by engaging in dialogue, reflection, and conceptual mapping strategies shown to enhance understanding in scientific domains (Akpan & Beard, 2023). This structured interaction with content helps demystify challenging topics, making them more accessible and less intimidating for learners. The TFA also supports inclusive learning, helping to narrow achievement gaps by providing equal opportunities for all students to engage with the material effectively. This is supported by emerging evidence that graphic organizers and structured learning supports are particularly beneficial for learners from diverse academic backgrounds, including low-achieving and language-minority students (Martínez-Hernández & Suárez, 2021). Therefore, the use of TFA in this study likely contributed not only to performance improvement but also to increased engagement and confidence among students. Furthermore, in the era of competency-based education, developing critical thinking and problem-solving skills is a priority. TFA nurtures these competencies by encouraging learners to connect prior knowledge with new information, evaluate evidence, and reason systematically (Duit, & Treagust, 2012b). These are indispensable skills in genetics education, where students must often synthesize information from multiple sources to explain complex biological processes.

In conclusion, the statistically and practically significant impact of the Thinking Frames Approach on students' performance in genetics underscores its pedagogical value. As science educators seek innovative strategies to enhance learning, particularly in abstract disciplines like genetics, TFA presents a research-backed, learner-centered approach that fosters deep understanding and academic success. The findings of this study contribute to the growing body of evidence supporting the use of structured cognitive tools in science education and call for their broader implementation in curriculum design and teacher professional development (Ebert, & Crippen, 2010).

2.7 Students' Conceptual Difficulties in Genetics

Genetics is widely recognized as one of the most conceptually challenging topics in secondary biology education. Senior High School (SHS) students often struggle with grasping its abstract nature, multilayered representations, and complex reasoning demands. Research across educational settings has consistently shown that misconceptions in genetics are not only widespread but also persist despite formal instruction. These misconceptions can hinder meaningful learning and limit students' ability to apply genetic knowledge in real-world contexts (Chapman & Martin, 2021; Duncan & Reiser, 2007).

One common area of difficulty lies in the understanding of dominance and recessive. Many students incorrectly interpret dominant traits as “stronger” or “more frequent” in a population, while recessive traits are assumed to be “weaker” or “less important” (Lewis & Kattmann, 2004). This misunderstanding often stems from the language used in instruction and textbooks, which may not clarify that dominance is a functional relationship between alleles, not a reflection of trait superiority or frequency.

Another frequent difficulty involves the mechanism of inheritance. Students often apply a simplistic one-gene-one-trait model, assuming that each trait is controlled by a single gene and follows Mendelian inheritance. This view fails to accommodate polygenic traits, incomplete dominance, codominance, and epigenetic influences, leading to conceptual errors when explaining real-world genetic phenomena (Gericke & Wahlberg, 2013). Moreover, students commonly confuse genotype and phenotype, often using these terms interchangeably without understanding the molecular basis that links genes to observable traits.

A particularly persistent difficulty is the interpretation and construction of genetic diagrams, such as Punnett squares and pedigree charts. Research by Adolphus *et al.* (2021) indicates that many SHS students struggle to accurately determine gametes, assign genotypes, and calculate phenotypic ratios. These issues are rooted in both procedural gaps and limited conceptual understanding of meiosis, segregation, and random fertilization. Without a solid grasp of the chromosomal basis of inheritance, students are unable to link these symbolic tools to real biological processes. Misunderstandings about meiosis and DNA replication further compound genetics learning challenges. Many students fail to differentiate between mitosis and meiosis, leading to confusion about how genetic variation arises (Sheldon, 2020). Others misinterpret DNA structure and function, believing that genes are traits themselves or that all cells contain identical gene expressions regardless of cell type. These misconceptions reflect deeper issues in molecular genetics literacy and point to the need for integrative, model-based teaching strategies.

The abstract and invisible nature of genetic processes such as gene expression, mutation, and chromosomal behavior also contributes to students' conceptual difficulties. Since these mechanisms cannot be observed directly, students must rely on mental models, analogies, and visual representations to understand them. However, if these models are inaccurate or inconsistently applied, they can reinforce misconceptions rather than correct them (Tibell & Rundgren, 2010).

The root causes of these difficulties are multifaceted. First, genetics is typically taught with an overemphasis on rote memorization and algorithmic problem-solving rather than conceptual reasoning. Second, teaching materials often present idealized Mendelian examples that oversimplify inheritance, giving students a false sense of certainty about trait prediction (Kampourakis, 2016). Third, many teachers themselves lack the deep conceptual knowledge or pedagogical tools needed to detect and address students' misunderstandings (Yarden, 2017). Additionally, students' prior knowledge often gained from everyday language or media is filled with inaccuracies that conflict with scientific explanations (e.g., thinking that all genetic diseases are inherited in a dominant-recessive pattern).

To address these challenges, researchers and curriculum developers advocate for instructional approaches that promote visual reasoning, metacognitive reflection, and conceptual integration. Strategies such as the Thinking Frames Approach, model-based reasoning, inquiry-based learning, and the use of analogies and simulations have shown promise in helping students overcome persistent misconceptions and build more coherent understandings of genetics (Gericke *et al.,* 2017; Zohar & Barzilai, 2015).

2.8 Structure of the Ghanaian Senior High Genetic Content

Basic genetic words including gene, genotype, phenotype, dominant, recessive, allele, locus, test cross, back cross, and others are covered in the Ghanaian Senior High Genetic Content**.**

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 2.1: 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. Replication of DNA, gametes as vehicles of inheritance.
	2.5.4 state and explain Mendel's first and second laws 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)

2.9 The Concept of Genetics

Genetics is a foundational discipline within biological sciences that explores how traits are inherited, expressed, and modified across generations. It focuses on understanding the structure, function, and behavior of genes, which are the molecular units of heredity composed of DNA. Modern genetics not only explains patterns of inheritance as initially proposed by Gregor Mendel but also delves into complex mechanisms such as gene expression, epigenetics, and genomic interactions that regulate biological development and diversity (Griffiths *et al.,* 2020).

At its core, genetics investigates the relationship between genotype (an organism’s genetic makeup) and phenotype (observable characteristics), emphasizing that traits are influenced by interactions between genes and environmental factors. These relationships are not always straightforward; for instance, traits can be influenced by multiple genes (polygenic inheritance), incomplete dominance, codominance, or gene-environment interactions. This complexity necessitates a systems-thinking approach in genetics education, especially at the secondary level (Tsui & Treagust, 2021).

One of the most significant advances in recent genetics has been the integration of molecular biology and genomics, which has expanded the field’s scope beyond Mendelian inheritance. With technologies like CRISPR gene editing, whole-genome sequencing, and transcriptomics, scientists can now manipulate genes with precision and understand their regulation in various biological contexts (Doudna & Charpentier, 2020). These breakthroughs have practical applications in agriculture, medicine, and forensic science, underscoring the relevance of genetics to real-world problem-solving.

In educational contexts, genetics presents cognitive challenges due to its abstract nature. Students must visualize unseen processes, interpret symbolic representations (e.g., Punnett squares, pedigrees, DNA models), and reason across multiple biological levels from molecules to cells to organisms. According to Chapman and Martin (2021), these cognitive demands contribute to widespread misconceptions among learners, such as confusing genes with traits, misunderstanding dominance, or oversimplifying inheritance patterns.

Recent research emphasizes the importance of teaching genetics not just as a body of content, but as a process of scientific reasoning and inquiry. For example, Duncan et al. (2019) argue that genetics instruction should move beyond rote memorization and instead help students develop explanations, construct models, and engage in argumentation about genetic phenomena. This aligns with the Next Generation Science Standards (NGSS), which promote learning genetics through crosscutting concepts and science practices.

Furthermore, the ethical and social dimensions of genetics such as privacy in genetic testing, and genetic modification are becoming central to the curriculum. Students are increasingly encouraged to engage in socio-scientific reasoning to evaluate how genetic technologies affect society and to develop informed views on controversial issues (Zohar & Barzilai, 2015).

2.10 Students' Views on the Use of Thinking Frames in Learning Science

Understanding students' perceptions of the instructional strategies used in their classrooms is critical to evaluating the success and sustainability of those methods. The Thinking Frames Approach (TFA), which combines visual scaffolding with metacognitive prompts to support students in constructing scientific explanations, has been praised not only for improving learning outcomes but also for fostering positive student engagement, increased confidence, and greater ownership of learning (McClure, Newbery, & Bird, 2008; Tanner & Jones, 2007). Empirical studies suggest that students generally respond positively to the use of thinking frames in science learning. Learners often report that the structured format of TFA helps them organize their thoughts, clarify difficult concepts, and improve their ability to explain scientific ideas. In McClure *et al.*'s (2018) *Learning to Learn* project, students expressed that thinking frames made science "less confusing" and "easier to write about." They appreciated the visual representation of cause-effect relationships, especially in topics like genetics and chemical reactions, where sequences and connections between ideas are essential.

Students have also reported that TFA enhances their confidence in learning science. In a study by Aydogdu and Kesercioglu (2021), learners noted that visual thinking tools helped them feel more in control of their learning. Rather than relying solely on memorization, students found they could explain processes in their own words, reflect on their understanding, and identify gaps in their reasoning. This self-monitoring aspect central to TFA's design encouraged learners to engage more meaningfully with scientific content. Learner feedback also emphasizes preference for guided structure over open-ended tasks. While inquiry-based learning and problem-solving approaches encourage autonomy, they can be cognitively overwhelming for students without adequate scaffolding. TFA serves as a bridge between structure and autonomy, helping students internalize scientific reasoning patterns while still giving them space to articulate ideas in personalized ways (Zohar & Barzilai, 2015). Students particularly valued explanation frames that used sentence starters (e.g., "This happens because…", “As a result…”), which helped them construct coherent, written responses in science assessments (Tang, 2016).

Moreover, students who initially struggled with science content or lacked confidence in their academic abilities expressed that TFA made science more accessible. In a study by Andrade, (2019), low-achieving students in chemistry showed significant gains in understanding and participation after being taught using TFA. Interviews revealed that these students felt less intimidated when working with thinking frames, as the templates gave them a sense of direction and structure. However, some students have voiced challenges with TFA, particularly when frames are used repetitively or without teacher modeling. When students are introduced to multiple frame types without adequate explanation, the strategy can become confusing rather than helpful. Research by Karamustafaoğlu and Kandaz (2022) found that while most students appreciated visual tools, they preferred when teachers used them interactively discussing the components of the frame together before individual work. This finding underscores the importance of teacher guidance and gradual introduction of TFA tools for successful adoption. Engagement studies also show that TFA supports collaborative learning. When used in group settings, thinking frames prompt students to articulate and debate scientific explanations, which strengthens peer learning and conceptual clarity (McClure *et al.,* 2020; Andrade *et al.,* 2016;). Students often reported enjoying discussions around their frame responses, noting that it helped them see other perspectives and refine their understanding through feedback. Students’ views on the use of Thinking Frames in science learning are largely positive. Learners appreciate the structure, clarity, and support that TFA provides, particularly in cognitively demanding topics like genetics. It enhances their confidence, deepens engagement, and supports metacognitive development. While challenges exist mainly related to poor implementation or overuse research consistently shows that when used effectively, TFA is not only a beneficial instructional tool but also a learner-preferred approach in science education.

2.11 Gender Differences in Science Achievement: A Focus on Biology and Genetics

Gender disparities in science education, particularly in student achievement and engagement, have been the subject of sustained educational research. While some studies report narrowing gender gaps in science performance over time (Etobro & Fabinu, 2017), others continue to highlight persistent differences in specific science domains, particularly at the secondary school level (Fikadu & Shimeles, 2019). Biology often perceived as a female-friendly science discipline presents a complex picture when examined through the lens of gender, especially in subfields like genetics, which demand abstract thinking, symbolic reasoning, and model-based problem-solving. In general science performance, studies from large-scale assessments like the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) have found that while boys tend to outperform girls in physics and chemistry, girls often perform equally or slightly better in biology-related assessments (Mullis *et al.,* 2020; OECD, 2019). However, this advantage does not consistently extend to all biological subtopics. Genetics, for example, poses unique conceptual and cognitive demands that may impact students differently based on gender-linked learning approaches and attitudes.

Research indicates that female students tend to exhibit stronger rote memorization, attention to detail, and reading comprehension skills, which may benefit them in descriptive areas of biology (Brotman & Moore, 2008). However, genetics education requires abstract conceptualization, symbolic reasoning, and diagrammatic interpretation, which studies suggest are areas where male students often excel (Wilgenbusch & Finson, 2000). This could partly explain why gender differences sometimes emerge in performance related to topics such as Mendelian inheritance, Punnett square construction, and allele frequency calculations.

A study by Gericke and Wahlberg (2013) examining Swedish upper secondary students' understanding of molecular genetics found that boys were more confident and accurate in solving genetics problems involving symbolic representation and probabilistic reasoning. Girls, on the other hand, demonstrated a more descriptive understanding but were less confident when engaging with tasks that required abstract model manipulation. This aligns with findings by Zohar and Sela (2003), who reported that gender-related achievement gaps in science often reflect differences in cognitive orientation rather than ability boys tending toward systemizing strategies and girls leaning toward contextual or narrative explanations. In the African context, gender differences in genetics education are often magnified by socio-cultural and classroom dynamics. A study by Adesoji and Raimi (2020) involving Nigerian senior secondary students showed that male students outperformed their female counterparts in genetics tasks, particularly in test items requiring multi-step reasoning and genotype-to-phenotype interpretation. The authors attributed this to a combination of gender-biased classroom interactions, societal expectations, and differential access to enrichment activities such as science clubs and competitions.

However, several studies also highlight that when instructional support is equitable and pedagogical tools such as thinking frames, inquiry-based learning, and collaborative tasks are employed, gender differences in performance tend to diminish. For example, Taber and Garcia-Franco (2010) demonstrated that the Thinking Frames Approach (TFA) significantly improved the performance of both male and female chemistry students, but the gains were slightly higher for female students, suggesting that structured scaffolds can empower girls to engage more confidently with abstract science concepts. Similarly, Zohar and Dori (2012) argue that gender disparities in high-level cognitive tasks like argumentation and metacognitive reasoning can be mitigated by creating inclusive classroom environments that emphasize reasoning over rote recall. Their findings underscore the importance of using pedagogical interventions that foster equal participation, peer learning, and visual reasoning all hallmarks of modern approaches to teaching complex subjects like genetics. In addition, classroom discourse plays a significant role. Alvermann and Moore (2022) note that male students are often more assertive in group discussions and problem-solving tasks, while female students may be less willing to take intellectual risks unless the environment supports collaborative, non-threatening engagement. These participation patterns can influence performance, especially in assessments where articulation of reasoning is key.

In conclusion, while general trends in science achievement suggest a female advantage in biology, gender-specific challenges persist in conceptual areas like genetics, where performance is mediated by reasoning style, confidence, prior exposure, and instructional support. Research consistently shows that gender disparities are not innate but shaped by contextual, cultural, and pedagogical factors.

Addressing these disparities requires intentional use of inclusive and supportive teaching strategies like TFA, metacognitive scaffolding, and cooperative learning that can level the playing field and enhance performance across gender lines.

2.12 The Role of Gender in Learning Styles and Science Cognition

Gender plays a significant role in shaping students' learning styles and cognitive approaches in science education. Contemporary educational research integrates both cognitive and sociocultural theories to explain how male and female students may engage differently with science content, processes, and representations (Eseine-Aloja, 2021). These differences are not simply rooted in biological sex but are the product of complex interactions between individual cognition, classroom practices, and broader cultural narratives around gender and science. From a cognitive standpoint, several studies suggest that gender may influence preferred modes of processing information. For instance, male students have been found to more often favor spatial, abstract, and analytical learning styles, which align with tasks that require manipulation of models, diagrams, and symbolic reasoning skills often emphasized in topics like physics and genetics (Stoet & Geary, 2018). Conversely, female students tend to prefer verbal, sequential, and contextual learning approaches, which may support stronger performance in narrative-rich, descriptive sciences such as ecology and human biology (González-Pienda *et al.,* 2017). These cognitive tendencies, however, are not deterministic. Rather, they are shaped by both educational experiences and instructional practices, emphasizing the importance of inclusive teaching strategies that accommodate a diversity of learning styles.

Recent neuroscientific and educational psychology research has emphasized that gender differences in learning are mediated by environmental factors rather than inherent abilities. Lindberg et al. (2021) found that instructional context, task framing, and teacher expectations significantly influence student confidence and strategy use in science.

The sociocultural perspective provides further insight by highlighting how gendered classroom interactions, cultural stereotypes, and societal expectations impact students' science learning. Vygotsky's sociocultural theory posits that learning is a socially mediated process influenced by language, tools, and participation in culturally meaningful activities (Vygotsky, 1978). In science classrooms, boys often receive more attention in experimental or technical tasks, while girls are more frequently assigned organizational or support roles, reinforcing stereotypical identities (Tan *et al.,* 2018). These dynamics can influence students' confidence, perceived competence, and long-term interest in science fields.

Moreover, the internalization of gender-based expectations can impact cognitive engagement. Female students, for instance, may experience stereotype threat a psychological phenomenon where awareness of negative stereotypes affects performance particularly in tasks involving mathematics or genetics (Spencer *et al.,* 2016). Studies such as that by Cimpian et al. (2019) show that girls, even at a young age, may self-select out of science-related activities if they internalize the belief that brilliance is required to succeed in those fields, a trait they may not associate with their gender due to societal messaging.

Importantly, research from the past decade also shows that pedagogical strategies can reduce or even eliminate gender disparities in science cognition. Teaching approaches such as thinking frames, inquiry-based learning, cooperative learning, and contextualized science instruction has been shown to support both male and female students by offering multiple entry points into learning (Ahmed & Abimbola, 2020; Zohar & Barzilai, 2015). These strategies promote equity by fostering metacognitive awareness, encouraging reflection, and allowing students to visualize and articulate their reasoning an approach especially valuable in abstract science topics like genetics.

In conclusion, the role of gender in science learning is best understood through an integration of cognitive preferences and sociocultural influences. While some general trends in cognitive style may exist between genders, they are deeply shaped by context, expectations, and educational experience. Teachers, therefore, have a critical role in designing learning environments that are inclusive, reflective, and supportive of all students regardless of gender especially in high-cognition areas like genetics, where both reasoning and representation matter.

2.13 The Concept of Academic Performance

Assessing the effectiveness of instructional strategies in science education is crucial for improving learning outcomes, particularly in conceptually demanding subjects like genetics. In contrast, conventional teaching methods often rely on lecture-based delivery and rote memorization, which may not sufficiently engage students or promote meaningful understanding of complex biological concepts (Tang & Chan, 2021). The significant performance disparity between the TFA and conventional groups in this study highlights the limitations of traditional instruction and supports a shift toward constructivist and learner-centered pedagogies in science education. Importantly, this study aligns with broader educational reforms that emphasize inquiry-based and visual learning strategies as effective tools for promoting deeper learning in STEM fields (Mclure *et al.,* 2018). TFA supports cognitive development by encouraging students to articulate their reasoning, identify patterns, and visualize relationships between genetic concepts. These metacognitive skills are essential for success in modern science education. Additionally, the large effect size observed in this study ($r = 0.87$) suggests that TFA not only improved test performance but likely enhanced students' confidence and engagement in genetics learning. Recent research shows that active learning strategies like TFA promote student motivation, especially when students feel supported by tools that help them organize and apply their thoughts (Mclure et al, 2020).

In conclusion, the results of this study provide strong empirical support for the superiority of the Thinking Frames Approach over conventional teaching methods in genetics education. Given the statistically significant improvement in student performance and the large effect size, educators and policymakers should consider integrating TFA into biology curricula to improve students' conceptual understanding and academic success. These findings also reinforce the importance of instructional innovation in addressing persistent challenges in science learning.

According to Noemy et al. (2017) academic performance is the quantifiable result of the learning process, as determined by the assessments made by the teachers using impartial test evaluations. Ampofo and Osei-Owusu (2015) and Balogun et al. (2020)

also defined academic performance as the measure of a student's ability to complete a particular piece of classwork in a formal educational context. From these definitions, it is apt to say that academic performance is the evaluation of a student's accomplishment in various academic disciplines. This means that academic performance is the marks a student gains at the end of a course or a lesson. Therefore, according to Zheng and Mustappha (2022), academic performance is not equal to academic achievement. Though both academic performance and academic achievement measure the outcomes of a student's learning, academic achievement is the sum of a student's ability to complete and reach a particular level following a course of study or training (Zheng & Mustappha, 2022), that is, the outcomes of students' academic progress as a result of their cumulative learning. This means that academic achievement is the evaluation of a student's overall performance over their academic career, while academic performance refers to the overall examination score in a subject or a course. In other words, if a student does not perform well in the individual lessons of a course or a subject, there is the likelihood to have poor academic achievement. An example of academic achievement is a student's WASSCE results earned at the end of the final year exams, while that of academic performance is a student's score or grade in a class test or an end of term or semester exams. Therefore, if a student persistently performs poorly in internally, there is a high probability to achieve abysmal final year results externally during their WASSCE. For the purpose of this study, academic performance was used. According to Bloom (2013), any educational objective should center on three main domains of human learning, viz, cognitive, affective and psychomotor domains. The cognitive domain entails the intellectual abilities of the learner, that is information processing, knowledge construction and application, problem solving, and conducting research;

the affective domain refers to the values, interests and feelings, that is the way that we handle things emotionally towards the subject and the learning process; while the psychomotor domain talks about the gross and fine motor skills acquired throughout the learning process (Hoque, 2016). Therefore, Zheng and Mustappha (2022) assert that, in measuring academic performance, the teacher should consider how all the domains of learning will be measured to obtain a comprehensive understanding of the students' learning outcomes.

2.14 Assessment Practices in Genetics Education

Assessment in genetics education plays a crucial role in evaluating students' understanding of abstract and complex biological concepts. Unlike content areas that lend themselves to surface-level recall, genetics requires students to apply higher-order thinking, including conceptual reasoning, visual interpretation, and problem-solving across multiple representational levels (molecular, cellular, organismal, and population). As such, the choice of assessment strategies greatly affects not only how students demonstrate their understanding but also what aspects of genetics learning are valued and reinforced in the classroom.

Traditional assessments in genetics often rely heavily on objective tests such as multiple-choice and short-answer questions. While these tools are efficient for assessing factual knowledge such as definitions of genotype and phenotype, or identifying Mendelian ratios they are limited in their ability to capture students' conceptual understanding, especially regarding gene interactions, inheritance mechanisms, and probabilistic reasoning (Chapman & Martin, 2021). Moreover, students may score well on such assessments while holding persistent misconceptions, as they often rely on test-taking strategies rather than a deep grasp of genetic principles (Lewis & Wood-Robinson, 2020). To address these limitations, many educators advocate for the use of formative and performance-based assessments that encourage students to demonstrate reasoning processes and articulate their thinking. For instance, concept mapping, model-based assessments, and explanation tasks have shown promise in revealing how students structure their knowledge and relate concepts in genetics (Gericke *et al.,* 2017; Duncan *et al.,* 2009). These assessments provide a more nuanced picture of student understanding and allow teachers to identify and address misconceptions in real-time.

Diagnostic assessments have also gained attention for their utility in uncovering students' prior knowledge and conceptual challenges. Tools such as two-tier tests, which require both an answer and a justification, are particularly effective in genetics, where students often hold scientifically inaccurate but intuitively appealing ideas for example, that dominant traits are more common or "stronger" than recessive ones (Adolphus *et al.,* 2021). Such assessments support formative decision-making by enabling teachers to tailor instruction based on identified learning gaps. Authentic assessments, such as case-based reasoning tasks, genetic pedigree analysis, or simulated genetic counseling scenarios, have also been successfully used to promote deeper engagement and assess transfer of learning. These strategies require students to apply genetic principles to real-world contexts and integrate ethical, social, and biological dimensions of genetics. According to Yarden (2017), such assessments not only evaluate conceptual understanding but also enhance scientific literacy and relevance, which are central goals of modern science education.

A growing body of literature also supports the use of argumentation-based assessments in genetics. These tasks prompt students to make claims, use evidence, and construct reasoned explanations about genetic phenomena. Zohar and Nemet (2018) found that incorporating argumentation in genetics instruction improved students' conceptual understanding, particularly in controversial or abstract areas such as genetic testing, cloning, or inheritance patterns. Such assessments align with the goals of the Next Generation Science Standards (NGSS), which emphasize scientific practices alongside core content knowledge.

Furthermore, metacognitive assessment tools, including reflection journals and thinking frames, have been successfully used to evaluate not only what students know, but how they think about what they know. The Thinking Frames Approach (TFA), in particular, offers structured scaffolds for students to explain genetic processes using visual and written formats. Studies by Ahmed and Abimbola (2020) and Tanner and Jones (2007) report that TFA enhanced assessments improve students' explanatory writing and reveal deeper understanding of topics such as meiosis, allele segregation, and inheritance. Despite the variety of innovative assessment tools, challenges remain. Many schools continue to prioritize high-stakes testing, which may narrow the curriculum and undervalue conceptual depth. Additionally, the implementation of alternative assessments often demands time, training, and resources that may be limited in under-resourced schools. As such, there is a need for professional development focused on assessment literacy, particularly in designing tasks that align with conceptual learning goals in genetics (Arias *et al.,* 2019).

2.15 Summary of Reviewed Literature

The reviewed literature provides a robust foundation for understanding the pedagogical and cognitive significance of the Thinking Frames Approach (TFA) in genetics education, particularly within the senior high school context. Theoretically, TFA is grounded in constructivist learning theory, which emphasizes knowledge construction through experience and reflection, as well as in metacognitive and visual learning principles. These frameworks collectively support the development of students' abilities to organize their thoughts, visualize complex relationships, and articulate scientific explanations effectively (Zohar & Barzilai, 2015; Tanner & Jones, 2007). In the context of genetics, which is conceptually dense and abstract, these scaffolds enable learners to navigate complex ideas such as inheritance, gene expression, and probability. Genetics education presents significant cognitive challenges due to its abstract nature and reliance on symbolic representations. Students often struggle to connect genotype with phenotype, interpret Punnett squares, or understand molecular mechanisms. Research reveals that traditional methods are often insufficient for fostering deep understanding, leading to misconceptions such as equating dominant traits with higher frequency or strength (Chapman & Martin, 2021). Innovative approaches like TFA are therefore critical in facilitating conceptual change and enhancing meaningful learning. Empirical studies on TFA have demonstrated its effectiveness in improving student outcomes in science. McClure, Newbery, and Bird (2008) found that TFA enhances students' ability to explain scientific phenomena, improves metacognitive awareness, and supports low-achieving learners through structured reasoning tools. When integrated with formative assessment and collaborative learning, TFA also promotes equity and deeper engagement, especially in topics requiring sequential and causal reasoning like genetics. In terms of student perception, learners generally view TFA positively. They report increased clarity, confidence, and understanding, particularly when engaging with complex content. Thinking frames help them visualize and verbalize their thoughts, enabling better performance in written and oral explanations (Ahmed & Abimbola, 2020). However, studies caution that the effectiveness of TFA depends on proper implementation, including guided modeling by teachers and contextual adaptation to learners' needs. Gender also plays a critical role in genetics learning and science cognition. While females often outperform males in descriptive areas of biology, males tend to excel in spatial and symbolic reasoning, giving them an edge in genetics tasks involving abstract models. These differences are explained by both cognitive preferences and sociocultural influences, including stereotype threat and classroom discourse patterns (Cimpian *et al.,* 2019; Stoet & Geary, 2018). Nonetheless, when strategies like TFA are applied equitably, they help bridge gender gaps by providing structured support that benefits both male and female students (Ahmed & Abimbola, 2020). Further, the literature highlights the importance of assessment in genetics education. Traditional multiple-choice tests often fail to capture students' conceptual understanding. Alternative assessments such as model-based tasks, argumentation, two-tier questions, and thinking frame-based explanations are more effective in diagnosing misconceptions and evaluating deep understanding (Duncan *et al.,* 2019; Zohar & Nemet, 2018). TFA-based assessments, in particular, provide students with the opportunity to explain reasoning processes, which is vital for genetics topics that require layered cognitive processing. Overall, the literature supports the implementation of TFA as an effective strategy for enhancing students' performance, conceptual understanding, and engagement in genetics education.

CHAPTER THREE

METHODOLOGY

3.0 Overview

The methodology used in this study was covered in this chapter. The topic area and the methodological paradigm used for this investigation are described first. This chapter goes into additional detail about the demographic, sample, and sampling technique used to calculate the study's sample size. This chapter also includes a detailed explanation of the research instrument used to gather the data for analysis, as well as the findings and conclusions pertaining to the validity and reliability of the study's instrument. In a similar vein, this chapter covered the data collection process and analysis methods. Finally, this chapter discusses the study's ethical considerations.

3.1 Study Area

The study was conducted in the Mampong Municipality located in the Ashanti Region of Ghana (Figure 3.1), Mampong Municipality forms part of the 43 Metropolitan, Municipal and District Assemblies (MMDAs) in the Ashanti Region, Ghana, with Mampong-Ashanti as its capital. It spans an approximate area of 23.9 km^2 and is situated between longitudes 0.05° and 1.30° West and latitudes 6.55° and 7.30° North. (Ghana Statistical Service, 2021). Currently, there are five public and one private SHS in the Municipality. The municipal area has 96 Primary Schools, 62 Junior Secondary Schools, five public Senior Secondary Schools and one private Senior High School, as well as a vocational training school. There are also two College of Education, one Nursing and Midwifery Training College and one University. Among the SHSs in the municipality is one single-sexed (female) school. (Ghana Statistical Service, 2021).

Figure 3.1: Geographical Map of Study Area

3.2 Research Design

The research design employed for this study was the quasi-experimental pretest/posttest non-equivalent control group design. The choice for the employment of this design is the fact that, this study aimed to make some causal inferences by making comparisons of pretest and posttest scores to determine the effect of the Thinking Frames Approach (TFA) and conventional teaching method on the academic performances of SHS Biology students (Cohen *et al.,* 2018).

Also, the study was carried out in more naturalistic setting, using intact classes, which employed the quasi-experimental pretest/posttest non-equivalent control group design. As a result, students were assessed on previous knowledge concerning Genetics. In order to determine whether participants had equivalent entry behaviors, hence the use of pretest. The posttest was then used to ascertain the efficacy of Thinking Frames Approach (TFA) and the Conventional teaching method on the academic performances of SHS Biology students. Thus, the major independent variable in this study was the Thinking Frames Approach (TFA) and the Conventional teaching method, while the dependent variable was students' academic performances in Genetics.

This study adopted a mixed-method approach, which combines qualitative and quantitative methodologies to collect and analyse data (Creswell & Tashakkori, 2007). Mixed-methods research integrates quantitative techniques such as experiments and surveys with qualitative approaches like interviews and focus groups (Creswell, 2003). According to Teddlie and Tashakkori (2009), mixed-method research approach can take various forms, including sequential explanatory design, sequential exploratory design, concurrent triangulation design, concurrent nested design, and concurrent transformative design. This study employed the sequential explanatory design, which begins with the collection and analysis of quantitative data, followed by qualitative data collection and analysis. This approach was selected to allow the quantitative findings to be clarified and enriched by the qualitative data, providing deeper insights into the research questions. Creswell and Clark (2011) stated that the sequential explanatory design is a two-stage mixed method design. This design first begins with the collection and analysis of quantitative data and followed by the collection and analysis of qualitative data.

3.3 Research Paradigm

As Kivunja and Kuyini (2017) stated, the term paradigm is used to describe a researcher's 'worldview'. That is, the viewpoint or a way of thinking that guide how research data are interpreted. This means that, a research paradigm is a method, model, or pattern for conducting research (Kelle & Reith, 2023; Creswell, 2009). This study operated in the realm of pragmatist paradigm. The pragmatism paradigm serves as the foundation for the study's philosophical viewpoint. The pragmatist paradigm was adopted because, it arose from philosophers who argued that, unlike the positivist paradigm, social reality cannot be fully captured, and unlike the interpretivist paradigm, it cannot be entirely explained through subjective meanings. Instead, pragmatism holds that the "truth" of the real world cannot be understood through a single scientific approach alone (Ugwu et. al., 2021). Thus, these philosophers contended that a non-paradigmatic viewpoint was insufficient and that is what was required instead was a worldview that would provide research methodologies or a mix of approaches that might provide light on participant behavior as it actually occurs. This study, which has its roots in pragmatism, took a pluralistic and methodologically heterogeneous approach to research, utilizing quantitative and qualitative approaches to analyse data.

3.4 Population

The target population for this study included all SHS Biology students within Mampong Municipality in the Ashanti Region, Ghana. The accessible population however, included all SHS 3 Biology students within Mampong Municipality. SHS 3 Biology students were selected because Genetics, according to the Biology syllabus, is studied in SHS 3 (Ministry of Education, 2010).

3.5 Sample

The sample size for this study comprised 200 SHS 3 Biology students from six intact classes selected randomly from two participating schools. That is, three intact classes from each school were sampled. In effect, there were a total of 114 males, while 86 were females. The two sampled schools were classified A, and B for quick identification and handling while maintaining anonymity. The distribution of participants according to school and gender is tabulated in Table 3.1.

Table 3.1: Participants' Distribution According to Schools and Gender

	Number of Male Biology Participants	**Number of Female Biology Participants**	**Total Number of Participants**
School A	57	47	104
School B	47	49	96
Total	104	96	**200**

3.6 Sampling Technique

Multi-stage sampling was employed to select the sample for this study, which according to Cohen *et al.,* (2018), means that it contains two or more stages in selecting a sample for a study. Therefore, at each stage of the sampling procedure, the sample population changes. The various stages for this study are presented in Table 3.2.

Table 3.2: Stages of Multi-Stage Sampling Technique Used in this Study

Stage	Sampling procedure	Activity	Sample size
Stage 1	Purposive sampling	Selection of public SHS offering Biology as elective.	4
Stage 2	Simple random sample	Selection of participating schools from the study area.	2
Stage 3	Simple random sample	Selection of intact classes.	6
Stage 4	Simple random sample	Assignment of intact classes into experimental and comparison groups.	6

Stage 1 – Purposive sampling was employed to select public Senior High Schools offering Biology as an elective subject. In effect, four public SHSs were selected at this stage from Mampong Municipality.

Stage 2 – Simple random sampling was employed to select the two participating schools from the four schools within Mampong Municipality. Each participating school was assigned to a treatment (teaching method) since there were two different treatments to be introduced to participants in their intact classes without randomisation (Creswell, 2014).

Stage 3 – Simple random sampling was employed to select three intact classes from each selected participating school. This is because, there were more than three intact Biology classes in each participating school. Three intact classes were selected in order to increase the sample size for this study.

Stage 4 – Random assignment was also done to assign selected intact classes into experimental and control groups. Each group was named according to the instructional method assigned to them, thus, resulting in Thinking Frames Approach (taught using Thinking Frames Approach), and conventional group (taught using conventional teaching method). Each participating school selected from different schools, therefore, had three participating intact classes exposed to the same treatment. This was done to control for interaction effect which would affect the validity of the study (Cohen *et al.,* 2018).

3. 6 Research Instruments

This research employed two research instruments, namely, Genetic concept Test (GCT) and a focus-group interview guide. The GCT comprised of five (5) essay type questions. The use of essay formats was based on the assertion of Oduro-Okyireh and Annor (2018), who argue that, essay test items reflect student knowledge of a subject much better than multiple choices, and therefore are the best format for testing higher-order behaviours and mental processes such as analysis and evaluation. Therefore, to reduce the inadequacies in the test formats, essay test items was used.

3.6.1 The Genetics Concept Test (GCT)

The GCT was designed by the researcher and covered the areas of Genetics based on the Ghana Education Service (GES) Biology syllabus. The GCT instrument served three main purposes in this study. Thus, it was used as a pretest, where students' answers were used to ascertain the levels of difficulty they encounter in genetics concepts. Also, the scores from the pretest using GCT was used to determine students' entry characteristics prior to the intervention. Moreover, GCT was used to determine the effectiveness of the Thinking Frames Approach through the post-test.

3.6.2 Focus-group Interview Guide

To gather additional evidence on the intervention's impact, interviews were conducted with students in the experimental group following the treatment. A focus group interview technique was employed with students from the three experimental classes.

The interviews were both interactive and semi-structured, using pre-designed questions as a guide. The sessions aimed to capture students’ perspectives on the effectiveness of the thinking frames approach compared to conventional methods. Each focus group interview lasted approximately one hour (1hr) during which notes were taken, and the conversations were audio recorded. These recordings and notes provided valuable data for analysis. Thematic analysis was conducted to identify recurring themes from the students’ responses. Themes included enhanced classroom engagement, the significance of thinking frames approach to genetics lessons in real life, improved understanding of genetic concepts, practical applications of genetics studies, and increased interest in genetics. The study issue was addressed using these themes: What are the views of SHS biology students on the use of TFA in teaching and learning of genetics?

3.7 Validity of the Instruments

Biology tutors and seasoned researchers were given the achievement test and interview guide to provide their opinions and suggestions, regarding the items' suitability for evaluating the constructs that the instruments were designed to examine. This was carried out in order to assess the instruments' validity. Following that, the required adjustments were done prior to the instruments being piloted.

Five experts were invited to assess the instruments, and during the assessment of the instruments by the experts, they were asked to rate the achievement test and interview guide based on their relevance, appropriateness of items, factual inaccuracies, grammatical errors, and whether the content is in align with the syllabus. Therefore, items were rated as essential or non-essential. Afterwards, Lawshe's (1975) content validity ratio (CVR) was used to determine the content validity of the GCT and interview guide. To determine the CVR, Content Validity Index (CVI) was calculated for each item on the instrument. CVI is determined by dividing the total number of experts who evaluated the items by the number of experts who rated the items as essential (Ayre & Scally, 2014). After determining the CVI for each item, the CVI is calculated for the entire instrument. This is the mean of all individual CVIs (Almanasreh *et al.,* 2018). The CVRs of the GCT and interview guide were then determined by dividing the overall CVI by the total number of items. Table 3.3 presents the Content Validity Ratio and Content Index for GCT.

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

Item	**Panel 1**	**Panel 2**	**Panel 3**	**Panel 4**	**Panel 5**	**Agreement**	**CVI**
1	X	X	X	X	X	5	1.00
2	X	X	X	X	X	5	1.00
3	X	X	X	X	X	5	1.00
4	X	X	X	X	X	5	1.00
5	X	X	0	X	X	4	0.80
CVR							**0.96**

O =non-essential

X= essential

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

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

N = total number of experts

N_E = Number of experts indicating items as essential.

According to Almanasreh et al. (2018), CVR varies between 1 and −1, where high values of CVR indicate the agreement of experts on the relevance of an item in the instrument. Therefore, as seen from Table 3.3, the CVR value for GCT was 0.96, which indicates a valid instrument. Table 3.4 also shows the CVI and CVR for the interview guide.

Table 3.4: Content Validity Index and Content Validity Ratio of Interview Guide

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

As revealed in Table 3.4, the CVR value for the interview guide was 0.80, which also indicates a valid instrument according to Almanasreh *et al.* (2018).

3.8 Pilot Testing of the Instrument

After determining the validity of the instrument, the GCT was pilot-tested. The participants used for the pilot test formed part of the target population but did not take part in the main study. Therefore, they all shared similar characteristics of the research participants. According to Hertzog (2008), a sample size ranging from 10 to 40 per group is endorsed for evaluating the adequacy of the research instrument. To ascertain the GCT's dependability, 41 SHS 3 biology students were given the test.

3.9 Reliability of Research Instrument

Since the pilot study's answers were essay-style, two raters were tasked with rating the completed items in order to evaluate the reliability of the research tools. Thus, using the inter-rater reliability method and Cohen's kappa, Cohen and Cohen (1983), the scores from the two raters were used to ascertain the internal consistency of the item scores. Table 3.5 displays the findings of the kappa measure of agreement between the two raters.

Table 3.5: Inter-Rater Reliability of Genetic Concept Test

		Value	Approximate Significance
Measure of Agreement	Kappa	.751	.001
N of Valid Cases		41	

According to Kottner *et al.* (2011), as a rule of thumb, values ≤ 0 indicate no agreement and 0.01–0.20 as none to slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate agreement, 0.61–0.80 as good or substantial agreement, and 0.81–1.00 as perfect agreement. In this study, the value of Kappa's measure of agreement as seen from Table 3.5 was 0.751, which is a substantial agreement, according to Kottner et al. (2011).

As a result, from Table 6, the Kappa measure of agreement of the score of the two raters for the GCT was 0.751, which Kottner et al. (2011), interpretes it as a substantial agreement. This suggests that the GCT was a trustworthy tool for the primary investigation.

3.10 Data Collection Procedure

As previously mentioned, the data collection process enabled the researcher to gather both quantitative and qualitative data. Three steps made up the data collection process.

3.10.1 Pre-intervention Stage

The headteachers of the schools chosen for the study were formally asked for their consent. These schools' biology teachers were duly informed as well. Teachers, administrators, and students from the sampled schools were assured of the confidentiality of the student data and the study's findings, as well as the study's significance and implications. Following the approval of various authorities, three intact SHS 3 biology classes from each school were chosen using simple random sampling, and they were divided into experimental and control groups.

For confidentiality and data entry purposes, the experimental school was identified as SCHOOL A (taught using the thinking frames approach), while control school was identified as SCHOOL B (taught using the conventional teaching method). The sampled schools were then visited to begin the pretest. In order to ensure that students were prepared for the pretest, students were informed one week prior to the conduction of the pretest. The purpose of the pretest was to make sure that all participants performed about equally before the intervention. The researcher gave out the pretest with the help of the sampled schools' biology tutors. The pretest was administered, and students in both groups had 45 minutes to complete the questions.

3.10.2 Intervention Stage

The second stage, which is the intervention stage, started after the pretest was successfully completed. To account for teacher differences, the researcher at this stage taught the subject matter to the two (2) groups. During the intervention stage, both the experimental and control groups were taught the same content; however, the experimental group was taught using the Thinking Frames Approach, whereas the control group was taught using the traditional method. Table 3.6 provides a summary of the various contents that were covered during the research, the treatment activities for experimental and control groups are illustrated in Table 3.7 and 3.8 respectively.

Table 3.6: Content of Genetics taught to Participants (Students)

SPECIFIC OBJECTIVES	CONTENT
The student will be able to:	
1. Explain and define some terms used in genetics with examples	Definition of terms with examples
2. Explain the basis of heredity and the concept of inheritance.	Heredity and Inheritance
3. Explain how hybrids are formed and Gene interacts	Hybrid formation and gene interaction
4. Explain variation, causes of variation consequences of variation and DNA recombinant.	Variation, causes of variation, consequences of variation and DNA recombinant.

3.10.3 Intervention Activities

Since the various groups were exposed to different treatments (teaching methods), treatment activities therefore differed across the two groups, thus Thinking Frame Approach and Conventional group. Tables 3.7 and 3.8 highlight the treatment activities for all groups.

Table 3.7: Intervention Activities for Thinking Frames Approach

TFA steps	Teacher and Students Activities
1. Setting the Scene (PDEODE) group/whole-class discussion	a) The teacher challenges alternate conceptions with a hands-on example in a real-world setting. b) To describe what transpired during the demonstration, students collaborate in groups and apply the Predict, Discuss, describe, Observe, Discuss, and Explain (PDE) framework. Based on the observations, groups employ argumentation to generate a verbal response to a higher-level thinking question, which is then presented to the class. The teacher leads students to think about the scientific model by asking questions.
2. Brainstorming	Students collect terms and expressions that they think will help them answer the issue.
3. See/Visualise	Students use labeled diagrams or visual timelines to create and convey their spoken representations.
4.Think/Sequence	Students create dot points for "what happens" and "why," building on the visual depiction of concepts and important terms. Students next write a paragraph explaining the phenomena and responding to the first questions using the main ideas that were thus generated.
5. Evaluation	The teacher assesses students' work based on how well they used scientific language and how well their explanations addressed cause and effect.

Teaching method introduced to the control group was mainly teacher-centered, precisely, lecture, as presented in Table 3.8

Table 3.8: Intervention Activities for Conventional Group

Stage	Activities
Stage 1 Introduction	The teacher presented the lesson to the students
Stage 2 Development	The teacher explained key points and write notes for students to copy
Stage 3 Application	The teacher gave students in-class examples and questions to solve
Stage 4 Evaluation	Using both formative and summative assessment techniques to determine the achievement of lesson objectives.

3.10.4 Post-Intervention Stage

Following the intervention phase, a posttest was administered, and students in the experimental and control groups had sixty minutes to finish it. Eight students were randomly selected from the experimental group to participate in the focus group interview. This was carried out in order to ascertain the students' opinions of the TFA in relation to the classroom teaching and learning of genetics.

3.11 Data Analyses Procedure

This study adopted quasi-experimental with mixed-method approach; therefore, data was analysed both quantitatively and qualitatively. To process, manipulate, and analyze the scores from the pre-intervention test and post-intervention test, descriptive and inferential statistical techniques was employed via Statistical Package for Social Sciences (SPSS) version 27.

Research Question 1

What is the effect of thinking frames approach on students' performance in genetics?

Research question one was answered using Wilcoxon Sign rank to analyse the effect of TFA on SHS biology students' performance in genetics.

Research Question 2

What difference exists between the academic performance of males and females' biology students instructed with the thinking frames approach in genetics?

Research question 2 was analysed using Mann Whitney U test to evaluate the difference in academic performance of males and females instructed using TFA.

Research Question 3

What is the difference between the academic performance of students taught genetics using TFA and those taught using conventional approach in genetics?

Research question 3 was analysed using Mann Whitney U test to evaluate the difference in academic performance of students taught genetics using TFA and those taught using conventional approach in genetics.

Research Question 4

What are the views of SHS biology students on the use of TFA in teaching and learning of genetics?

Responses from focus group interview were transcribed and analysed using Braun and Clarke reflexive thematic analysis to ascertain the views of students on the use of TFA.

3.12 Ethical Considerations

The collection of data from human subjects for any reason without ethical approval would be regarded as unethical in educational research (Creswell, 2014). Therefore, when a researcher or a group of researchers conduct qualitative, quantitative, or mixed-method research in educational institutions, ethical issues must be considered. Some of the ethical issues considered in this study are discussed in the following sub-sections.

Participating students were assured of their confidentiality of any data provided relating to this study. Consequently, confidentiality was ensured before, during, and after the study. For example, students were assured of their anonymity. The researcher initially briefed the participants on the study's objectives and provided confidentiality protection and anonymity procedures to report the research results. Hence, their names were not disclosed in any way. Additionally, participants were assured that any information they provide would not be used against them in any way.

Informed consent generally refers to the idea that before human participants volunteer to participate in research, they should have full disclosure about their involvement in it. Participants must be aware of the purpose of the study and freely choose to participate (Cohen *et al.,* 2018). Thus, the study's participants were fully informed of what was asked of them, how the data would be used, and more importantly, what (if any) potential effect there could be. The study followed all criteria for the privacy of the participating schools and the participants. Communications between the participants and the researcher was initially made possible through the approval of the respective authorities of the selected school.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

The results and discussions of this investigation are presented in this chapter. The goal of this chapter is to provide a thorough analysis of the information gathered, starting with a close look at the research participants' demographics. The chapter also looked at additional in-depth assessments. Descriptive and inferential statistics were used to analyze the collected data. The Statistical Package for the Social Sciences (SPSS) version 27 was used to compile, sort, and code the participant data. The following research questions serve as the basis for the findings:

1. What is the effect of thinking frames approach on students’ performance in genetics?
2. What difference exists between the academic performance of males and females’ biology students instructed with the thinking frames approach in genetics?
3. What is the difference between the academic performance of students taught genetics using TFA and those taught using conventional approach in genetics?
4. What are the views of SHS biology students on the use of TFA in teaching and learning of genetics?

4.1 Demographic Characteristics

The gender distribution within both the experimental and control groups is a critical component of the study’s analysis, it provides insights into the demographic composition of each group and setting the stage for a more nuanced interpretation of academic performance outcomes (Figure 4.1).

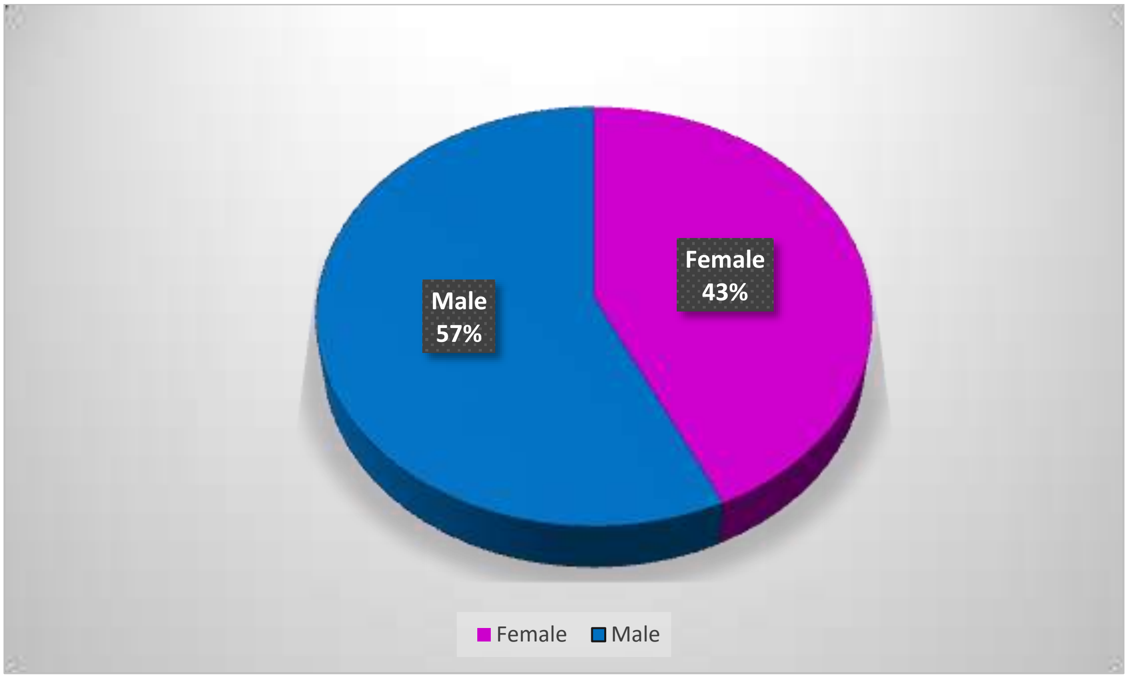


Figure 4.1: Gender Distribution of Participants

Out of the total sample (200), 43% (86) of the participants were females, while 104 were males representing 57%. This distribution indicates a higher representation of male students compared to their female counterparts in the study sample.

4.2: Data Suitability

Prior to analysing the study's outcomes, normality tests were performed to ensure that the data was suitable. The findings are presented in the following subsection: The scores from the students in this study was subjected to a normality test to determine whether parametric or non-parametric tests should be used. Normality checks were carried out utilizing the numerical approach. Thus, mathematically, the Kolmogorov-Smirnov and Shapiro-Wilk tests were performed. Normality tests were performed under the "null hypothesis that the data sets are normally distributed" (Pallant, 2011a). This indicates that the null hypotheses are rejected when the Kolmogorov-Smirnov test yields a p-value larger than 0.05. Table 4.1 presents the results of the normality tests.

Table 4.1: Results of Normality on students' Scores

Groups	**Kolmogorov-Smirnov**[a]			**Shapiro-Wilk**		
	Statistic	**Df**	**Sig.**	**Statistic**	**Df**	**Sig.**
Pretest of Experimental Group	.124	96	.001*	.934	96	.001*
Posttest of Experimental Group	.168		.001*	.912		.001*
Pretest of Control Group	.096		.030*	.972		.035*
Posttest of Control Group	.135		.001*	.956		.003*

a. Lilliefors Significance Correction
***Significant since p < 0.05**

Table 4.1, presents the results of normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) conducted to assess whether students' pretest and posttest scores were normally distributed for both the experimental and control groups. Across all groups, the significance values (p-values) for both tests were less than 0.05. The experimental group's pretest and posttest scores had Shapiro-Wilk p-values of .001, and the control group's posttest score had a Shapiro-Wilk p-value of .003. Since all p-values are below the threshold of .05, the assumption of normal distribution is violated. This justified the use of non-parametric statistical tests such as the Wilcoxon Signed Rank Test and the Mann-Whitney U Test for further analysis in the study.

4.3 Results of the Study

4.3.1 Results for Research Question 1

What is the effect of thinking frames approach on students' performance in genetics?

The impact of thinking frames approach on student performance was objectively assessed. This was accomplished by conducting a Wilcoxon signed-rank test on students' pretest and posttest results in the experimental group. Table 4.2 displays the Wilcoxon signed-rank test on pretest and posttest scores.

The effect of thinking frames approach on students' performance in genetics

Table 4.2: Wilcoxon Sign rank Test results on the effect of TFA on students' performance in genetics.

Groups	N	Test Statistic	Mean	z	r	*p*
Pretest	104	5460	9.2	8.86	0.87	.001*
Posttest			35.9			

***Significant since $p < 0.05$**

Table 4.2 shows the results of the Wilcoxon Signed Rank Test, which was used to determine the impact of the Thinking Frames Approach (TFA) on students' performance in genetics. The analysis compared the pretest and posttest scores of 104 students in the experimental group. The test yielded a significant result (p = .001), with a large z-value (8.86) and a very strong effect size (r = 0.87). The increase in mean ranks from the pretest (9.2) to the posttest (35.9) demonstrates a substantial improvement in performance. These findings indicate that the TFA had a statistically significant and practically meaningful positive effect on students' understanding and achievement in genetics.

4.3.2 Results for Research Question 2

What difference exists between the academic performance of male and female biology students instructed with the thinking frames approach in genetics?

The difference in student performance between males and females was determined by performing a Mann-Whitney U test on both students' pretest and posttest scores to offer rationale for the intervention. The Mann-Whitney U test was performed since the data was not normally distributed. Table 4.3 shows the Mann-Whitney U test of the students' pretest results prior to the intervention.

Difference between the academic performance of males and females' biology students instructed with the thinking frames approach in genetics.

Table 4.3: Mann Whitney U test results on the Pretest of male and female biology students taught genetics using the Thinking Frames Approach.

Groups	N	*U*	Mean rank	z	*p*
Female	47	1165.50	48.8	-1.14	.254
Male	57		55.55		

Table 4.3 presents a gender-based comparison of pretest scores within the experimental group using the Mann-Whitney U test. Female students (N = 47) had a mean rank of 48.8, while male students (N = 57) had a mean rank of 55.55. The z-value of -1.14 and the p-value of .254 suggest that the difference is not statistically significant. These results imply that male and female students had comparable levels of prior knowledge in genetics before the TFA intervention.

The posttest result of male and female students taught genetics using the thinking frame approach is presented on table 4.4.

Table 4.4: Mann Whitney U test results on the Posttest of male and female biology students taught genetics using thinking frame approach

Groups	N	*U*	Mean rank	z	*p*
Female	47	1226.5	50.1	-0.76	.446
Male	57		54.48		

Table 4.4, examines posttest performance differences between male and female students within the experimental group after the TFA intervention. Female students had a mean rank of 50.1, while male students had a slightly lower mean rank of 54.48. The z-value (-0.76) and p-value (.446) indicate that the difference is not statistically significant. This result suggests that the TFA was equally effective for both male and female students, with no gender-based disparity in performance following the intervention.

4.3.3 Results for Research Question 3

What is the difference between the academic performance of students taught genetics using TFA and those taught using conventional approach in genetics?

The difference in student performance between the two groups was determined by performing a Mann-Whitney U test on both students' pretest scores to offer rationale for different interventions. The Mann-Whitney U test was performed since the data was not normally distributed. Table 4.5 and 4.6 shows the Mann-Whitney U test of the students' pretest and posttest results prior to the intervention.

Difference between the academic performance of students taught genetics using TFA and those taught using conventional approach in genetics.

Table 4.5: Mann Whitney U test results on the Pretest of students taught genetics using TFA and those taught using conventional approach in genetics.

Groups	**N**	***U***	**Mean rank**	**z**	***p***
Control Group	96	5085	99.53	.23	.82
Experimental Group	104		101.39		

Table 4.5 reports the Mann-Whitney U test results comparing the pretest scores of the control group (N = 96) and the experimental group (N = 104). The mean ranks were 99.53 for the control group and 101.39 for the experimental group. The z-value (.23) and the p-value (.82) indicate no statistically significant difference between the two groups before the intervention.

The posttest results of students taught genetics using the thinking frame approach and those taught using conventional approach in genetics is presented on Table 4.6.

Table 4.6: Mann Whitney U test results on the Posttest of students taught genetics using TFA and those taught using conventional approach in genetics.

Groups	N	*U*	Mean rank	z	r	*p*
Control Group	96	9984	48.5	12.27	0.87	.001*
Experimental Group	104		148.5			

***Significant since p < 0.05**

Table 4.6 provides the results of a Mann-Whitney U test comparing the posttest scores of students in the experimental group (who received the TFA intervention) and the control group (taught using conventional methods). The experimental group had a substantially higher mean rank (148.5) compared to the control group (48.5). The test yielded a highly significant z-value (12.27) and p-value (.001), with a large effect size (r = 0.87). These results strongly indicate that the Thinking Frames Approach significantly enhanced students' academic performance in genetics compared to traditional teaching methods**.**

4.3.4 Results of Research Question 4

The views of SHS biology students on the use of TFA in teaching and learning of genetics

This research question sought to determine how students taught using the Thinking Frames approach view or perceive its effectiveness. Therefore, to answer this research question, a face to face, semi structured interview was conducted. Students' views were recorded with their permission and transcribed using reflexive thematic analysis developed by Braun and Clarke (2006). It was discovered that students had positive insights about the integration of Thinking Frames approach in teaching and learning genetic concepts. The various themes generated from the interview are presented in Table 4.7, with explanations and representative statements from students (all names are pseudonyms).

Table 4.7: Thematic presentation of Student's views on the Thinking Frames approach

Themes	Topic
Theme 1	Improved Understanding in Genetic Concepts
Theme 2	Increased interest in Genetics
Theme 3	Retention of the Concept
Theme 4	Confident in solving genetic Questions
Theme 5	Real-Life Application

Theme 1: Improved Understanding of Genetic Concepts

Many students reported that the use of Thinking Frames Approach significantly enhanced their understanding of genetic concepts such as variation, allele, inheritance etc. compared to traditional instructional methods. These topics, often abstract and invisible to the naked eye, were rendered tangible through pictures videos in the predict, observe and explain stage in the thinking frames approach. This allowed students to manipulate genetic structures, observe dynamic processes, and receive real-time feedback, thereby promoting conceptual clarity and improved academic outcomes. These advancements not only facilitated a deeper engagement with the material but also fostered collaborative learning environments where students could explore complex ideas together. As a result, educators observed a marked increase in student confidence and enthusiasm towards the subject matter, ultimately leading to better understanding of knowledge. The views of the student to bolster this claim include:

Student1 who asserted that; "At first, I thought genetics was a very hard and boring topic in biology but when I was introduced to it, it seemed very good and understandable to me. I really loved the topic. I was able to accomplish my long-cherished questions which seemed very rhetorical to me at first. I enjoyed the contributions by Gregor Mendel, the father of genetics".

Student 2 also asserted that; "Yes, I really understood genetics and it was interesting to me because genetics is a topic quite confusing but due to the method of teaching you used it helped me understand it a lot".

Student 3 also assessed that, "my understanding in genetics has been improved greatly because the lessons on genetics were real to me due to, the videos and pictures used".

Student 4 also assessed that; "the method of teaching genetics as a study has help me to understand somethings I did not know before include genotype, phenotype, blood group, rhesus factor, mutation and many more, it has also given me more knowledge on agglutination and its consequences".

Student 5 assessed that "how genetics was taught has given me more knowledge and understanding on blood transfusion and detailed information in genetics which was very difficult for me, especially about antigens and antibodies".

Theme 2: Increased interest in Genetics

Students expressed that learning genetics using Thinking Frames Approach reignited their interest in the subject. Previously, many found genetics abstract, unrelatable, or overly difficult. However, the Thinking Frames Approach introduced, interactivity, and learner autonomy transforming the classroom from a passive to an engaging learning environment. This was effective because;

Student 6 poised that, "genetic itself is broad topic which needs attention and participation in it and the way and method used to teach made it very easy and interesting".

Student 7 also assessed her interest in genetics saying, "the class was interactive, the teacher did not spoon feed me but facilitated. I now find interest in every term I couldn't explain and have deeper understanding in it now".

Student 1 also voiced that, "genetics was one of the topics so many teachers have been teaching me but I couldn't get the detailed explanation because of the method used which was very one sided on the part of the teacher which made me inactive, but for this method it is very interesting and makes the class very interactive".

Student 2 also assessed that "I found genetics interesting because of the method used which involved illustrations, diagrams, pictures, and videos for us to understand every point and every lesson".

Theme 3: Retention of the Concept

Students reported that the thinking frames approach significantly enhanced their ability to retain and recall genetic concepts. The combination of interactive activities and visual explanations enabled students to adopt processes such as variation, rhesus factor, and mutation. Unlike traditional methods that often relied heavily on text and teacher-centred lectures, the thinking frames approach allowed learners to manipulate genetic models, observe step-by-step animations, and revisit difficult processes thereby strengthening memory through engagement and retention.

Student 3 noted that; "Sir, because we watched videos on the genetics to get clear understanding of the concept it has really stuck in my brain".

Student 4 also noted that; "the diagrams and the method of teaching has helped my understanding and can now draw genetic diagrams and explain concepts in my WASSCE when we start".

Student 6 also noted that, "Sir, the method you used has make me recapture and remember the genetic concepts".

Student 8 noted that, "Sir, I can now with the kind of methos you used when I go home, I can teach my parents about deletion, inversion, insertion and translocation of chromosomes".

Theme 4: Confident in solving genetic Questions

Many students reported that the Thinking Frames approach significantly increased their self-efficacy with colleagues in the classroom during learning of genetics. The use of real-world examples and scenarios made the lessons more interesting and relatable. Some views of the students from the focused group discussions included:

Student 7 who declared that, "I am confident in solving genetic questions because I really understood every aspect of genetics during the lesson and have been educated enough to solve questions related to genetics".

Student 5 also propounded that; "Yes! I can solve genetic questions because from the beginning the method used mesmerized me and my curiosity being piqued made me fond of the topic and can now solve genetic questions without any confusion".

Student 4 stated that, "I'm very glad I can solve genetic questions now because the method used to teach was really helpful and made me full of joy".

Student 1 propounded that "Sir, I am very optimistic in solving questions concerning genetics because the teacher method used to teach made us felt very okay due to the fact that we were very active in the lesson".

Theme 5: Real-Life Application

Students who were in the experimental groups expressed that the Thinking Frames approach enabled them to connect rhesus factor, variation, inheritance, agglutination, ABO blood transfusion to real-life biological and social contexts. What had previously seemed abstract and difficult to relate to everyday experience was now perceived as tangible and relevant. Through visual representation and interactivity, learners were able to recognise the role genetics plays in personal health, family inheritance, and biological identity. This is further reinforced by the views of;

Student 6 who asserted that, "the videos and diagrams used to explain the ABO blood system has help me understand the reason I need to know my blood group whether I'm viable to donate blood to another person".

Student 3 also asserted that, "having a Siamese twins and people having undeveloped hands and ears is not related to witches and wizards but it's purely scientific and its embedded genetically".

Student 2 also poised that, "black man can give birth to an albino when he and her wife carries the recessive gene of albino in them".

Student 1 also proclaimed that "I now know the reason behind a couple being fair in complexion but gives birth to children who are dark in complexion".

Student 5 decreed that "many things said to her by her grandmother is purely superstition and have had greater and deeper understanding of genetics and can now teach her grandmother and parents as well".

The findings from the thematic analysis indicated that the Thinking Frames approach to teaching genetics was highly effective in enhancing student engagement, understanding, and interest. By linking genetic concepts to real-world life, students found the material more relevant and meaningful. This approach not only improved their comprehension of the subject matter but also motivated them to apply their knowledge in practical ways and pursue further studies in the field of genetics.

4.4 Discussion of Results

The study's results are examined in this part in light of the research questions. The study investigated if the Thinking Frames Approach improves biology students' academic performance more successfully than the traditional approach. Gender was included as a moderating variable because the sample comprised both male and female students. The outcomes of the research questions serve as a reference for discussing the findings in light of the study's variables.

4.4.1 Discussion of Findings for Research Question 1

The effect of Thinking Frames Approach on students' academic performance in genetics.

Findings from the study demonstrated that students who were taught using the TFA showed a statistically significant improvement in their academic performance compared to their pre-intervention results. The Wilcoxon Signed Rank Test revealed a large effect size (r = 0.87) with a highly significant p-value (p = .001), indicating that the TFA produced meaningful learning gains and strongly enhanced conceptual understanding in genetics. This suggests that TFA is not only effective in supporting knowledge acquisition but also in improving overall student achievement in complex biology topics. These results are consistent with empirical evidence from earlier studies that highlighted the value of TFA in science classrooms. For example, Higgins and Baumfield (2004) reported that TFA improved students' ability to explain and reason scientifically, while McClure, Newbery, and Bird (2008) found that it facilitated structured reasoning and promoted independent thought. Similarly, Fensham and Bellocchi (2013) demonstrated that TFA enhanced students' academic achievement, particularly in abstract areas such as chemical bonding, by reducing cognitive overload and providing visual scaffolds. The present study's findings extend these conclusions to the context of genetics education in Ghana.

Genetics, by its very nature, involves abstract and multi-layered concepts such as gene expression, segregation, and molecular inheritance. Students often find these topics difficult to understand, leading to persistent misconceptions and poor performance. Chapman and Martin (2021) opined that students struggle with ideas such as dominance and allele interactions, and they recommended the use of structured scaffolds similar to TFA to overcome these difficulties.

Findings from this study affirm that TFA is a powerful pedagogical tool for making genetics more comprehensible and less intimidating for learners. One reason for this effectiveness is that TFA provides students with both visual and verbal scaffolds, enabling them to externalize their thought processes. The use of diagrams, sentence starters, and sequencing templates allows learners to organize, refine, and communicate their reasoning systematically.

Research by Treagust et al. (2018) further supports this by showing that visual scaffolding helps students to sequentially connect prior knowledge with new scientific concepts. In the context of the present study, these scaffolds likely reduced cognitive overload and helped students navigate the abstract relationships inherent in genetics. The findings also align with constructivist learning theories, which underpin the TFA. Constructivism emphasizes that learners actively build their understanding through reflection and interaction, rather than passively receiving knowledge. As McClure et al. (2020) observed, the greatest benefits of TFA emerge when teachers integrate the frames into inquiry-based learning and reflective dialogue.

In this study, students were encouraged to generate explanations, justify their ideas, and revise their misconceptions within structured frames. This process mirrors the constructivist goal of fostering deeper conceptual change and higher-order thinking.

Furthermore, the results of the present study resonate with literature on metacognition in science learning. TFA explicitly supports metacognitive awareness by requiring students to reflect on their thinking, monitor their explanations, and evaluate their reasoning. Andrade (2019) noted that such metacognitive interventions improve learners' ability to regulate their thinking in tasks that require explanation and argumentation. This suggests that the improvement in genetics performance observed in this study were not simply due to memorization but a reflection deeper level of cognitive engagement.

An additional implication of these findings is the role of TFA in promoting equity and inclusion in the classroom. Research by Martínez-Hernández and Suárez (2021) found that graphic organizers and structured scaffolds are especially beneficial for students with weaker backgrounds or limited prior knowledge

4.4.3 Discussion of Findings for Research Question 2

Difference in academic performance of male and female biology students instructed with the thinking frames approach in genetics.

The Mann-Whitney U test was used to examine gender-based differences in pretest and posttest scores of male and female biology students taught genetics using the Thinking Frames Approach (TFA). The pretest results (Table 4.3) show that female students (N = 47, Mean Rank = 48.8) and male students (N = 57, Mean Rank = 55.55) had comparable levels of prior knowledge in genetics, with the z-value of -1.14 and p-value of .254 indicating no statistically significant difference. Similarly, the posttest results (Table 4.4) revealed that female students (Mean Rank = 50.1) and male students (Mean Rank =

54.48) performed at nearly the same level after instruction, with a z-value of -0.76 and p-value of .446, again showing no significant difference. These findings suggest that the TFA intervention was equally effective for both genders and did not create or widen performance gaps.

Gender differences in science achievement have long been debated. While some research points to narrowing gender gaps in recent years (Tanner & Jones, 2007), others highlight persistent disparities in particular domains. Large-scale international assessments such as TIMSS and PISA reveal that boys often outperform girls in physics and chemistry, while girls tend to perform equally or slightly better in biology (Mullis et al., 2020; OECD, 2019). However, this trend does not consistently extend to all biology subfields. Genetics, in particular, requires abstract reasoning, symbolic manipulation, and probabilistic thinking, which are often linked to male students' strengths in spatial and model-based reasoning (Wilgenbusch & Finson, 2000). Conversely, female students' strengths in detail orientation, reading comprehension, and memorization (Brotman & Moore, 2008) may not fully compensate for the abstract demands of genetics, potentially leading to mixed findings on gender performance in this topic.

This study is in consistent with Gericke and Wahlberg (2013), who noted that male Swedish students showed greater accuracy and confidence in molecular genetics tasks involving symbolic reasoning, while female students demonstrated a stronger descriptive understanding but less confidence in abstract problem solving. Similarly, Zohar and Sela (2003) reported that boys tend to adopt systemizing, logic-based strategies, while girls often employ narrative or contextual approaches. In African contexts, gender disparities in genetics achievement are often reinforced by socio-cultural dynamics and classroom practices. Adesoji and Raimi (2020), for instance, found that Nigerian male students outperformed females in multi-step reasoning tasks in genetics, attributing the disparity to gender-biased interactions and unequal access to enrichment activities.

However, when equitable instructional methods such as TFA, inquiry-based learning, and collaborative problem-solving are employed, gender disparities tend to diminish. Studies show that structured scaffolds allow both male and female students to engage confidently with abstract science content (Achor, 2024 McLure, 2020; Etobro & Fabinu, 2017). By providing visual, verbal, and conceptual supports, the TFA guides learners through systematic reasoning steps, neutralizing the influence of gender-specific cognitive preferences. This finding is consistent with recent studies showing that structured pedagogical strategies can minimize gender-linked differences in performance (Usher & Morris, 2022; Millar & Atkinson, 2020).

This present study reinforces the argument that gender disparities in science learning are not innate but shaped by context, pedagogy, and classroom culture. As Hyde (2016) and Wang and Degol (2017) argue, curriculum design and teaching strategies often account more for performance gaps than inherent ability differences. The fact that no significant gender difference was found in both the pretest and posttest results highlights the importance of equitable instructional design. Moreover, it reflects that prior knowledge in genetics did not differ significantly by gender (Makarova et al., 2019; Stoet & Geary, 2018), and that the TFA provided an inclusive learning environment where both boys and girls benefitted equally.

These findings carry practical implications for science education. Beede et al. (2021) and UNESCO (2022) emphasize that gender-responsive pedagogies are critical in closing achievement gaps in STEM fields. The neutrality of the outcomes here suggests that the TFA does not privilege one gender over another but instead promotes inclusive engagement. Classroom discourse also plays a role; as Alvermann and Moore (2022) note, boys often dominate group discussions, while girls may be more hesitant to take intellectual risks. Structured scaffolds like TFA, however, ensure that all learners can participate meaningfully regardless of assertiveness or confidence levels.

From a policy perspective, integrating evidence-based approaches such as TFA into teacher training and curriculum development can enhance both equity and effectiveness in science instruction. As Azevedo and Marques (2023) argue, cognitive scaffolding tools not only improve performance but also create fairer assessment outcomes across demographics. The results of this study therefore provide empirical support for the adoption of TFA as a gender-sensitive instructional model in genetics teaching.

In conclusion, the absence of statistically significant gender differences in both pretest and posttest results demonstrates that the Thinking Frames Approach promotes equitable learning outcomes in genetics. This aligns with global goals of minimizing achievement gaps in STEM education and confirms the value of inclusive, scaffolded instructional strategies. By adopting approaches such as TFA, educators can foster gender-equitable learning experiences that empower all students to master complex science concepts.

4.4.4: Discussion of Findings for Research Question 3

Difference between the academic performance of students taught genetics using TFA and those taught using conventional approach in genetics.

The Mann-Whitney U test was employed to compare the academic performance of students taught genetics using the Thinking Frames Approach (TFA) with those taught through conventional methods. The pretest results (Table 4.5) revealed that the control group (N = 96, Mean Rank = 99.53) and the experimental group (N = 104, Mean Rank = 101.39) had statistically comparable levels of prior knowledge, with a z-value of .23 and a p-value of .82 indicating no significant difference. This baseline equivalence confirmed that both groups began the study on an equal footing, ensuring that subsequent differences in achievement could be attributed to the instructional method rather than variations in prior knowledge (Zhou et al., 2022; Millar & Atkinson, 2020).

The posttest results demonstrated a striking divergence between the two groups. Students in the experimental group, who were taught using TFA, achieved a substantially higher mean rank (148.5) compared to those in the control group (48.5). The test yielded a highly significant z-value of 12.27, a p-value of .001, and a large effect size (r = 0.87). These results provide compelling evidence that TFA significantly enhanced students' academic performance in genetics, far surpassing the outcomes of conventional teaching methods.

The effectiveness of TFA can be attributed to its scaffolded and structured learning design. Unlike conventional lecture-based methods, which often promote rote memorization, TFA supports conceptual understanding through visual diagrams, guided questioning, and structured reasoning. Such scaffolding is particularly effective in genetics, a topic that demands abstract and hierarchical reasoning (Cooper et al., 2019). By encouraging students to articulate thought processes, identify patterns, and connect concepts, TFA fosters deeper comprehension and long-term retention of knowledge (Ainsworth & Loizou, 2020).

This present study is in consistent with Tang and Chan (2021) who argued that lecture-based instruction does not adequately support learners' active engagement in conceptually challenging areas of science, reinforcing the need for constructivist, student-centered approaches. The findings of this study strongly align with such perspectives, demonstrating that TFA offers a more effective pathway for mastering genetics concepts. Beyond test scores, the large effect size (r = 0.87) suggests that TFA likely improved students' confidence, motivation, and engagement in science learning. Active learning approaches such as TFA are known to increase student participation and foster positive attitudes toward learning, particularly when students feel supported by tools that help them organize and apply their ideas (Mclure et al., 2020). These metacognitive and affective benefits further strengthen the case for adopting TFA in science classrooms. This outcome is consistent with broader educational reforms that emphasize inquiry-based and visual learning strategies as effective tools for advancing STEM education. UNESCO (2022) stresses the importance of learner-centered pedagogies that empower students to develop critical reasoning and problem-solving skills, which are essential for success in modern scientific fields. TFA, by combining visual scaffolds with structured reasoning, embodies these principles and demonstrates their value in improving genetics learning outcomes.

4.4.2 Discussion of Findings for Research Question 4

The views of SHS biology students on the use of TFA in teaching and learning of genetics.

Understanding students' views of the instructional strategies used in their classrooms is critical to evaluating the success and sustainability of those methods. The Thinking Frames Approach (TFA), which combines visual scaffolding with metacognitive prompts to support students in constructing scientific explanations, has been praised not only for improving learning outcomes but also for fostering positive student engagement, increased confidence, and greater ownership of learning (McClure & Newbery, 2018). Empirical studies suggest that students generally respond positively to the use of thinking frames in science learning (Gilbert & Justi, 2016; Grevatt, Gilbert, & Newberry, 2007). Learners often report that the structured format of TFA helps them organize their thoughts, clarify difficult concepts, and improve their ability to explain scientific ideas. In McClure et al.'s (2018) *Learning to Learn* project, students expressed that thinking frames made science "less confusing" and "easier to write about." They appreciated the visual representation of cause-effect relationships, especially in topics like genetics and chemical reactions, where sequences and connections between ideas are essential. Students have also reported that TFA enhances their confidence in learning science. In a study by Aydogdu and Kesercioglu (2021), learners noted that visual thinking tools helped them feel more in control of their learning. Rather than relying solely on memorization, students found they could explain processes in their own words, reflect on their understanding, and identify gaps in their reasoning. This self-monitoring aspect central to TFA's design encouraged learners to engage more meaningfully with scientific content (Franke, & Bogner, 2013).

Learner feedback also emphasizes preference for guided structure over open-ended tasks. While inquiry-based learning and problem-solving approaches encourage autonomy, they can be cognitively overwhelming for students without adequate scaffolding. TFA serves as a bridge between structure and autonomy, helping students internalize scientific reasoning patterns while still giving them space to articulate ideas in personalized ways (Zohar & Barzilai, 2015). Students particularly valued explanation frames that used sentence starters (e.g., "This happens because…", "As a result…"), which helped them construct coherent, written responses in science assessments (Tanner & Jones, 2007).

Moreover, students who initially struggled with science content or lacked confidence in their academic abilities expressed that TFA made science more accessible. In a study by Mclure, (2020), low-achieving students in chemistry showed significant gains in understanding and participation after being taught using TFA. Interviews revealed that these students felt less intimidated when working with thinking frames, as the templates gave them a sense of direction and structure. However, some students have voiced challenges with TFA, particularly when frames are used repetitively or without teacher modeling. When students are introduced to multiple frame types without adequate explanation, the strategy can become confusing rather than helpful.

Research by Karamustafaoğlu and Kandaz (2022) found that while most students appreciated visual tools, they preferred when teachers used them interactively discussing the components of the frame together before individual work. This finding underscores the importance of teacher guidance and gradual introduction of TFA tools for successful adoption. Engagement studies also show that TFA supports collaborative learning. When used in group settings, thinking frames prompt students to articulate and debate scientific explanations, which strengthens peer learning and conceptual clarity (McClure *et al.,* 2018; Newberry *et al.,* 2011). Students often reported enjoying discussions around their frame responses, noting that it helped them see other perspectives and refine their understanding through feedback. Students' views on the use of Thinking Frames in science learning are largely positive. Learners appreciate the structure, clarity, and support that TFA provides, particularly in cognitively demanding topics like genetics. It enhances their confidence, deepens engagement, and supports metacognitive development. While challenges exist mainly related to poor implementation or overuse research consistently shows that when used effectively, TFA is not only a beneficial instructional tool but also a learner-preferred approach in science education.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER STUDIES

5.0 Overview

The main conclusions drawn from the data analysis in the preceding chapter are summarized in this chapter. It draws conclusions based on the results, highlighting the impact of Thinking Frames Approach on Senior High School students' understanding of genetics. The chapter further provides recommendations for educators, policymakers, and researchers, aimed at enhancing science instruction through the integration of digital tools. Lastly, it outlines suggestions for future research to build upon the insights gained from this study.

5.1 Summary of Key Findings

This study set out to evaluate the effectiveness of TFA on Senior High School students' performance in genetics. The research questions aimed to determine (1) the effect of TFA on students' academic performance, (2) students' views of TFA in genetics learning, and (3) gender differences in performance when TFA is applied and the difference in performance of using TFA and conventional method. The study found a significant positive effect of TFA on students' academic performance in genetics. Quantitative analysis showed a statistically significant improvement ($p = .001$, $r = 0.87$), indicating that students taught using TFA performed better than those taught with conventional methods. Also, students generally held positive views toward TFA. They appreciated its structure, clarity, and the support it provided in understanding challenging genetic concepts. The approach increased their confidence, engagement, and ownership of learning, fostering a more active and motivated learning environment. The focus was on the overall positive impact of TFA across genders. In addition, students instructed with TFA outperformed their counterparts taught through conventional methods. The improvement was statistically significant, supporting the superiority of TFA in enhancing performance in genetics.

5.2 Conclusion

Based on the findings of the study, it can be concluded that the Thinking Frames Approach (TFA) is a highly effective instructional strategy for enhancing students' understanding, engagement, and performance in genetics. The significant improvement in academic achievement, coupled with positive student perceptions of clarity, confidence, and motivation, underscores the pedagogical value of TFA. Additionally, the approach benefits both male and female students, suggesting its broad applicability across gender. These results advocate for the integration of TFA into science curricula and professional development programs to foster deeper conceptual understanding and improve science education outcomes. Overall, TFA represents a promising innovation that can address persistent challenges in teaching complex scientific concepts like genetics.

5.3 Recommendations

Based on the findings and conclusions, the following recommendations are made:

1. It is advised that Biology instructors in the Mampong Municipality adopt the Thinking Frames Approach (TFA) when teaching genetics, as it helps students overcome learning difficulties and enhances their academic performance. Students perceived that TFA enabled them to connect new concepts to prior knowledge, promoted active engagement during lessons, and improved their retention of the concepts taught. Teachers in Mampong Municipal should phase out overreliance on traditional lecture-based methods in genetics instruction and promote TFA as a superior alternative that enhances conceptual clarity and leads to significantly better academic outcomes.
2. Since the study found no significant performance difference between male and female students taught with TFA, Mampong schools should encourage equitable implementation of the TFA across gender-diverse classrooms to foster inclusive science education and close traditional gender gaps in STEM.

5.4 Suggestions for Further Studies

Several avenues for further studies have been proposed based on the findings of this study. First and foremost, future researchers should consider conducting studies with larger, normally distributed samples to enable the use of parametric tests such as t-tests or ANOVA for greater statistical power when evaluating TFA's effectiveness.

Also, future researchers may consider conducting a longitudinal study to explore the retention of genetics knowledge among students who are taught using TFA. While the current study revealed immediate academic gains, it remains unclear whether these improvements persist over an extended period. Investigating the long-term effects of Thinking Frames Approach will provide valuable insight into its sustainability and influence on lasting conceptual understanding.

Lastly, future researchers may consider exploring the effectiveness of TFA across diverse educational settings, including various regions, school types, and among different age groups, to assess its generalizability.

REFERENCES

Achor, E. E. (2024). Gender equity in science teaching: A Nigerian perspective. *Journal of Science Pedagogy*, 18(1), 44–60.

Adak, S. (2017). Effectiveness of constructivist approach on academic achievement in science at secondary level. *International Journal of Research in Social Sciences*, 7(3), 460–466.

Adesoji, F. A., & Raimi, S. M. (2020). Gender differences in secondary school students' performance in genetics. *Nigerian Journal of Science Education*, 28(2), 123–135.

Adolphus, T., Aderonmu, T., & Onyeji, A. C. (2021). Diagnostic assessment of students' understanding of genetics concepts. *African Journal of Educational Research*, 15(1), 67–84.

Ahmed, A., & Abimbola, I. O. (2020). Effects of thinking frames on secondary school students' achievement in genetics. *Journal of Science Education Research*, 9(3), 14–26.

Ahmed, B. A., Opatola, A. A., Yahaya, L. A., & Sulaiman, J. A. (2018). Alternate conceptions in genetics among senior secondary school students in Nigeria. *Journal of Science Education, 7(2), 55–61.*

Ainsworth, S., & Loizou, A. T. (2020). The role of visual representations in learning genetics. *International Journal of Science Education*, 42(1), 56–78.

Akpan, B., & Beard, R. (2023). Constructivism and cognitive scaffolding in science education. *Science Education International*, 34(1), 8–18.

Almanasreh, E., Moles, R., & Chen, T. F. (2018). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *14*(8), 1–8.

Alvermann, D. E., & Moore, D. W. (2022). *Adolescent literacy: A position statement*. National Council of Teachers of English.

Amoako, G., & Ameyaw, E. (2022). Challenges facing teaching and learning of genetics in senior high schools in Ghana. *Ghana Journal of Education, Learning and Development,* 18(2), 101–115.

Ampiah, J. G. (2004). *Instructional strategies for effective teaching and learning of science in basic schools*. University of Cape Coast Press.

Ampofo, J. A., & Osei-Owusu, B. (2015). Academic performance in Ghanaian schools: Trends and challenges. *Ghana Education Review*, 10(2), 45–59.

Andrade, M. S. (2019). Metacognitive instructional strategies in science classrooms. *International Journal of Science and Mathematics Education*, 17(4), 589–607.

Andrade, M. S., Cook, K., & Page, M. (2016). Student collaboration and conceptual change in biology. *Journal of Biological Education*, 50(4), 380–392.

An, Y.-J., & Mindrila, D. (2020). Characteristics of learner-centered teaching in K–12 classrooms. *Educational Research Quarterly*, 43(4), 3–25.

Appiah, J. (2012). Constructivist teaching practices and students' academic achievement in basic science. *Ghana Journal of Education*, 9(1), 44–58.

Arias, A. M., Davis, E. A., & Palincsar, A. S. (2019). Professional development for assessment in science education. *Science Education*, 103(4), 907–938.

Aydogdu, B., & Kesercioglu, T. (2021). Students' perceptions of thinking frames in science learning. *Journal of Educational Research and Practice*, 11(2), 144–153.

Ayre, C., & Scally, A. J. (2014). Critical values for Lawshe's content validity ratio: Revisiting the original methods of calculation. *Measurement and Evaluation in Counseling and Development*, *47*(1), 79–86.

Azevedo, F., & Marques, R. (2023). The role of cognitive conflict in science education: A systematic review. *International Journal of Science Education, 45*(2), 213–234. https://doi.org/10.1080/09500693.2022.2163456

Beede, D. N., Julian, T. A., Langdon, D., McKittrick, G., Khan, B., & Doms, M. E. (2021). Women in STEM: A gender gap to innovation. *Economics and Statistics Administration Issue Brief*, 11(5), 1–10.

Begg, A. (2015). Constructivism: Theory and practice. *Mathematics Education Research Journal*, 27(3), 319–336.

Begum, R. (2018). Traditional teaching methods in science classrooms: A critical review. *Asian Journal of Education and Social Studies*, 5(2), 1–7.

Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, 53(7), 1082–1112.

Bhutto, M. Y., & Chhapra, I. U. (2013). Constructivist learning environment: A tool for academic success. *International Journal of Academic Research in Progressive Education and Development*, 2(3), 132–140.

Black, P., & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, 80(2), 139–148.

Bloom, B. S. (2013). *Taxonomy of educational objectives: The classification of educational goals*. David McKay Company. (Original work published 1956)

Bloomfield, D., Martin, S., & Peters, L. (2010). Conventional vs. learner-centered teaching in biology. *Science Education Review*, 9(2), 34–42.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, 45(9), 971–1002.

Bruner, J. S. (1960). *The process of education*. Harvard University Press.

Carter, M., Ferzli, M., & Wiebe, E. (2007). Writing to learn by learning to write in the disciplines. *Journal of Business and Technical Communication*, 21(3), 278–302.

Chapman, A., & Martin, S. N. (2021). Secondary students' misconceptions in genetics: A review. *International Journal of Science Education*, 43(1), 49–68.

Chang, J. Y., Sung, Y. T., & Chen, I. D. (2016). Multiple representations and science explanation. *Journal of Research in Science Teaching*, 53(7), 1020–1045.

Chifwa, S. M. (2015). *Impact of constructivist teaching strategies on students' performance in science*. Zambia Educational Journal, 12(1), 77–88.

Chika, E. (2012). Barriers to student-centered learning in science education in Africa. *Journal of Educational Policy and Entrepreneurial Research*, 2(5), 35–45.

Chu, H. (2008). Students' learning difficulties in genetics: A case study in the UK. *British Journal of Science Education,* 24(4), 309–321.

Cimpian, A., Mu, Y., & Erickson, L. (2019). Gender stereotypes and science participation. *Child Development Perspectives*, 13(2), 95–101

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum.

Cooper, B., Newberry, M., & McClure, J. (2019). Thinking frames and conceptual learning in biology classrooms. *Science Teaching Review*, 34(3), 128–143.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). SAGE Publications.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). SAGE Publications.

Creswell, J. W. (2014). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Pearson Education.

Creswell, J. W., & Clark, V. L. P. (2011). *Designing and conducting mixed methods research* (2nd ed.). SAGE Publications.

Creswell, J. W., & Tashakkori, A. (2007). Developing publishable mixed methods manuscripts. *Journal of Mixed Methods Research*, *1*(2), 107–111.

Crimer, D. (2019). The impact of teaching methods on students' achievement in science: A meta-analysis. *Journal of Educational Psychology*, 31(2), 112–130.

CRDD. (2010). *Biology teaching syllabus for senior high school*. Curriculum Research and Development Division, Ghana Education Service.

Danso, K. (2016). Senior high school students' misconceptions in genetics in Ghana. *International Journal of Educational Research*, 5(1), 27–39.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, 64, 135–168.

Dimitrios, B., Labros, S., Nikolaos, K., Maria, K., & Athanasios, K. (2013). Traditional teaching methods vs. modern teaching methods. *International Journal of Education and Research*, 1(4), 1–12.

Dogru-Atay, P., & Tekkaya, C. (2008). Constructivist instruction with computer animations: The effects on science achievement, science process skills, and attitudes toward science. *Journal of Science Education and Technology*, 17(4), 370–377.

Dorgu, T. E. (2015). Different teaching methods: A panacea for effective curriculum implementation in the classroom. *International Journal of Secondary Education*, 3(6), 77–87.

Doudna, J. A., & Charpentier, E. (2020). Genome editing: The new frontier of biomedical research. *Science*, 367(6481), 126–128.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23(7), 5–12.

Duncan, R. G., Freidenrich, C., Chinn, C. A., & Bausch, A. (2009). *Promoting scientific literacy: A conceptual framework*. Science Education, 93(5), 905–937.

Duncan, R. G., Rogat, A. D., & Yarden, A. (2009). A learning progression for genetics. *Journal of Research in Science Teaching*, 46(7), 655–674.

Duncan, R. G., & Reiser, B. J. (2007*).* Reasoning across ontologically distinct levels: Students' understandings of molecular genetics. *Journal of Research in Science Teaching,* 44(7), 938–959. https://doi.org/10.1002/tea.20186

Duncan, R. G., Rogat, A. D., Lee, H. S., & Mikeska, J. N. (2019). Assessment in genetics education. *Journal of Science Teacher Education*, 30(5), 487–505.

Duit, R., & Treagust, D. F. (2012). Conceptual change: A powerful framework for science teaching and learning. *International Journal of Science Education*, 34(7), 1027–1052.

Duit, R., & Treagust, D. F. (2012b). How can conceptual change contribute to theory and practice in science education? *International Journal of Science Education*, 34(2), 243–281.

Dutta, P. (2010). Classroom teaching: Traditional and modern methods. *Asian Journal of Educational Research*, 2(1), 40–46.

Dzidzinyo, B. (2020). Conceptual difficulties in genetics among SHS students in Ghana. *Journal of Science Education*, 14(2), 91–103.

Ebert, E. S., & Crippen, K. J. (2010). Teachers and technology: Using graphic organizers in science education. *Science Scope*, 33(9), 54–59.

Efgivia, M., Ali, R., & Adlina, S. (2021). Foundations of sociocultural constructivism in education. *Journal of Educational Psychology*, 39(3), 215–228.

Ekong, F. I., Akpan, B. B., Anongo, T., & Okrikata, E. (2015). Influence of selected variables on students' academic performance in genetics. *International Journal of Education and Research*, 3(9), 145–155.

Eisenkraft, A. (2003). *Expanding the 5E model*. Science Teacher, 70(6), 56–59.

Eseine, A. (2021). Gender differences and academic performance of students in biology in Nigeria. *Nigerian Journal of Education and Practice*, 13(1), 24–32.

Eseine-Aloja, G. N. (2021). Gender and cognition in science learning. *African Journal of Educational Studies*, 10(1), 1–15.

Etobro, A. B., & Fabinu, O. E. (2017). Students' perceptions of difficult concepts in biology in senior secondary schools in Lagos State, Nigeria. *Global Journal of Educational Research,* 16, 139–147.

Fauzi, A. (2018). Students' misconceptions in genetics: A study on high school students. *Journal of Physics*: Conference Series, **1013**(1), 012048. https://doi.org/10.1088/1742-6596/1013/1/012048

Fensham, P., & Bellocchi, A. (2013). Teaching abstract science with thinking frames. *Science Education Review*, 12(1), 15–26.

Fernando, S., & Marikar, F. M. M. T. (2017). Constructivist teaching/learning theory and participatory teaching methods. *Journal of Curriculum and Teaching*, 6(1), 110–122.

Fikadu, T., & Shimeles, S. (2019). Exploring gender differences in science achievement. *Ethiopian Journal of Science Education*, 12(2), 1–13.

Franke, G., & Bogner, F. X. (2013). Students' attitudes toward science using hands-on activities. *Journal of Science Education and Technology*, 22(5), 866–874.

Gericke, N., & Wahlberg, S. (2013). Students' understanding of molecular genetics. *Journal of Biological Education*, 47(2), 102–110.

Gericke, N., Wahlberg, S., & Hagberg, M. (2017). Assessing conceptual change in genetics. *Research in Science Education*, 47(1), 91–113.

Ghana Statistical Service. (2021). *2021 Population and Housing Census*. Accra, Ghana: GSS.

Gilbert, J. K., & Justi, R. (2016). *Modelling-based teaching in science education*. Springer.

González-Pienda, J. A., Fernández-Cueli, M., García, T., Valle, A., Rodríguez, C., & Cabanach, R. G. (2017). Self-regulation and academic achievement in science education. *Frontiers in Psychology, 8,* 481. https://doi.org/10.3389/fpsyg.2017.00481

Grevatt, J., Gilbert, J., & Newberry, M. (2007). Thinking frames: Tools for scientific thinking. *School Science Review*, 88(324), 93–100.

Griffiths, A. J. F., Wessler, S. R., Carroll, S. B., & Doebley, J. (2020). *Introduction to genetic analysis* (12th ed.). W. H. Freeman.

Gupta, M. (2013). Foundations of constructivist teaching. *International Journal of Learning and Development*, 3(5), 78–90.

Hadiprayitno, G., Muhlis, M., & Kusmiyati, K. (2019). Analysis of misconceptions on genetics concepts among high school students. *International Journal of Educational Research Review*, 4(1), 84–91.

Hargrove, C. (2023). Choosing effective teaching strategies. *Journal of Instructional Development*, 46(2), 101–116.

Herlina, S., & Ilmadi, Y. (2022). Constructivist learning in science classrooms. *Science Learning Journal*, 9(1), 40–48.

Hertzog, M. A. (2008). Considerations in determining sample size for pilot studies. *Research in Nursing & Health*, *31*(2), 180–191.

Higgins, S., & Baumfield, V. (2004). Thinking through science: Learning to Learn. *School Science Review*, 85(312), 65–72.

Hill, J. D. (2002). The traditional vs. progressive debate in teaching methods. *Teaching Journal,* 18(2), 45–58.

Hoque, M. E. (2016). Three domains of learning: Cognitive, affective and psychomotor. *Journal of Education and Practice*, 6(28), 1–8.

Hruby, G. G., & Roegiers, A. M. (2013). Piaget and education: A critical reassessment. *Journal of Developmental Learning*, 10(2), 33–48.

Hyde, J. S. (2016). Gender similarities and differences in abilities. *Annual Review of Psychology*, 67, 373–398.

Kampourakis, K. (2016). Students' understanding of Mendelian genetics. *Science & Education*, 25(3), 319–341.

Kampourakis, K. (2017). *Making sense of genes*. Cambridge University Press.

Kazeni, M. M. M., & Onwu, G. O. M. (2012). Theoretical grounding of constructivist practices. *South African Journal of Education*, 32(2), 207–219.

Karamustafaoğlu, S., & Kandaz, U. (2022). Teachers’ perception of visual thinking strategies. *Turkish Journal of Science Education*, 19(2), 300–312.

Kelle, U., & Reith, F. (2023). Paradigms and mixed methods in social research: The development of a research programme. *International Journal of Social Research Methodology*, *26*(1), 23–38.

Kim, M. (2005). The effects of constructivist teaching approach on students’ learning in science. *Science Education Review*, 4(2), 34–48.

Kılıç, D., Taber, K. S., & Winterbottom, M. (2016). Students' difficulties in learning genetics: A review of research. *Journal of Biological Education*, 50(3), 275–285.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education*, *6*(5), 26–41.

Kottner, J., Audigé, L., Brorson, S., Donner, A., Gajewski, B. J., Hróbjartsson, A., … Streiner, D. L. (2011). Guidelines for reporting reliability and agreement studies (GRRAS) were proposed. *Journal of Clinical Epidemiology*, *64*(1), 96–106.

Langheinrich, J., & Bogner, F. X. (2015). Student conceptions about DNA and gene expression. *Journal of Science Education and Technology,* 24(5), 720–731.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, *28*(4), 563–575.

Lee, Y. (2017). Effects of teacher-centered instruction on student learning outcomes. *International Journal of Instructional Methodologies*, 10(3), 78–89.

Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance – Do students see any relationship? *International Journal of Science Education,* 22(2), 177–195.

Lewis, J., & Kattmann, U. (2004). Traits, genes, particles and information: Re-visiting students' understandings of genetics. *International Journal of Science Education*, 26(2), 195–206.

Lewis, J., & Wood-Robinson, C. (2020). Genetics assessment strategies: From knowledge to understanding. *Education and Science Journal*, 45(1), 55–70.

Lindberg, S. M., Hyde, J. S., & Hirsch, L. A. (2021). Gender and science performance: Context and classroom. *Educational Psychology Review*, 33, 469–491.

Li, J. (2016). *Cultural foundations of learning: East and West.* Cambridge University Press.

Magak, J. O. (2016). The effect of constructivist teaching approaches on students' academic achievement in biology. *Kenya Journal of Education and Learning*, 3(2), 112–120.

Mackatiani, C. I., Imbova, M., & Wambua, K. (2018). Teacher-centered versus learner-centered teaching methods in Kenya. *International Journal of Education and Research,* 6(10), 15–26.

Machová, I., & Ehler, E. (2021). Secondary school students' views and perceptions of genetics. *Journal of Biological Education*, 55(3), 240–253.

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education*, 4, 60.

Martínez-Hernández, C., & Suárez, M. (2021). Scaffolding for inclusion: Using structured thinking tools to close achievement gaps in science. *International Journal of Inclusive Education*, 25(4), 416–433.

McLure, F., & Newberry, M. (2020). Using Thinking Frames to support science learning in secondary education. *International Journal of Science Pedagogy*, 8(1), 11–24.

McLure, F. (2018). Evaluating the Thinking Frames Approach in Australian science classrooms. *Australian Journal of Education*, 62(4), 403–420.

McLure, F. (2020). Metacognitive scaffolding in science learning through visual reasoning. *Journal of Science Teaching and Learning*, 14(2), 65–77.

McClure, L., Newbery, M., & Bird, A. (2008). *Learning to Learn: Using thinking frames in the classroom*. Cams Hill Consortium.

Mclure, L. (2020). Scaffolding conceptual understanding with thinking frames. *British Journal of Science Education*, 12(3), 225–243.

McClure, J., & Newberry, M. (2018). Evaluating thinking frames in UK science classrooms. *Educational Practice and Theory*, 40(1), 7–23.

McLure, L., Newberry, M., & Gilbert, J. (2020). Thinking frames and inquiry-based learning. *Journal of Science Education*, 23(2), 98–113.

McLure, L., Treagust, D. F., & Tsui, C. Y. (2021). Visual representations and student reasoning in biology. *Research in Science Education*, 51(1), 147–169.

McCombs, B. L. (2015). *Learner-centered psychological principles: A framework for school redesign.* Theory Into Practice, 54(2), 117–127.

Ministry of Education. (2010). *Teaching syllabus for Biology (Senior High School)*. Accra: Curriculum Research and Development Division (CRDD).

Millar, R., & Atkinson, D. (2020). Comparative efficacy of active versus traditional instruction in science. *Science Education*, 104(6), 1062–1084.

Montessori, M. (1917). *The advanced Montessori method*. Frederick A. Stokes Company.

Mullis, I. V. S., Martin, M. O., & Foy, P. (2020). *TIMSS 2019 International Results in Science*. TIMSS & PIRLS International Study Center.

National Research Council. (2012). *A framework for K–12 science education*. National Academies Press.

Newberry, M. (2011). Scaffolding reasoning in science education. *International Journal of Science Teaching*, 14(1), 30–41.

Newberry, M., Gilbert, J., & Bird, A. (2007). *Thinking Frames Approach Resource Pack*. AstraZeneca Science Teaching Trust.

Newberry, M., McClure, L., & Bird, A. (2005). Evaluating student science writing. *Science Education Journal*, 22(1), 13–24.

Newberry, M., Gilbert, J., & McClure, J. (2011). Using thinking frames to support written explanations in science. *School Science Review*, 93(343), 109–116.

Newberry, M. (2016). Visual tools in cognitive development: Enhancing science learning with thinking frames. *Journal of Learning Design*, 9(3), 25–38.

Ng, M. W., & Chan, K. S. (2021). Visual literacy in biology: A framework for learning genetics with visual tools. *Journal of Biological Education*, 55(3), 323–333.

Noemy, P., García, M., & Torres, L. (2017). *Students' attitudes toward science learning in secondary schools.* Journal of Educational Research, 110(3), 295–305.

Ochieng, J. (2020). *Effect of learner-centered approaches on students' performance in biology in Kenya.* International Journal of Education and Research, 8(4), 55–67.

Oduro-Okyireh, G., & Annor, R. S. (2018). Evaluation of item writing flaws in multiple choice questions of a higher education institution in Ghana. *International Journal of Humanities Social Sciences and Education*, *5*(3), 62–71.

OECD. (2019). *PISA 2018 Results (Volume I): What Students Know and Can Do*. OECD Publishing.

Oinam, A. (2017). Challenges of implementing student-centered learning. *International Journal of Research in Education,* 6(2), 89–96.

Ojo, J. (2024). Learning genetics: A review of challenges and innovations. *Journal of Science Education Review*, 12(1), 22–30.

Olugbenga, T. A. (2021). Learner-centered instruction in 21st-century classrooms. *Educational Perspectives*, 14(2), 78–89.

Pallant, J. (2011a). *SPSS Survival Manual: A step by step guide to data analysis using SPSS* (4th ed.). Open University Press.

Piaget, J. (1952). *The origins of intelligence in children*. International Universities Press.

Piaget, J. (1970). *Science of education and the psychology of the child*. Orion Press.

Piaget, J. (1976). *Piaget's theory*. In Inhelder, B., Chipman, H. H., & Zwingmann, C. (Eds.), *Piaget and his school*. Springer.

Sampson, V., Enderle, P., Grooms, J., & Witte, S. (2013). Writing to learn by learning to write in science: A design-based research project. *Reading & Writing Quarterly, 29*(2), 75–95.

Schnepps, M. H., & Sadler, P. M. (2018). Using dynamic visualizations to teach genetics. *American Biology Teacher*, 80(1), 27–33.

Schunk, D. H. (2012). *Learning theories: An educational perspective* (6th ed.). Pearson.

Sheldon, C. (2020). Teaching mitosis and meiosis: Challenges and strategies. *Science Teaching Review*, 14(2), 55–70.

Shin, H., Sutherland, L. M., & Shin, S. (2021). Cognitive development and genetics learning. *Journal of Biological Education*, 55(4), 421–432.

Shuchi, S. (2017). Teacher-centered vs learner-centered approaches. *Asian Journal of Education and Learning*, 3(2), 17–23.

Sobirova, Z., & Karimova, F. (2021). The effectiveness of traditional teaching. *Asian Journal of Research in Education and Social Sciences*, 1(1), 45–55.

Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat and women's math performance. *Current Directions in Psychological Science*, 25(3), 161–166.

Stern, F., & Kampourakis, K. (2017). Genetic literacy and conceptual understanding. *Science Education*, 101(3), 468–490.

Stoet, G., & Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science*, 29(4), 581–593.

Sumarni, W. (2015). Challenges in implementing student-centered approaches in chemistry education. *Indonesian Journal of Science and Education*, 4(1), 15–23.

Taber, K. S., & Garcia-Franco, A. (2010). Learning and teaching with thinking frames. *Chemistry Education Research and Practice*, 11(1), 5–10.

Tan, E., Barton, A. C., Kang, H., & O'Neill, T. (2018). Equity in science education. *Review of Educational Research*, 88(2), 285–325.

Tang, K. S. (2016). The role of diagrams in genetics learning. *Science Education*, 100(5), 1003–1028.

Tang, K. S., & Chan, Y. Y. (2021). Visual representations and meaning-making in science education. *Research in Science Education*, 51(3), 785–807.

Tanner, H., & Jones, S. (2007). Using thinking frames in science education. *Science Education International*, 18(3), 189–204.

Taber, K. S., & Winterbottom, M. (2016). Students' understanding of genetics and the need for innovative teaching approaches. *Journal of Biological Education*, 50(2), 120–130.

Tambaya, T. B., Alade, I. A., & Samaila, I. (2016). Gender disparity and academic achievement in science education. *International Journal of Gender Studies in Developing Societies,* 1(2), 105–116.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. SAGE Publications

Thomas, G. (2013). *Education: A very short introduction*. Oxford University Press.

Tibell, L. A. E., & Rundgren, C. J. (2010). Educational challenges of molecular life science: Characteristics and implications for education and research. *CBE—Life Sciences Education, 9*(1), 25–33. https://doi.org/10.1187/cbe.08-09-0055

Topçu, M. S., & Sahin-Pekmez, E. (2009). The effect of problem-based learning on students' conceptual understanding in genetics. *Journal of Science and Technology Education,* 2(1), 11–19.

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2018). Multiple representations in science teaching. *Science Education*, 102(4), 768–792.

Treagust, D. F., & Tsui, C. Y. (2013). *Multiple representations in biological education*. Springer.

Tsui, C. Y., & Treagust, D. F. (2021). Systems thinking in genetics. *Science Education Review*, 20(1), 20–31.

Ugwu, C. C., Enemuo, E. O., & Onu, F. M. (2021). Rethinking research paradigms in education: Emphasis on pragmatism. *International Journal of Advanced Academic Research*, *7*(5), 1–12.

Umida, M., Zaynitdin, A., & Sevara, N. (2020). Constructivist learning approaches in science classrooms. *European Journal of Research and Reflection in Educational Sciences*, 8(2), 55–64.

UNESCO. (2022). *Gender equality in STEM education: Global report*. Paris: UNESCO Publishing.

Usher, E. L., & Morris, D. B. (2022). Equity in science education: Addressing classroom bias through inclusive strategies. *Review of Educational Research*, 92(3), 345–379.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Vygotsky, L. S. (1994). The social development theory. In *Foundations of constructivism*. Routledge.

WAEC Chief Examiners' Report. (2018). *Chief Examiners' Reports on Biology*. West African Examinations Council.

WAEC Chief Examiners' Report. (2019). *Chief Examiners' Reports on Biology*. West African Examinations Council

WAEC Chief Examiners' Report. (2020). *Chief Examiners' Reports on Biology*. West African Examinations Council

WAEC Chief Examiners' Report. (2021). *Chief Examiners' Reports on Biology*. West African Examinations Council

WAEC Chief Examiners' Report. (2022). *Chief Examiners' Reports on Biology*. West African Examinations Council

Wang, M. T., & Degol, J. L. (2017). Gender gap in STEM: The roles of identity, interest, and self-efficacy. *Educational Psychology Review*, 29(1), 119–140.

Westwood, P. (2017). *What teachers need to know about teaching methods*. ACER Press.

Whittle, R. J., Telford, J., & Benson, D. (2018). Science teaching methods and their influence on learning outcomes: A review of the literature. *Journal of Educational Research and Practice,* 8(1), 55–67.

Wilgenbusch, T., & Finson, K. D. (2000). Student gender and achievement in genetics instruction. *Journal of Research in Science Teaching*, 37(5), 582–593.

Woolfolk, A. (2010). *Educational Psychology* (11th ed.). Pearson Education.

Woolfolk, A. (2016). *Educational psychology* (13th ed.). Pearson Education.

Yarden, A. (2017). Genetics education in secondary schools. *Science Education Review*, 16(3), 220–230.

Zhou, M., Ouyang, X., & Peng, Y. (2022). Addressing prior knowledge bias in comparative studies. *Educational Measurement and Evaluation*, 41(2), 139–156.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching,* 39(1), 35–62. https://doi.org/10.1002/tea.10008

Zohar, A., & Barzilai, S. (2015). Promoting students' argumentation skills. *Science Education International*, 26(3), 246–267.

Zohar, A., & Dori, Y. J. (2012). Metacognition in science education: Trends and research. *Contemporary Science Education*, 12(3), 223–244.

Zohar, A., & Nemet, F. (2018). Argumentation and conceptual change in genetics. *Science Education*, 102(5), 889–915.

Zohar, A., & Sela, D. (2003). Gender differences in metacognition and science learning. *International Journal of Science Education*, 25(4), 435–455.

Zheng, H., & Mustappha, A. (2022). Academic performance and academic achievement: Clarifying the difference. *Educational Measurement Journal*, 8(2), 32–40.

APPENDICES

APPENDIX A

GENETICS CONCEPTS TEST (GCT)

These questions are part of a research titled **—*Effect of Thinking Frames Approach on Students' Academic Performance in Genetics in Senior High Schools***

SCHOOL: ………………………………………………….

CLASS: ………………………………………………..........

Male**:** ☐ Female: ☐

Code: ☐

Answer All Questions (40 marks)

1. Brown eyed colour (B) is dominant over blue-eyed colour (b). A brown eyed man married a blue-eyed woman. Explain briefly what eye colours their children will have. **6 marks**
2. A man of blood group A married a woman with blood group AB. Write the possible genotypes of;
   a) The man **2 marks**
   b) The woman **2 marks**
   c) Write all the possible genotypes of their offsprings. **4 marks**
3. Differentiate between the following
   a) Continuous and discontinuous Variation **3 marks**
   b) Heritable and non-heritable variations **3 marks**
4. Explain the following
   a) Genotype **2 marks**

b) Allele **2 marks**

c) Phenotype **2 marks**

d) Variation **2 marks**

5. With the aid of a diagram explain

   a) Duplication **3 marks**

   b) Insertion **3 marks**

   c) Translocation **3 marks**

   d) Inversion **3 marks**

APPENDIX B

INTERVIEW GUIDE

Focus Groups Interview Guide to Determine the views of SHS Biology Students on the Use of Thinking Frames Approach in the Teaching and Learning of Genetics

1. How does the way genetics was taught improve your understanding in genetic concepts?
2. To what extent has your interest in genetics increased during the teaching of genetics?
3. How well do you remember genetics concepts learned in previous lessons?
4. How confident do you feel when solving genetics-related questions or problems after the method used?
5. How has your understanding of genetics influenced your views or everyday life?

APPENDIX C

MARKING SCHEME FOR GENETIC CONCEPT TEST

1. Eye Colour Inheritance (6 marks)

Brown eye colour is controlled by a dominant gene (B), while blue eye colour is controlled by a recessive gene (b). A person with brown eyes can have either BB (homozygous) or Bb (heterozygous) genotype. A person with blue eyes can only have the bb genotype.

If a brown-eyed man (with genotype either BB or Bb) marries a blue-eyed woman (bb), their children's eye colours will depend on the man's genotype:

- If the man is BB, all children will inherit one B from him and one b from the woman, resulting in Bb, meaning all children will have brown eyes.
- If the man is Bb, then there is a 50% chance a child will be Bb (brown eyes) and 50% chance of bb (blue eyes).

So, depending on the father's genotype, the children may all have brown eyes or a mix of brown and blue eyes.

2. Blood Group Inheritance

a) Genotype of the man (2 marks)

A man with blood group A can have either IAIA (homozygous) or IAO (heterozygous) genotype.

b) Genotype of the woman (2 marks)

A woman with blood group AB must have the genotype IAIB, because AB is a result of inheriting one A gene and one B gene.

c) Possible genotypes of their offspring (4 marks)

Depending on whether the man is IAIA or IAO, the possible offspring will be:

- If the man is IAIA: the children can be either IAIA (blood group A) or IAIB (blood group AB).
- If the man is IAO: the children can be IAIA (blood group A), IAIB (blood group AB), IAi (blood group A), or IBi (blood group B).

So, the possible genotypes of the children are IAIA, IAi, IAIB, and IBi, leading to blood groups A, B, and AB.

3. Differences

a) Continuous vs. Discontinuous Variation (3 marks)

Continuous variation involves characteristics that show a range of differences from one extreme to another, such as height or weight. These traits are influenced by multiple genes and the environment.

Discontinuous variation involves traits that are clearly defined and fall into distinct categories, such as blood group or the ability to roll the tongue. These are usually controlled by one or a few genes and are not affected by the environment.

b) Heritable vs. Non-Heritable Variations (3 marks)

Heritable variations are genetic differences that are passed from parents to offspring through DNA. Examples include eye colour, blood group, and genetic disorders. non-heritable variations are changes that occur due to environmental factors and are not passed on genetically. Examples include scars, weight gained from diet, or knowledge acquired through learning.

4. Explanation of Terms

a) Genotype (2 marks)

Genotype refers to the genetic makeup of an individual. It is the combination of alleles inherited from the parents. For example, a person may have a Bb genotype for eye colour.

b) Allele (2 marks)

An allele is an alternative form of a gene. For each gene, an individual inherits one allele from each parent. For example, the gene for eye colour may have two alleles: B (brown) and b (blue).

c) Phenotype (2 marks)

Phenotype refers to the observable traits or physical appearance of an individual, such as eye colour, height, or blood type. It results from the interaction of the genotype with the environment.

d) Variation (2 marks)

Variation is the difference in characteristics between individuals of the same species. It can be caused by genetic factors (inherited genes) or environmental factors (like climate or lifestyle).

5. a) Duplication (3 marks)

Duplication is a mutation where a section of a chromosome is copied and inserted again. This results in repeated genes in the chromosome.

b) Insertion (3 marks)

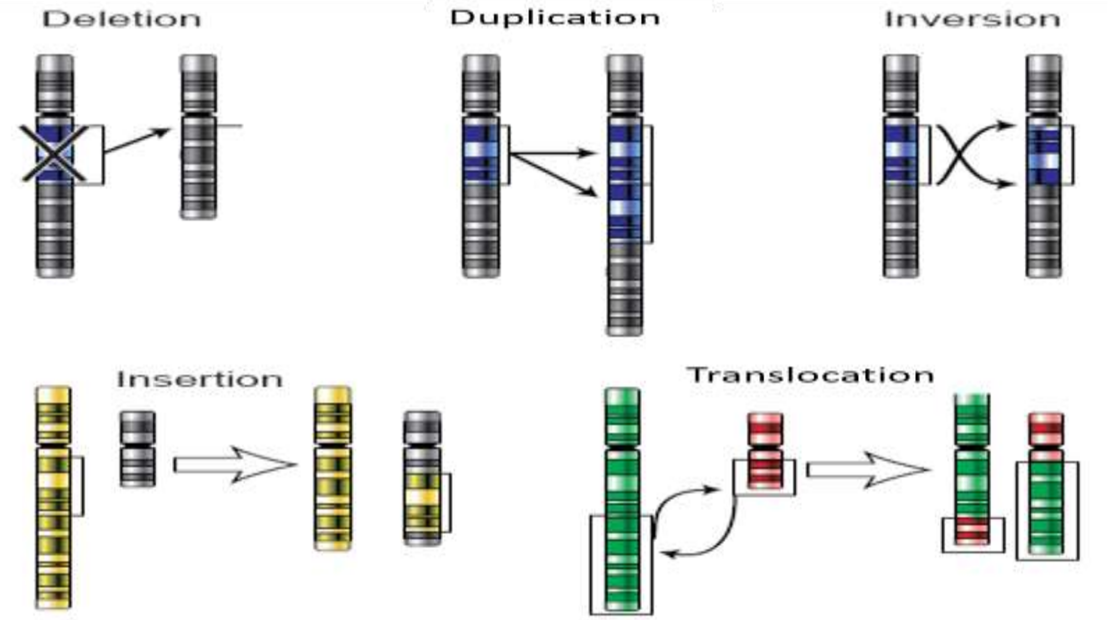
Insertion is a type of mutation where a new piece of genetic material is added into the chromosome. This can disrupt the normal function of genes.

c) Translocation (3 marks)

Translocation is a mutation where a segment of one chromosome breaks off and attaches to a different, non-homologous chromosome. This can result in abnormal gene expression or diseases.

d) Inversion (3 marks)

Inversion is a mutation where a segment of the chromosome breaks off, reverses its orientation, and reinserts into the chromosome. This changes the order of genes.



APPENDIX E

LESSON PLAN FOR THINKING FRAMES APPROACH AND CONVENTIONAL METHOD

INTERVENTION

Thinking Frames Approach

TFA steps	Teacher and Students Activities
1. Setting the Scene (PDEODE) group/whole-class discussion	a) Teacher presents a practical demonstration using an everyday context challenging alternative conceptions. b) Students work cooperatively in their groups using the Predict, Discuss, Explain, Observe, Discuss and Explain (PDE) framework to explain what happened in the demonstration. Groups use argumentation to produce a verbal explanation to a higher order thinking question based on the observations, which is shared with the class. Teacher uses questioning to prompt consideration of the scientific model.
2. Brainstorming	Students gather keywords and phrases that they believe will be useful in answering the question**.**
3. See/Visualise	Students produce and communicate their verbal representations in the form of labelled diagrams or pictorial timelines

4.Think/Sequence	Building on the pictorial representation of concepts and key words students produce dot points of ‘what happens’ and ‘why’. Using the key points thus produced, students then produce a paragraph to explain the phenomenon and answer the questions originally posed.
5. Evaluation	Teacher evaluates students work in terms of how successfully their explanations addressed cause and effect and how they scientific language.

NUMBER ON ROLL: 104

Lesson	**Duration**	**Learning objectives**	**Teaching and Learning materials**	**Teacher Activities**	**Student Activities**	**Evaluation**
Lesson 1: Introduction to Genetics and Basic Terms	**60 min**	Define genetics and explain its significance. Identify and describe basic genetic terms (gene, allele, genotype, phenotype, dominant, recessive, locus, etc.).	Charts illustrating genetic traits. Videos on basic genetic principles. Flashcards for key terms.	- Define genetics and explain its importance (15 min). - Introduce basic terms: gene, allele, genotype, phenotype, dominant, recessive, locus, etc. (25 min). - Discuss real-life examples (20 min).	- Brainstorm examples of inherited traits (15 min). - Work in groups to define key terms and find real-life examples (20 min). - Share findings in class discussion (25 min).	Define five key genetic terms and provide examples.

		Relate genetic concepts to real-life examples.				
Lesson 2: Structure of Chromosomes and DNA Replication	**60 min**	Describe the structure and function of chromosomes Explain the process of DNA replication. Identify key components of a chromosome	3D chromosome and DNA models. Microscopes and prepared slides of chromosomes. Diagrams of DNA replication.	- Explain the structure of chromosomes using diagrams (20 min). - Demonstrate DNA replication with a 3D model (20 min). - Assign an activity to label chromosome parts (20 min).	- Observe chromosome models (20 min). - Participate in a group discussion on why DNA replication is important (20 min). - Label and describe chromosome parts (20 min).	**Exercise:** Draw and label a chromosome, explaining its structure.
Lesson 3: Mendel's Laws and Monohybrid	**60 min**	Explain Mendel's experiments with pea plant	1. Diagrams of Mendel's pea plant	- Explain Mendel's experiments with pea plants (15 min).	- Discuss inherited traits in families (15 min).	Solve a monohybrid cross

Inheritance		Describe Mendel's First Law (Law of Segregation) Solve a monohybrid cross using Punnett squares.	experiments 2. Punnett square chart 3. Worksheets for monohybrid cross problems.	- Introduce Mendel's First Law (Law of Segregation) (20 min). - Solve a monohybrid cross using Punnett squares (25 min).	- Work in groups to complete a Punnett square activity (20 min). - Present findings (25 min).	problem and explain the results.
Lesson 4: Dihybrid Inheritance and Mendel's Second Law	**60 min**	Explain dihybrid inheritance and independent assortment. Apply Mendel's Second Law (Law of Independent Assortment) Solve dihybrid	Dihybrid cross charts. Flashcards with genetic traits. Practice worksheets.	- Explain dihybrid inheritance and independent assortment (20 min). - Solve dihybrid cross problems using Punnett squares (20 min). - Assign class	- Work in pairs to solve dihybrid cross problems (20 min). - Discuss results and correct errors in class (20 min). - Answer teacher's guided questions (20 min).	Solve two dihybrid cross problems.

		cross problems using Punnett squares.		exercises (20 min).		

Lesson	Duration	Learning Objective	Teaching and Learning Materials	Teacher Activities	Student Activities	Evaluation
Lesson 5: Sex Determination and Sex-Linked Traits	**60 min**	Explain how sex is determined in humans. Describe sex-linked traits such as color blindness, hemophilia, and	Diagrams of sex chromosomes. Case studies on sex-linked disorders. Punnett square worksheets	- Explain how sex is determined in humans (20 min). - Discuss sex-linked traits (color blindness, hemophilia, baldness)	- Work in groups to solve sex-linked trait problems (20 min). - Discuss why sex-linked disorders are more common in males (20 min).	Explain why hemophilia is more common in males than females.

		baldness. Solve X-linked trait problems using Punnett squares.		(20 min). - Solve X-linked trait problems using Punnett squares (20 min).	- Present findings (20 min).	
Lesson 6: Variation – Continuous vs. Discontinuous	**60 min**	Define variation and Explain its types (continuous and discontinuous). Differentiate between genetic and environmental variation. Identify real-life examples of	Charts displaying examples of variation. Data collection sheets for classroom survey. Videos on genetic and environmental influences	- Define variation and explain types (continuous, discontinuous) (20 min). - Show examples of genetic vs. environmental variation (20 min). - Facilitate class discussion on real-life	- Identify traits in the class that show variation (20 min). - Work in groups to classify variations as continuous or discontinuous (20 min). - Present findings (20 min).	Differentiate between continuous and discontinuous variation.

		variation.		variations (20 min).		
Lesson 7: Causes and Consequences of Variation	**60 min**	Explain causes of variation (mutation, crossing over, independent assortment). Describe the consequences of variation (natural selection, artificial selection). Understand the role of mutations in genetic variation.	Diagrams of genetic mutations. Case studies on evolution and selection. Research articles on genetic variation.	- Explain causes of variation (mutation, crossing over, independent assortment) (20 min). - Discuss consequences of variation (natural selection, artificial selection) (20 min). - Assign a research task on genetic mutations (20 min).	- Research and present examples of mutations (20 min). - Discuss the role of variation in evolution (20 min). - Answer guided questions (20 min).	Research how mutations contribute to genetic variation.

LESSON PLAN FOR CONVENTIONAL METHOD

NUMBER ON ROLL; 96

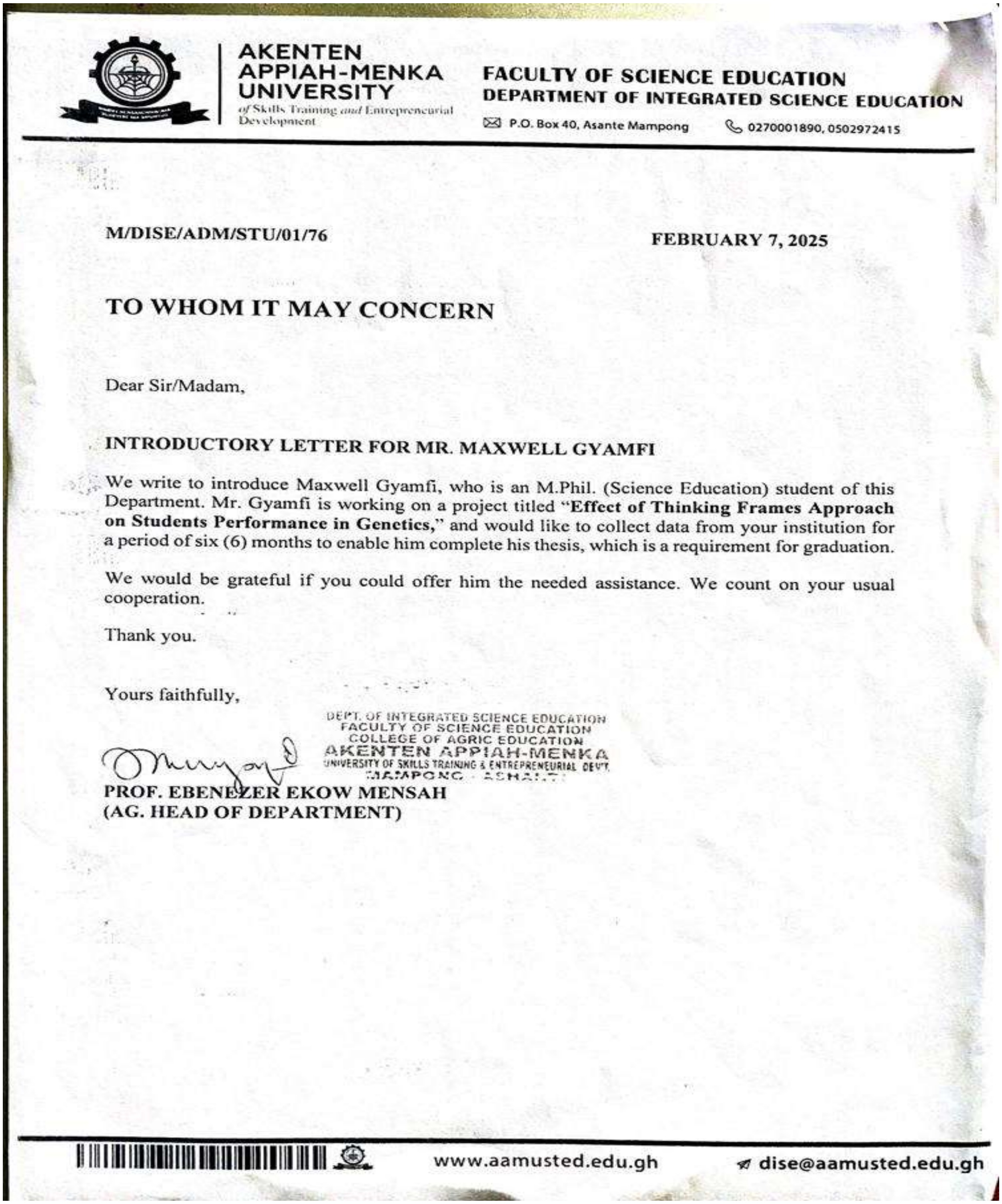
DATE/TIME/ TLMs	**OBJECTIVES** **TOPIC/CONTENT**	**TEACHER-LEARNER ACTIVIES**	**CORE POINTS.**	**EVALUATION/ REMARKS**
9-11AM **2hours**	**OBJECTIVES;** By the end of the lesson, the student will be able to: 1. Explain genes, genotype, phenotype, heredity, and variation. 2. State Mendel's 1st and 2nd laws of inheritance. 3. Differentiate between continued variations from	**INTRODUCTION**; **RPK.** Revise students' knowledge on cell cycle/ division. **5mins** **DEVELOPMENT** 1. Guide students to discuss inheritance (heredity), genes, genotype, phenotype, alleles, and locus, test-	Cell division Genes are the unit of inheritance	**CLASS TEST** a) genes b) heredity c) genotype d) phenotype **2marks for each.** **(10marks)**

	discontinue variation.	crossing. **45mins**		2. state the main difference between continue and discontinue variation **4marks**
A cardboard showing pictures of pea plants.	**Topic**; Genetics Sub-topic; inheritance in organisms. Mendel’s laws of inheritance	2. With the help of the TLM pasted on the board, assist students to state the Mendel’s laws of inheritance. **30mins**	Mendel's First Law (law of inheritance) Mendel's Second Law (law of segregation) Third Law of Mendel (law of independent assortment)	4. Brown eye color (B) predominates over blue eye color in humans (b). A man with brown eyes wed a woman with blue eyes.

	Variation and types of variations in organism.	Variation is the differences that exist among organisms. Types of variation; continue and discontinue variations.	Give a brief explanation of the possible eye colors of their children using a diagram.**10marks**

1hour **A** cardboard showing pictures of cow, sheep, goat, human being, grasses and other plants.		6. Assist students to mention at least four (4) causes of variations. **25mins** **CONCLUSION;** Summarise major points to end the lesson. Ask oral questions to ascertain their level of understanding. **5mins**	Mutation Random fusion of gametes independent assortment Cross-over Environmental factors; diet, wind velocity, light intensity, other organisms. Genetic factors; codominance, segregation and	

			recombination, polygenic characters.	



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M/DISE/ADM/STU/01/76 **FEBRUARY 7, 2025**

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

INTRODUCTORY LETTER FOR MR. MAXWELL GYAMFI

We write to introduce Maxwell Gyamfi, who is an M.Phil. (Science Education) student of this Department. Mr. Gyamfi is working on a project titled "**Effect of Thinking Frames Approach on Students Performance in Genetics,**" and would like to collect data from your institution for a period of six (6) months to enable him complete his thesis, which is a requirement for graduation.

We would be grateful if you could offer him the needed assistance. We count on your usual cooperation.

Thank you.

Yours faithfully,

DEPT. OF INTEGRATED SCIENCE EDUCATION
FACULTY OF SCIENCE EDUCATION
COLLEGE OF AGRIC EDUCATION
AKENTEN APPIAH-MENKA
UNIVERSITY OF SKILLS TRAINING & ENTREPRENEURIAL DEV'T
MAMPONG - ASHANTI

PROF. EBENEZER EKOW MENSAH
(AG. HEAD OF DEPARTMENT)

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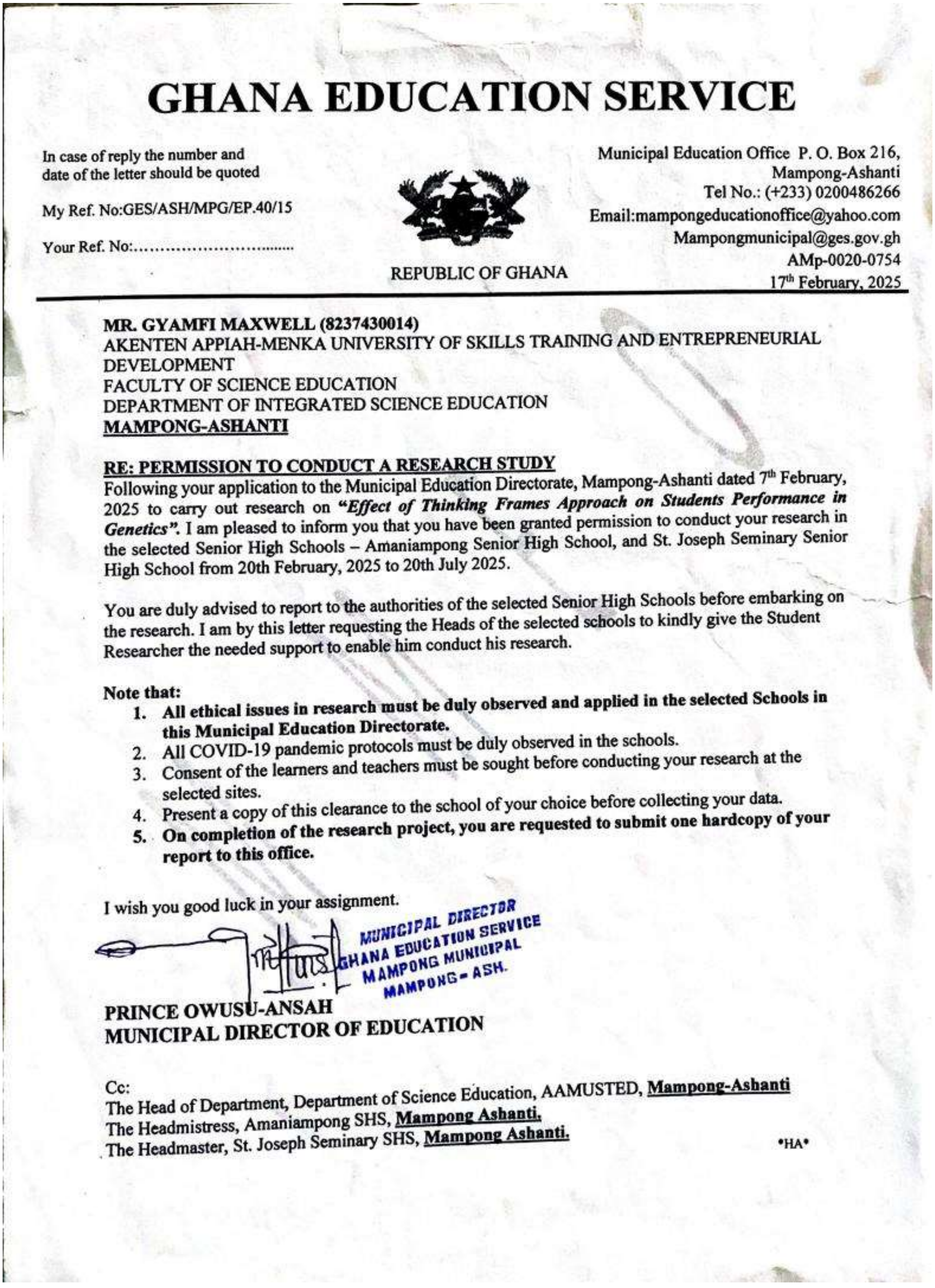

GHANA EDUCATION SERVICE

In case of reply the number and
date of the letter should be quoted

My Ref. No:GES/ASH/MPG/EP.40/15

Your Ref. No:…………………………..

REPUBLIC OF GHANA

Municipal Education Office P. O. Box 216,
Mampong-Ashanti
Tel No.: (+233) 0200486266
Email:mampongeducationoffice@yahoo.com
Mampongmunicipal@ges.gov.gh
AMp-0020-0754

17th February, 2025

MR. GYAMFI MAXWELL (8237430014)
AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT
FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF INTEGRATED SCIENCE EDUCATION
MAMPONG-ASHANTI

RE: PERMISSION TO CONDUCT A RESEARCH STUDY

Following your application to the Municipal Education Directorate, Mampong-Ashanti dated 7th February, 2025 to carry out research on ***"Effect of Thinking Frames Approach on Students Performance in Genetics"***. I am pleased to inform you that you have been granted permission to conduct your research in the selected Senior High Schools – Amaniampong Senior High School, and St. Joseph Seminary Senior High School from 20th February, 2025 to 20th July 2025.

You are duly advised to report to the authorities of the selected Senior High Schools before embarking on the research. I am by this letter requesting the Heads of the selected schools to kindly give the Student Researcher the needed support to enable him conduct his research.

Note that:

1. **All ethical issues in research must be duly observed and applied in the selected Schools in this Municipal Education Directorate.**
2. All COVID-19 pandemic protocols must be duly observed in the schools.
3. Consent of the learners and teachers must be sought before conducting your research at the selected sites.
4. Present a copy of this clearance to the school of your choice before collecting your data.
5. **On completion of the research project, you are requested to submit one hardcopy of your report to this office.**

I wish you good luck in your assignment.

MUNICIPAL DIRECTOR
GHANA EDUCATION SERVICE
MAMPONG MUNICIPAL
MAMPONG- ASH.

PRINCE OWUSU-ANSAH
MUNICIPAL DIRECTOR OF EDUCATION

Cc:
The Head of Department, Department of Science Education, AAMUSTED, **Mampong-Ashanti**
The Headmistress, Amaniampong SHS, **Mampong Ashanti.**
The Headmaster, St. Joseph Seminary SHS, **Mampong Ashanti.**

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