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EFFECT OF CLASSROOM DISCUSSION ON ACADEMIC OUTCOMES OF STUDENTS IN GENETICS AT WINNEBA SENIOR HIGH SCHOOL

MAXWELL ASARE

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EFFECT OF CLASSROOM DISCUSSION ON ACADEMIC OUTCOMES OF STUDENTS IN GENETICS AT WINNEBA SENIOR HIGH SCHOOL

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DECLARATION

Student's Declaration

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

Signature …………..……………..

Date: …….……..…………………

Supervisor's Declaration

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

Name of Supervisor: Professor Yaw Ameyaw (PhD)

Signature …………..……………..

Date: …….……..…………………

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DEDICATION

To my dearest mum, Agartha Ferkaa Kwayie.

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LIST OF ABBREVIATIONS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BAT	Biology Achievement Test
CAI	Computerized Assisted Instruction
CAL	Computerized Assisted Learning
CCE	Cooperative Class Experiment
CTL	Centre for Teaching and Learning
DNA	Deoxyribonucleic Acid
ERMT	Educational Research Method Test
ESPT	Educational Statistics Performance Test
FIL	Focused Interactive Learning
GAT	Genetics Achievement Test
GE	Genetic Engineering
GES	Ghana Education Service
GM	Genetic Modification
GMFs	Genetically Modified Foods
GMOs	Genetic Modification of Organisms
I^AI^A	Genotype for Blood Group A (Homozygote)
I^AI^B	Genotype for Blood Group AB
I^AI^O	Genotype for Blood Group A (Heterozygote)
I^BI^B	Genotype for Blood Group B (Homozygote)
I^BI^O	Genotype for Blood Group B (Heterozygote)
IBL	Inquiry-Based Learning
IBT	Inquiry-Based Teaching

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$I^O I^O$	Genotype for Blood Group O
MCQs	Multiple-Choice Questions
mRNA	Messenger Ribonucleic Acid
NRC	National Research Council
NSES	National Science Education Standards
RNA	Ribonucleic Acid
rRNA	Ribosomal Ribonucleic Acid
SAT	Standardized Ability Test
SAT-M	Scholastic Aptitude Test Mathematics
SCL	Student Centered Learning
SEPT	Standards for Educational and Psychological Testing
SGAT	Standardized Genetics Achievement Test
SPSS	Statistical Package for Social Sciences
tRNA	Transfer Ribonucleic Acid
WAEC	West African Examination Council
WASSCE	West African Senior Secondary Certificate Examination
XX	Female
XY	Male

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ABSTRACT

Genetics, the biological Science that deals with how traits are transferred from parents to their offspring plays a tremendous role in the lives of individuals in this 21st century but most Senior High School (SHS) students' in Ghana have challenges in obtaining conceptual understanding of the topic particularly due to the instructional approaches teachers' employ in its lesson delivery. The author of this study therefore, investigated the effect of classroom discussion on academic outcomes of students in genetics at Winneba Senior High School. Five hypotheses and assumptions guided the study. Constructivists' theory of learning was adopted for the study. The positivist paradigm and the quantitative approach underpinned the study paradigm and its approach respectively. Solomon four group design was employed for the study. The study population consisted of all Biology students in Winneba SHS, Central Region with the target population being all SHS 2) whereas the accessible population comprised Science One and Two students. Simple random sampling (lotto technique) was used to select thirty-two (32) students with sixteen (16) students each from Science One (1) and Science Two (2) as the experimental and control group respectively. Standardized Genetics Achievement Test (SGAT) was the instrument designed to gather data from the respondents. Data was analyzed using SPSS by employing inferential statistics (2x2 ANOVA and t-Test) all tested at 0.05 level of significance and descriptive statistics (means, standard deviations, minimum, and maximum scores). The study revealed students in the experimental group performed better than their counterparts in the control $[F(1,32)=45.68, p<0.05]$. Furthermore, it was established by the ANOVA analysis that the pre-SGAT was sensitive $[F(1,32)=4.37, p< 0.05]$ in the control group $[df=14, t=1.87, p< 0.05]$ but not in the experimental group $[df=14, t=0.99, p> 0.05]$. Finally, it was found that neither sex outperformed each other academically $[df=14, t=2.04, p>0.05]$. It is therefore recommended that because $[F(1,32)=45.68, p<0.05]$, classroom discussion should be employed predominantly by Biology teachers at Winneba Senior High School when teaching abstract topics such as genetics to enable conceptual understanding of the concepts among students the former and to increase their academic outcomes the latter. Finally, owing to the fact that $[F(1,32)=4.37, p<0.05]$ Biology instructors at Winneba Senior High School Senior High School classrooms should organize tests for their students on regular basis to enable them to learn from their mistakes in previous tests to help them perform better in subsequent ones.

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CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter deals with background to the study, statement of the problem, purpose of the study, research objectives, research questions, research hypotheses, significance of the study, delimitations of the study, limitations of the study, assumptions of the study, and operational definition of terms.

1.2 Background to the Study

Education plays a pivotal role in maximizing an individual's potentials making it a prerequisite for meaningful and sustained national economy (Amosa & Olubode, 2013). In Ghana, second-cycle education is recognized as critical to the country's quest to develop at a faster rate since it is the most accessible form of higher education with a greater potential of sustaining higher levels of literacy, increasing political awareness, strengthening democracy, and producing a pool of middle-level manpower crucial to national development (Quist, 2003). Science Education is an indispensable tool that no nation, developed or developing and wishing to progress in socio-economic sphere will afford to relegate the learning of it in their High Schools. It is also regarded as an essential component in numerous people portfolio as success in it at school enhances their chances of securing places at more prestigious tertiary institutions.

Lederman, Antink, and Bartos (2014) opined that scientific literacy entails using scientific knowledge in making decisions about personal and ethical situations. Consequently, the knowledge of Biology contributes to scientific literacy since it enables one to understand the world in which we live (Karen, 2008; Kaunang, 2014). Ekong, Akpan, Anongo, and Okrikata (2015) asserted that this discipline has its core in the field of genetics which enable students to comprehend the nature of organisms and how traits are transferred from parents to offspring. However, students' learning and achievement in genetics have been declining over recent years (Muraya & Kimamo, 2011). These declines in performance in genetics over the years are influenced by instructors not employing expository approaches to enhance meaningful learning among learners to stand up to challenge the objectives of Biology Education (FAWE, 1998; Karen, 2008; Orora, Keraro, & Wachanga, 2014; Otuka & Uzoechi, 2009).

The sole aim of any teaching is to achieve the objectives particularly students' academic outcomes which solely depends on the effectiveness and quality of the teacher which is often expressed in the teacher's knowledge of the subject matter and teaching methods. Besides having ethical and moral dilemmas regarding applications of genetics knowledge, several Biology teachers possess conceptual difficulties in understanding and teaching basic concepts in genetics (Bryce & Gray, 2004; Tekkaya, Ozkan, & Sungur, 2001). Borgerding, Sadler, and Koroly (2013) opined that though Science teachers are the real implementers of issues in genetics literacy but their unwillingness to implement these issues in their classes constitute to students learning challenges. Students learning challenges in genetics is a result of teachers difficulties in subject matter knowledge regarding the abstract issues in genetics (Steele & Aubusson, 2004 p. 470), lack of teachers' confidence in handling discussions related with controversial issues in their classes (Bryce & Gray, 2004), curricular restrictions and external examinations (Lazarowitz & Bloch, 2005), and lack of time and resources (Kwon & Chang, 2009; Zeller, 1994).

Skryabina (2000) attributed the inability and declines in performances of students in answering questions relating to genetics to the abstractness, complexity, sophistication of the concepts, and short or no allocation of hours for genetics practical. Similarly, Ndirangu (2000) supported that the declines in performance of students in genetics is due to lack of creativity, interest, confidence, and self-drive towards Science and decried the lack of expository approaches to the teaching of Science subjects and concepts, stating this as the cause of the poor mastery of essential skills and concepts in genetics.

Kirima (2000) cited in Samikwo (2013) blamed teachers' for students' decline in performance in genetics after finding out that the teachers lacked qualification, innovation, and mastery of basic scientific concepts in his experimental study.

Misconceptions arise in genetics as it is usually related to patterns of inheritance which leads to numerous learning challenges among students. Jana, Kubiatko, and Muhammet (2016) on Czech High School students' misconceptions about basic genetic concepts revealed that most students' misconceptions in genetics dimension was DNA, the function of mRNA, and their knowledge about transmission of genetic information from DNA to trait was confusing. Lewis, Leach, and Wood-Robinson (2000) discovered that a common misconception of High School students is that cells with different function have different genetic information.

Venville and Treagust (1998) identified students' obsolete and passive way of understanding the concept "gene" and solving all practical questions using Mendelian genetics in spite of its unsuitability. Shaw, Van, Zhang, and Boughman (2008) found that students roblems with explanation of dominant gene, recessive gene, hierarchy of DNA, definitions of gene, DNA, and chromosome.

Ehindero and Ajibade (2000) posited that teaching is a process of continuous personal development, self-discovery, alongside an emerging understanding of the teaching and learning process. Cazden (2001) purported that despite the promise of student-centered approaches such as classroom discussion to enhance meaningful learning of abstract

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concepts, teacher talk dominates in most elementary and secondary classrooms and the methodology as a form of interaction between teachers and students to enhance meaningful learning is rare in most Secondary School classrooms which in turn leads to rote memorization of concepts among students (McCann, Johannessen, Kahn, & Flanagan, 2006).

Martins and Fidelia (2018) supported the assertion when they coined that traditional approach of teaching make teachers spend much time in delivering lessons as if learners are “tabula rassa” (empty headed) as behaviorists theory of learning ranted with a student-centered methodology such as classroom discussion appearing to be discouraged. Lee (2001) opined that since traditional instructional strategies rely on textbooks, lecture, and presenting information in a de-contextualized manner, it leads to lack of motivation and interest to learn Biology on part of students which results in their low academic outcomes.

Due to the merits accompanied with student-centered approach such as classroom discussion, instructors should be encouraged to adopt it to promote the active involvement of students’ to increase their academic performance (Glomo-Narzoles, 2015; Robyn & Adrian, 2003). Seweje (2010) purported that during this approach, the teacher is a facilitator whose main role is to help learners to become active participants in their learning in order to establish meaningful connection between prior knowledge, new knowledge, and the processes involved in learning so as to produce in-learner skills that will enable them to compete successfully in technological and scientific dominated society. Gall and Meredith (1990) alluded that classroom discussion improve students’ mastery of subject matter and problem-solving ability.

Ellis, Calvo, Rafael, Levy, David, and Tan (2004) summarized their findings on classroom discussion as a teaching and learning tool which yield merits amongst students and pointed to literature that classroom discussion is a quality approach to teaching which ensure leadership roles among students and yield higher academic achievement. Akinleye (2010) purported that when students are given the opportunity to be listened to and guided in a non-threatening atmosphere, they perform in terms of problem-solving and decision making. Webb and Mastergeorge (2003) opined that through such kind of interactions, students learn to cross examine issues, share ideas, elucidate differences, and construct new understanding to enhance meaningful learning. Garside (1996) compared learner outcomes of material taught via lectures and discussion groups and found that classroom discussions yielded significantly numerous learning outcomes with regard to higher-level items such as application and further reiterated that active learning is a key component for developing critical thinking skills and the strategy allow students to elaborate, defend, extend their positions, opinions, and beliefs (p. 215).

Seweje (2010) opined that since teachers are the implementers of the curriculum, they need to be flexible, dynamic, thoughtful, and able to work with change. Seweje (2010) suggested further that the hallmark of competent teachers is their ability to reflect on their teaching strategies in order to meet the needs of their students. Since knowledge about genetics is critically important, Biology teachers should implement their instruction in a manner that enhance meaningful learning among students in order for them to be genetically literate to develop informed views regarding issues in genetics (Kelchtermans, 2009; Leslie & Schibeci, 2003).

Samikwo (2013) posited that students whose teachers motivate them during class discussion enable them to develop positive attitudes toward the subject and perform better in examinations and stressed on the need to employ this strategy within the classroom setting. Johnson, Johnson, and Smith (2007) elucidated that in individual learning, how students perceive and interact with one another is a neglected aspect of instruction and pointed to literature that learning takes place with ease under teachers that are well organized and concluded that the way teachers interact with students' influences their motivation and attitudes toward learning. Eggen and Kauchak (2001) asserted that a teachers' effectiveness is impeded when the teacher is unfamiliar with the body of the knowledge of the subject matter being taught and the specific methodology employed during lesson delivery. They further reiterated that the manner in which students perceive teachers in terms of their knowledge of content and subject matter significantly affect their academic outcomes.

Bangbade (2004) found out that teachers' attributes have a significant relationship with students' academic performance. According to the author, such attributes included; teachers' knowledge of subject matter, communication skills, emotional stability, good human behavior, and interest in the job. Bangbade (2004) concluded that students whose teachers lack these qualities do not perform well during tests. Since students are future citizens in societies, it is vital for teachers to employ strategies that make students genetically literate individuals in order to make informed judgments and decisions about scientific and technological issues by utilizing genetics knowledge (Boerwinkel, Swierstra, & Waarlo, 2014; Bowling, Acra, Wang, Myers, Dean, Markle, & Huether, 2008).

Since genetics literacy in Science classrooms prepare students for their future roles as they learn aspects of gene and their mode of transmission from generation to generation, employing classroom discussion enable students to meaningfully understand problems of genetic nature rather than relying on superstitions and other mystical explanations which in turn shall enable them to provide scientific explanations of genetic defects that may be found in their families and communities. With the rapid increase in genetic

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technologies, being well informed about genetics issues such as genetic testing, stem cell research, gene therapy, and Genetically Modified Foods (GMFs) as well as being aware of the ethical, legal, and moral controversies that are emanating from genetic technologies is crucial (Sturgis, Cooper, & Five-Schaw, 2005).

Hott, Huether, and McDnerney (2002) concluded that there is an increasing importance of genetics in daily life so there is a need to pay greater attention to the concept of genetics in High school Science curriculum. Since these issues are indispensable parts of scientific literacy, being scientifically literate does not mean having accurate scientific understanding about genetic technologies but also make informed decisions about socially and ethically controversial issues (Halverson, Freyermuth, Marcelle, & Clark, 2010; Tsui & Treagust, 2010). Public understanding of genetics is a necessity for all individuals in this 21st century makes it a critical aspect of scientific literacy teachers should pay greater attention to (Duncan, Freidenreich, Chinn, & Baush, 2011; Kampourakis, Reydon, Patrinos, & Strasser, 2014; Miller, 2004).

1.3 Statement of the Problem

Misconceptions, the major predictor of most students' misunderstandings in genetics can be astounded with the help of a student-centered approach such as classroom discussion to promote meaningful learning rather than other instructional methodologies. Cimer (2012) pointed that genetics is a challenging and an abstract topic belonging to various levels of organization making its misconceptions appear often than other topics in Biology. Kacovsky (2015) posited that numerous students have problems with the understanding of all abstract topics making it challenging for them to learn the former resulting in low academic outcomes among them the latter. The researcher had observed that most students within this institution and the comments from other colleagues that most students usually complain of the abstract and the challenging nature of genetics concepts leading to their lack of motivation to learn the topic and usually point that numerous instructors employ strategies that do not enable them to meaningfully comprehend the concepts when delivering genetics lessons. These create all sorts of misconceptions and learning challenges amongst them leading to their decline in performance in the topic. This problem is disturbing and if not checked, may jeopardize the placement chances of most Senior High School students in tertiary institutions not only in Biology Education but also in other Biology related disciplines.

Similarly, the WAEC Chief Examiner for Biology in 2017 supported this by reporting that most candidates had challenges in providing a suitable answer to the question requiring them to provide the possible genotypes of the man when the blood group of the baby and the woman was given and further emancipated that majority of students constructed the genetic crosses and omitted the crossing sign “X” at the parental genotype level. In the same vein, the question on recombinant DNA technology was not answered by most students in a manner that was satisfying and suggested that the hallmark of competent teachers in ensuring conceptual meaning among students is their ability to employ student-centered strategies to overcome the problems students face in answering genetics questions. What students’ usually suggest is that that when tutors employ a student-centered approaches in delivering its concepts they will have a conceptual meaning to it and classroom discussion is a potent instructional strategy that result in cognitive conflict amongst learners.

Martins and Fidelia (2018) in their study reported that classroom discussion yielded higher academic outcomes and attitudes of student instructors’ which motivated them to agree to resort to it during their lesson deliveries. Webb and Mastergeorge (2003) reported that teachers should employ classroom discussions in delivering Biology lessons to serve as intervention to overcome the challenges students face and to clear the misconceptions they hold. Similarly, Larson (2000) commented that classroom discussion is a useful teaching technique for developing the outcomes of any curriculum since it enhances higher-order thinking skills that enable students to interpret, analyze, and manipulate information since it makes learners not passive recipients of information from instructors but rather active participants who can manipulate meanings from tutors.

Despite the potentials associated with this strategy in improving learners' conceptual understanding of abstract concepts, there is a paucity in literature regarding the magnitude to which studies have been carried out in the nation to investigate the effect of classroom discussion on academic outcomes of students' in genetics at the Senior High School level. This study therefore, seeks to fill this gap.

1.4 Purpose of the Study

The study sought to ascertain the effect of classroom discussion on academic outcomes of second year Biology students in genetics at Winneba Senior High School, Central Region.

1.5 Objectives of the Study

The objectives of the study were to:

1. determine the genetics pretest scores of experimental and control group students.
2. determine the effect of classroom discussion on academic outcomes of experimental and control group students in genetics.

3. ascertain the potentials of pretesting on academic outcomes of control group students in genetics.
4. determine the effect of pretesting on academic outcomes of experimental group students in genetics.
5. determine the effect of classroom discussion on academic outcomes of male and female students in genetics.

1.6 Research Questions

The following research questions guided the study:

1. What are the pretest scores of experimental and control group students in genetics?
2. What are the effect of classroom discussion on academic outcomes of experimental and control group students in genetics?
3. What are the potentials of pretesting on academic outcomes of control group students in genetics?
4. What are the effects of pretesting on academic outcomes of experimental group students in genetics?
5. What are the effects of classroom discussion on academic outcomes of male and female students in genetics?

1.7 Research Hypotheses

Ho1- There is no statistically significant difference between the mean genetics pretest scores of experimental and control group.

Ho2- There is no statistically significant difference between the mean genetics academic performance scores of experimental and control group.

Ho3- There is no statistically significant difference between the mean genetics academic performance scores of the experimental group.

Ho4- There is no statistically significant difference between the mean genetics academic performance scores of the control group.

Ho5- There is no statistically significant difference between the mean genetics academic performance scores of male and female students in the experimental group.

1.8 Significance of the Study

The study shall enable Biology students at Winneba Senior High School clear certain misconceptions they hold about genetics concepts which in turn shall help them to improve upon their academic performance. It shall make them aware on the need to pay greater attention to genetics literacy due to its enormous roles it plays in their lives and within their various communities. In furtherance, it shall inform Biology instructors at Winneba Senior High School on the need to adopt classroom discussion when delivering genetics lessons and to develop positive attitudes towards the topic as it has an influence on students' academic outcomes. It shall also make them aware on the need to exhibit certain attitudes in the classroom settings since it has a direct bearing on students' academic performance. The study shall also inform various head teachers and teachers at Winneba Senior High School on the kind of textbooks they should recommend for their students since numerous Biology textbooks are sources of students' misconceptions which in turn lead to all sorts of their learning challenges. The information generated from the study can be used school administrators, teacher educators, textbook writers, and curriculum developers to improve teaching and learning of Biology in Senior High Schools in Ghana. Conclusively, the findings made from the study will add to literature on the effect of classroom discussion.

1.10 Delimitations of the Study

Delimitations are the characteristics that are in the control of a researcher that limit the scope and define boundaries of a study (Simon, 2011). Though several learning theories exist but the researcher adopted the constructivists' theoretical framework due to the instructional methodology employed to downplay the problem. The positivist paradigm was employed as a result of the research instrument employed for the study. The Solomon four experimental group design was adopted since the researcher decided to delve more into internal and external validity of the study.

1.11 Limitations of the Study

Orodho (2008) defined limitations as the constraints or draw backs both critical and practical that a researcher has little or no control over. The study is limited to only second year Biology students in Winneba Senior High School, Central Region since that was where the researcher identified that the problem was persistent. Absenteeism on part of some of the students on certain occasions compelled the researcher to postpone certain days during data collection.

1.12 Assumptions of the Study

Mugenda and Mugenda (2003) defined assumption as any fact that a researcher takes to be true without actually verifying it (p. 15). Leedy and Ormrod (2001) posited that assumptions are so basic that without them, "the research problem itself cannot exist" (p. 62) since researchers are usually curious of obtaining the available information concerning the problem under investigation. The following assumptions were made to guide the study:

1. Heads at the Science department in Winneba Senior High School, Central Region likewise all Biology instructors shall give an honest concern for the researcher to effectively undertake the study.

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2. Biology students in Winneba Senior High School, Central Region attain conceptual meaning to biological concepts when teachers subject to them to classroom discussion.
3. Biology teachers in Winneba Senior High School, Central Region are aware of the various teaching methodologies.
4. Biology teachers in Winneba Senior High School, Central Region have adequate training.
5. Biology students under the study will cooperate and give honest responses during the administration of the research instrument.

1.13 Definition of Terms

Amino acid: A type of an organic acid that contains a carboxyl functional group (COOH) and an amine functional group (NH_2) as well as a side chain (designated as R) that is specific to the individual amino acid.

Biology: A natural Science that studies life and living organisms including their physical structure, chemical processes, molecular interactions, physiological mechanisms, development, and evolution.

Cell: The basic unit of life found within living organisms.

Chromatid: One of the usually paired and parallel strands of a duplicated chromosome joined by a single centromere.

Chromosome: The microscopic thread-like structure usually located in the nucleus of a cell that carries hereditary information in the form of genes.

Discussion: The activity in which people talk about something and tell each other their ideas or opinions.

Dominant Gene: A gene that masks or suppresses the expression of the alternate form of the same gene.

DNA: An extremely long macromolecule found in the nucleus of organisms that is the main component of chromosomes being the material that transfers genetic characteristics in all life forms.

Gametes: The reproductive cells used during sexual reproduction to produce a new organism (zygote) which is formed during a process of cellular reproduction known as meiosis.

Gene: The basic physical unit of heredity; a linear sequence of nucleotides along a segment of DNA that provides the coded instructions for synthesis of RNA which when translated into protein, leads to the expression of hereditary character.

Genetics: A branch of Biology that deals with the heredity and variation of organisms.

Genetically Modified Foods: Foods derived from organisms whose genetic material (DNA) has been modified in a way that does not occur naturally, e.g. through the introduction of a gene from a different organism.

Misconceptions: Commonly held beliefs about Science that has no basis in actual scientific fact.

Mutation: The change in DNA sequence of an organism.

mRNA: A type of RNA that carries the genetic information needed to make proteins.

Recessive Gene: A gene whose expression is overshadowed by a dominant gene.

Science: The pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence.

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Somatic cell: Any cell in a living organism rather than the reproductive cells.

1.14 Structure of the Thesis

The thesis is organized into five chapters. Chapter one is the introductory part which considered the background to the study, statement of the problem, and the purpose of the study. It further points out the study objectives, research questions, and the relevant hypothesis. Finally the chapter catered for significance of the study, delimitations of the study, limitations of the study, assumptions made for the study likewise the significant terms that need to be defined. Chapter two dealt with the available literature related to the study. Chapter three presented the methodology employed for the study which constitutes the research paradigm, its design, and the approach. It also takes into consideration the population under study, the sampling technique, and the instrument employed to gather data. Finally, pilot testing, validity and reliability of research the instrument, procedures for data collection, and its analysis procedures were delved into likewise the study ethics. Chapter four emphasized on results and discussion based on the data gathered from the research respondents. Finally, chapter five concentrated on the summary, key findings, conclusions, recommendations, and suggestions for further studies.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter reviews the available literature related to the topic under discussion and its summary in order to identify the knowledge gap. It shall consider the following strands:

- Theoretical Framework
- Academic Achievement
- Sex and Academic Outcomes
- Efficacy of Classroom Discussions
- Methods of Teaching Genetics and their Efficacies
- Misconceptions about Genetics Concepts
- Why Genetics Learning Challenges
- Summary of Literature

2.2 Theoretical Framework

Constructivists' theory of learning basing on the idea that learners construct and build their own knowledge about the world around them through experience underpinned the study. Constructivists believe that the construction of new understanding is a combination of prior knowledge and new information (Driver, 1988; Piaget, 1970; Vygotsky, 1978). von Glasersfeld (1995) stated that learning is not a stimulus-response phenomenon, but a process that requires self-regulation and the development of conceptual structures through reflection and abstraction.

According to Jonassen (1994), constructivism is misconstrued as a learning theory that compels students to "reinvent the wheel" (p. 35). Constructivism taps into and triggers students' innate curiosity about the world and how things work. Students do not actually reinvent the wheel but, rather, attempt to understand how it turns and how it functions.

In the classroom setting, constructivists' view of learning point towards a number of different teaching practices. In the most general sense, it usually means encouraging students to use active techniques (experiments, real-world problem solving, class discussions, cooperative approach) to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing. The teacher makes sure he/she solicits for students' preexisting conceptions and guides the activity to address them to enhance meaningful learning (Oliver, 2000). There is no "tabula rasa" (empty-headed) on which new knowledge is etched in constructivists' classrooms. Learners come to learning situations with knowledge from their previous experience with such prior knowledge influencing the new or modified knowledge they construct from novel learning experience thus, learners confront their understanding in light of what they encounter in the firsthand learning situation (Phillips, 1995). Learners remain active throughout this process by applying their current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge and based on that judgment, they can modify knowledge (Phillips, 1995).

Constructivists opine that people produce knowledge and form meaning based upon their experiences. Ratanaroutal and Yutakom (2006) stated that the major concepts within the constructivism learning theory which create the construction of an individual's new knowledge are accommodation and assimilation. Assimilating enables an individual to incorporate new experiences into the old experiences. This aids the individual to develop new outlooks, rethink what were once misunderstandings, and evaluate what is important which ultimately alter their perceptions. Accommodation, on the other hand, is reframing the world and new experiences into the mental capacity already present. Individuals conceive a particular fashion in which the world operates.

Cognitive constructivism as Jean Piaget coined deals about how the individual learner understands things in terms of developmental stages and learning styles and social constructivism coined by Vygotsky emphasizes on how meanings and understandings grow out of social encounters. Cognitive constructivists view each learner as an individual capable of performing a particular task with regards to his/her developmental stage. This asserts that in the classroom settings, teachers should take into consideration the learners' developmental stages before allowing them to solve problems and or perform a particular task. Social constructivists view each learner as a unique individual with unique needs and background. They encourage the learner to arrive at his or her own version of the truth, influenced by his or her background and culture and take into account the background and the culture of the learner throughout the learning process. The learner's background helps to shape the knowledge and truth that the learner creates, discovers, and attains in the learning process (Creswell, 2003).

Petty (2009) asserted that the learner has a responsibility for his or her learning in order to make impacts about his or her life. Teachers who are constructivists are aware of the role of prior knowledge in students' learning, recognizing that students are not blank slates or empty vessels waiting to be filled with knowledge like what behaviorists opined. Instead, they believe that students bring with them a lot of prior experiences, knowledge, and beliefs that they use in constructing new understandings (Jones, 1998). Constructivism teaching fosters critical thinking and creates motivated and independent learners because instructors subject them to the ideas of creation of knowledge. Jones (1998) and Creswell (2003) pointed out that learners do not simply mirror and reflect what they read but they construct their own understanding. Social constructivist scholars view learning as an active process where learners learn to discover principles, concepts and facts for themselves. They believe learners are active in construction rather than passively receiving information and believe that reality is constructed by our ones activities and people as members of a society invent the properties of the world.

Knowledge is a product of human beings and is socially and culturally constructed. In the classroom constructivist teachers usually encourage learners to use active learning techniques such as practical work, pairing, group discussions, brainstorming, role play, video games, simulations, slides, and real life problem solving to create knowledge by reflecting on what they are doing and talking about what they are doing (Yu-Chien, 2008). This influences the pedagogical skills they employ to teach problematic topics such as genetics since these strategies enable learners to construct knowledge by themselves.

Jones (2002) asserted that students' preconceptions are very resistant to change since they are based on a child's early experiences, intuitions and form a filter for later learning. In order for understanding to take place, teachers should elicit students' prior concepts and build on these concepts during instruction by providing educational experiences that confront prior conceptions or provide a cognitive conflict in order to promote conceptual development. The use of a cognitive conflict involves placing a student in a position in which the application of his or her own understanding of a problem leads to cognitive difficulties which the student must then resolve.

Since learning occurs through learners' experiences, it is important that teachers prepare class activities that engage the learners in the lesson. The learners should be given opportunities to work independently and this can be done by giving exercises that they can do individually, in pairs or in groups such as summarizing the main points of a lesson. They should also be given minds-on activities such as discussions, problem solving, and case studies that promote analysis, synthesis, and evaluation of what has been learnt (Yu-Chien, 2008). Teachers' who use constructivists idea of teaching enable students to verify the scientific laws and principles, retain what they have learnt or taught, and to bridge the gap between theory and practice.

2.3 Academic Achievement

Determinants of students' academic performance have been the subject of on-going debate among educators, academics, and policy makers. The extent of student's learning in academics may be determined by the grades a student earns for a period of learning. Academic achievement refers to numerical sources of a students' knowledge which measure the degree of the individuals' adaptation to school work and the educational system (Kobaland & Musek, 2001). Academic success is reliant upon students' attitudes towards academic work. In educational institutions, academic success is measured by how well students deal with their studies, how they cope with, accomplish different tasks given to them by their teachers, and the extent to which a student, teacher, or institution has achieved educational goals (Ankomah, 2002). As an outcome of education, academic performance owes the capacity to achieve what one is tested on or what one has been taught which usually compels instructors to employ the appropriate strategies that boost students' to meaningfully comprehend concepts in order to achieve the of goals of various institutions (Otoo, 2007). Academic performance constitutes what a student is capable of achieving when he or she is tested on what he or she has been taught which is related to intellectual capacity (Otoo, 2007). Academic achievement reveals performance on talk with measures comprehension, quality, accuracy of answers of tests, quality and accuracy of problem solving, frequency and quality of desired outcome, time and rate to solution, time on task, level of reasoning and critical thinking, creativity, recall and retention, and transfer of task (Cary, Roseth, David, & Roger, 2008).

Dimbisso (2009) opined that academic achievement measures the extent to which one accomplishes or performs in a particular subject area and is indicated by grades and marks or scores of descriptive commentaries. He made it worth-knowing that academic achievement comes out with the extent to which one accomplishes or performs in a particular subject area which is indicated by grades, marks or scores or either descriptive commentaries and added that it depicts how students deal with their studies and how they cope with or accomplish different tasks given to them by their teachers in a fixed time or academic year. Ferla, Martin, and Younghong (2009) opined the notion of academic self-concept referring it to an individuals' knowledge and perceptions about themselves regarding academic achievement and convictions that students make to enable them to be academically-oriented in order to successfully perform a given academic task at a designated level. They further asserted that academic self-concept represents a more past oriented aggregate and relatively stable judgment about one's self perceived ability in a particular academic domain whilst academic self-efficacy represents a context specific and relatively future-oriented judgment about one's confidence for successfully performing an upcoming subject-specific academic task.

Academic performance is measured in terms of examination marks, the grading of which concerns the ability of individuals to use the knowledge and skills acquired by allowing students to demonstrate their knowledge by tackling written and oral test performing, presenting, turning in homework, participating in class activities, and discussions. Performance results are shown in the form of letter or number grades and side notes that describe how well a student has done which also allow educators and institutional heads to rank students and or sort them on a scale that is numerically obvious and also a means of holding teachers and schools accountable for the components of each student and his/her grade (Cary *et al.,* 2008).

Students are also evaluated by their performance on standardized tests geared towards specific age based on a set of achievement objectives that students in each group are expected to meet. In the past, academic performance was often measured more by year but today, teachers observations make up the bulk of the assessment as summation or numerical method which is used in determining how a student is performing in a fairly recent invention which relates to curriculum content and the learners' intellectual ability which depends on the learners' competence referred to as academic achievement or scholastic functioning (Babatunde & Olanrewaju, 2014).

2.4 Sex and Academic Outcomes

Enormous efforts have been employed by Science educators in investigating into the academic outcomes between male and female students over the past decades. This is because females are usually undermined that Science is a difficult subject so they may find it challenging to perform to expectations. There is evidence that female students are more susceptible than male students to the negative consequences of “fear of success” or “fear of failure” (Leitenberg, 1990). Sex differences in the frequency and intensity of depressed moods have been well documented with women generally the more frequently depressed sex (Nolen-Hoeksema, 2001). Dysphoric affect is a more salient emotional motivation for women than for men with women making up an increasingly large proportion of the undergraduate population (Goldin, Katz, & Kuziemko, 2006). There is no distinguishing difference in the achievement of students in respect to sex as females are being encouraged and sensitized into developing positive attitudes towards Science (Sungur & Tekkaya, 2003). Several studies have indicated that, a students’ sex has no significant influence on their academic achievement in students’ overall performance in Science (Olasehinde & Olatoye, 2014; Oludipe et al., 2012). Raimi and Adeoye (2002) in their study on sex differences as a determinant of students’ performance in Integrated Science found out that there was a statistically significant difference between male and female students in terms of their Science achievement scores and their attitudes towards Science in favour of the male students

Yoloyo (1994) studied students’ achievement by comparing the percentage of male and female candidates that had credit and above in Science subjects between 1981-1984 reported that male students consistently performed better than female students even in the so-called “female subjects”. Amogne (2015) analyzed sex disparity in regional examination in Ethiopia using the 2014 grade 8 regional examination results of 538 students from 13 randomly selected schools in Dessie Town and found that female students slightly outperformed male students in Chemistry and Physics while in Biology male students performed slightly better than females.

Hashim, Ababkr, and Eljack (2015) examined the influence of inquiry-based Science teaching on Junior Secondary School students' academic achievement and found that inquiry-based Science teaching was significantly in favor of male students as the male students' had higher mean achievement score than females. A study conducted by Adigun, Onihunwa, Irunokhai, Sada, and Adesina (2015) study in Nigeria showed no statistically significant difference between academic performance of female and male students.

Etaga, Abidemi, Umeh, and Eriobu (2017) in their study found that female students were not only effective but they also obtained the best grade points (First class, Second class upper and lower) with the highest marks in Mathematics, Physics and Chemistry.

Bayerbach and Smith (2003) conducted a study into the nature and origin of sex differences in ability and achievement in Science. The findings of the study revealed that there was a statistically significant difference between male and female students test scores. Smith (2004) investigated sex as a factor in problem-solving in the use of grid map to study plant distribution in an abandoned school garden and reported no statistically significant difference in achievement of male and female students.

Gallagher and Delisi (1994) examined sex differences in Scholastic Aptitude Test Mathematics (SAT-M) problem solving among high-ability students. The study examined whether male and female students of high mathematical ability use different solution strategies in Mathematics that had previously yielded sex differences in correct responding. Findings on pattern of sex differences on SAT-M problems among high-ability students shows that female students outperformed male students on conventional problems whereas the male students outperformed female students on unconventional problems. Gafoor and Shilna (2014) results showed that test format has effect on achievement and interaction between sex and test format on students' academic achievement in favor of the male students.

Ogunkola and Bilesanmi-Awoderu (2000) carried out a research on the effectiveness of laboratory-based and lecture methods on students' achievement in Biology and found out that students' achievement in Biology was not sensitive to the sex of the students. Mobark (2014) determined the influence of sex on the effect of using cooperative learning strategy on graduate students' academic performance in Statistics and Educational Research method courses. The data collected were analyzed using independent t-Test statistics which revealed that there was no statistically significant difference in academic performance of male and female students at the pretest, posttest, and delayed posttest.

Pandian (2004) investigated the effects of cooperative computer-assisted learning on male and female students' academic outcomes in Biology. The analysis of results indicated that sex did not express any statistically significant influence on academic achievement in Biology. Samuel and John (2004) examined how a type of cooperative learning strategy known as the Cooperative Class Experiment (CCE) teaching method affect students' achievement in Chemistry. They found that there was no statistically significant difference in sex achievement between the experimental and control groups, but females had a slightly higher mean score than males did. Similarly, Nnorom (2015), on effects of cooperative learning instructional strategy on student's achievement in Biology in Nigeria found no statistically significant interaction between the method and

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sex of students and their academic outcomes but females had a greater mean score than their male counterparts.

2.5 Efficacy of Classroom Discussion

The method employed by teachers in sharing knowledge with students is factor influencing learning achievement of students at all tiers of the education system. While appropriate instructional methods are likely to enhance cognitive achievement among students, inappropriate approaches instructors use in delivering certain concepts stifle students' knowledge retention making learning objectives unachievable (Chang, 2010; Henson, 2004). Consequently, aligning instructional methods with the needs and preferences of students is important for higher learning achievement (Zeeb, 2004). Zeeb further asserted that students whose learning styles do not match with instructional methods employed by teachers are less likely to develop interest in learning.

Odundo (2003) supported by pointing out that in the absence of learner interest in a subject, concentration level drops and learning achievement is greatly impaired. Lowman (1987) highlighted this viewpoint that teacher student interchange in the classroom is discussion. In one, the teacher gives students an opportunity to clarify content or ask for opinions on related topic.

While communication in the classroom is effective, the teacher also instructs the students on how to respect each other even if they disagree with each other resulting in a major effect on students' academic outcomes (Larson, 2000; Mitchell, 2010). Constructivists view student learning as an active process that allows each student to develop his or her learning through social experiences which in turn enable students to connect the classroom content to real-life situations (Atwood, Turnball, & Carpendale, 2010). Therefore, it is important for teachers to make connections between Science topics being learned in the classroom and students' prior knowledge by allowing

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learners to communicate their thoughts to their classmates in a way that is respectful and conducive to Science learning (Emdin, 2010; Larson, 2000; Shemwell & Furtak, 2010).

The most potent argument for discussion in postsecondary classrooms is its potential for boosting student achievement and engaging students in high levels of learning (Rocca, 2010; Wade, 1994). Oyedeji (1996) explained that discussions work on the principle that the knowledge and ideas of several people are more likely to find solutions or answers to specified problems or topics. This is in line with the saying that "Two heads are better than one" and students subjected to it achieve high academic outcomes. Discussion is a variety of forums for open-ended, collaborative exchange of ideas between a teacher and students for furthering students thinking, learning, problem-solving, understanding, and literacy appreciation (Wilkinson, 2009).

In a learner-centered class, students take a participative role by leading discussions and teachers become facilitators. In this regard, teachers facilitate student's discussion and interject only when necessary by allowing students to put the concept language to use and explore aesthetics of learning materials (Eken, 2000). Interactive teachers allow for diverse learning styles among their students and encourage active involvement of all students, while helping them to improve upon their individual weaknesses (Curtin, 2005 p. 40). Students are also encouraged to ask questions, define problems and lead conversations to enable them clear misconceptions they hold (Chika, 2012). Besides, classroom discussions connect students' world with learning pursuits in the classroom by improving the application of acquired knowledge which in turn ensures conceptual meaning among students the former and enhances problem-solving the latter (Bush, 2006; Kumar, 2006).

Classroom discussions are advantageous in a number of ways, for instance, they promote democratic participation in the learning process, encourages critical thinking, meets student's communication needs and improves performance (Cummins, 2007). The positive impacts of this method has also been documented by Chika (2012), who indicated that classroom discussion as an interactive method between students and teachers is more powerful in enhancing learning achievement than other learners-centered pedagogies after comparing lecture, activity-based and discussions impact on students' academic outcomes in a study. Arends (1997) also asserted that classroom discussions can be used to teach complex academic materials and can help teachers accomplish important social learning, human relations, and goals.

The National Science Education Standards (NSES) asserted that students should discuss data analysis and its conclusions with their peers so that they may provide evidence to support their experimental results (NRC, 1996). A positive learning environment generates thinking and speaking as scientists when communication is encouraged and the teacher allows students to think on their own without always having the right answer (Emdin, 2010; Mitchell, 2010). Once teachers are comfortable with allowing students to discuss their thoughts aloud with each other, learners will begin to build on their own learning while gaining insight from their peers. When participating in classroom discussions, pupils are active in their learning and they are able to associate the topics with experiences they have had in their lives already (Larson, 2000). Student and teacher talk play a crucial role in teaching and learning in classroom settings since spoken language is the central medium by which teachers teach and arguably, the primary means by which students learn as "speech makes reflection processes easier for which students to relate new knowledge to old" (Cazden, 2001). Educative dialogue has represented a forum for learners to develop understanding by listening, reflecting, proposing, and incorporating alternative views which enable students to improve upon their academic outcomes especially in Science related disciplines (Michaels, O'Connor, & Resnick, 2008).

Schleppegrell (2004) in a study found that classroom discussions played a tremendous role in enabling students to achieve high academic outcomes of what they learnt since they were able to master the linguistic conventions of History, Science, and Social Studies as well as the formal academic language that marks their identities as educated persons. Mercer and Howe (2012) concluded that when teachers actively engage students in reflective discussions of what they are studying, it helps them to learn, develop their understanding, and prepares them well for independent learning which in turn increases academic performance (p. 14).

Muzumara (2008) and Petty (2009) opined that during class discussions, students learn a number of skills such as being open to new ideas, making eye contact with the speaker, being attentive, organizing thoughts, speaking clearly, taking notes, allowing speakers to express their thoughts without interruption and respecting other people's ideas. Brooks and Brooks (1999) in their study highlighted methods of learning that are most effective with a corresponding amount of information that is best retained after instruction and asserted that classroom discussions yield a significant role in enhancing student's ability to recall what they have learnt.

Zakaria and Iksan (2007) emphasized that SCL such as classroom discussions puts forth students' prior knowledge as it influences future learning and concluded that since student-initiated questions are more common in discussion classes, their needs and interests are dealt with more readily and spontaneously than in other methods. Gage and Berliner (1988) summarized the objectives of classroom discussions as thinking critically, democratic skills, complex cognitive objectives, speaking ability, ability to participate, and attitude change amongst students. Vedanayagam (1994) posited that the major purpose of using discussion is to encourage students to evaluate events, topics, or results, to clarify the bases for their judgments, and to become aware of other points of view.

Davar (2012) stated that some learners assume responsibility by taking leadership roles in the group which enable them to collaboratively construct their knowledge and pointed out that learners can construct concept maps during class discussions and solve questions involving high level items with regards to Science concepts (p. 15). In Mathematics for example, students learn how to explore mathematical ideas, make and test conjectures, and learn to use the formal language of the discipline when they are engaged in discussions (Smith, Hughes, Engle, & Stein, 2009; Walshaw & Anthony, 2008).

In the context of dialogue in classrooms, "every student subjected to it constructs and discloses his or her weaknesses which the instructor diagnoses to enable them to gain conceptual meanings and to enrich understanding for all participants" (Eeds & Wells, 1991). In addition, classroom discussions lead to more interest in interdisciplinary and connected learning (Cox & Richlin, 1993). Crone (2001) in a study on classroom discussions in undergraduate classrooms concluded that the methodology motivates students to learn, engage them in higher level of thinking, and increase their class morale as it gives effective feedback to teachers which enable them to diagnose the students learning challenges as they communicate their thoughts making them to develop positive towards instruction.

Koschmann, Kelson, Feltovich, and Barrows (1996) on computer-supported collaborative learning purported that meaningful group discussions leads to cognitive benefits by engaging students in deep reflections on their ideas. Also, the cognitive processes involved in asking questions, providing explanations in response to questions and elaborating on one's ideas to provide these explanations, all contribute to learning (Cohen, 1994; Slavin, 1996).

Albion and Gibson (2000) emphasized the importance of including collaboration in multimedia-based, problem-solving environments, stating that the efficacy of problem-based learning stems from discussions among group members. Rocca's (2010) study on student participation in the college classroom concluded that classroom discussion promotes learning in postsecondary classrooms by actively involving students in college learning experience the former and increased their academic outcomes the latter (p. 190). Hardman and Mroz (1999) on a study on the use of classroom discussions to deliver literacy lessons found that that discussions give students a means to draw on the knowledge and experience that they bring to their courses giving them more responsibility and control over their learning which in turn increased their academic outcomes. In general, many postsecondary educators view discussion as an alternative to lecture that is seen as encouraging passive acceptance of information rather than deep engagement with ideas (Steen, Bader, & Kubrin, 1999; Windschitl, 1999).

Harton, Richardson, Barreras, Rockloff, and Latane (2002) examined the impact of an approach to classroom discussion which was termed "Focused Interactive Learning" (FIL) on students' achievement in five undergraduate Psychology classes reported that students performed better on end-of-chapter test items they had discussed than on chapters they had not discussed.

de Grave, Schmidt, and Boshuizen (2001) also reported a positive effect of classroom discussion on experimental group medical students achievement in blood pressure regulation and found that students in the experimental group recalled 25% more

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information from the text than the control group students who had not discussed blood pressure regulation. Christianson and Fisher (1999) reported that students enrolled in a discussion Biology class compared to students enrolled in large lecture or laboratory classes, developed a deeper understanding of osmosis and diffusion.

Lyon and Lagowski (2008) found that students in a general Chemistry class who volunteered to participate in small discussion groups outperformed students who did not participate in these groups on course examinations and final grades. Birney and McKeachie (1995) reported that students taught by discussion generally achieved superior performance on measures of thinking, retention after the final exam, motivation, and attitude change and concluded that positive effects of classroom discussions go beyond exam scores and course grades. Josten (1996) examined the effect of discussion on the reading comprehension of 80 developmental readers in a 2-year college setting and found that although the combined scores for the discussion and control groups were not significantly different, the sections of students who engaged in discussions performed significantly better than the control group.

Levin (1995) found that classroom discussion is a crucial variable in in-service teachers' ability to learn from case studies. Experimental and control conditions each consisting of 12 teachers subdivided into two groups of six teachers were involved in the study. All the groups read and wrote about a case and then read and wrote about the same case a second time several weeks later. Between these two events, the experimental group participated in a discussion of the case study. The second time they wrote about the cases, teachers in the discussion group, compared to the teachers in the control group, elaborated on their original thinking and displayed changes in their understanding of the case study.

Copeland and Decker (1996) reported that students who discussed video cases in groups of three were somewhat more effective adopting, transforming, or creating new ways of making meaning of the vignettes they worked with over one third of the time. Bolt (1998) also reported an improvement in Physical Education students' general propensity to identify problems and proposed solutions when they participated in case study discussions. Comparisons of small group discussions to lecture-based courses in various fields have typically shown small group discussions result in greater quantitative conceptual learning than lecture alone (Capar & Tarim, 2015).

Levin (1995) on the contributions of case discussions to teachers' thinking indicated that discussions helped student teachers and less experienced teachers clarify and elaborate on their ideas about issues in a case. Caulfield and Persell (2006) in their study presented evidence that the experimental group students that were taught using classroom discussions performed better than their counterparts in the control who were taught using the traditional strategy. Garside (1996) found higher overall test scores in lecture-based sections of a communications class, but the small group discussion sections scored significantly better on higher level thinking items.

Abdulhamid (2010) conducted a study on the effect of two teaching methods on Secondary School students' in Agricultural Science performance and found that classroom discussions had an impact on students' performance in the subject. Falode, Adewale, Ilobeneke, Falode, and Robinson (2015) in their study on effects of discussion instructional strategy on the achievement of Secondary School students in Human Geography found that discussion method is more effective in improving students' achievement and retention. Gokhale (1995) explored the effects of group discussions on drill-and-practice and critical thinking tests and concluded that collaborative learning had a positive effect on critical thinking by helping students to learn from each other's experiences and knowledge and stimulating more in-depth reflection. In Rushton's in-depth qualitative study (2003), findings showed that pre-service teachers' interactions with students and mentoring teachers helped them cope with their doubts and abilities which led to increase in their self-efficacy.

Wilson (1996) examined the effectiveness of field experiences in a teacher certification program for elementary Science, Mathematics, and Technology students noted that the participants preferred small group discussions since they pointed it as a methodology that increases their self-efficacy. Brown and Inouye (2008) asserted that learners' self-efficacy increases when they observe multiple people similar to themselves discussing and solving problems related to technology integration making them have interest in the subject which in turn leads to an improvement in their academic outcomes.

Ebrahim (2012) in his experimental study compared the effectiveness of lecture method and classroom discussions on Kuwait students' achievement in Science subjects and their use of social skills with a sample of 163 elementary Science students and found that students in experimental group taught by discussions showed a significant academic achievement and social skills than their counterparts in the controls.

Similarly, Reza, Abozar, Ali, and Akbar (2013) also found similar results in their study amongst Tehran students which intended to measure the impact of discussions on first grade male students' academic achievement in Science subjects and the level of their test anxiety. Their analysis revealed the effectiveness of the approach on academic success and in reducing test anxiety on students in experimental group than the controls.

Gillies and Boyle (2010) coined that discussions enable students to gain and create both academic and social relationships to accomplish shared goals within educational settings.

Hypothesized benefits of discussion include higher-order thinking and reasoning skills (Sun, Anderson, & Morris, 2015; Webb, Franke, Turrou, & Ing, 2015), reading comprehension (Applebee, Langer, Nystrand, & Gamoran, 2003; McKeown, Beck, & Blake, 2009), overall engagement (Henning, 2005; Nystrand, 1997), and collaboration and communication skills (Cazden & Beck, 2003). A body of evidence had indicated that academically rigorous discussions in classrooms positively affected students' academic performance across various disciplines; Language Arts (Lee, 2001), Mathematics (Chapin, O'Connor, & Anderson, 2003; Lampert & Ball, 1998), High School Physics (Minstrell, 1989), elementary Chemistry (Warren & Rosebery, 1996) and middle school Science (Sohmer, 2000).

2.6 Methods of Teaching Genetics and their Efficacies

Teaching methods are the ways instructors employ to convey learning materials to learners. Amadi (1992) stated that instructional methods refer to all the things the instructor does in the classroom to enable the learner learn. Ugboaja (2008) asserted that instructional methods involve the instructors' skills and manipulations on the subject matter and the learning situations in order to secure positive and desired response for learners. Instructional methods according to Otagturuagu (1997) are organized in a sequence of steps by means of which information is consistently presented to learners which are in line with a given discipline. For a particular instructional method to be appropriate and efficient it has to be in relation with the characteristics of the learner and the type of learning it is supposed to bring about as well as how students learn (Westwood, 2008). Genetics is a topic which is being taught by instructors by employing numerous instructional methodologies. Some of these teaching strategies are outlined below:

2.6.1 Inquiry-Based Approach

Inquiry-based Science instruction deals with posing a problem to students and providing them with the appropriate materials to investigate into it to solve the problem (Maxwell, Lambeth, & Cox, 2015). This process is characterized by actions such as probing, searching, exploring, and investigating (Martinello & Cook, 2000). The inquiry approach is often referred to as "guided discovery" where teachers guide students' inquiry' until the students discover specific Science concepts predetermined by teachers. This method of teaching assumes that all students have the same level of background knowledge in the subject matter and are able to absorb the material at the same pace (Lord, 1999). Inquiry-based learning (IBL) make students to discover everything in their near environment, develop strong arguments about the natural and physical world surround them based on strong justifications, become aware of the significance of Science, and construct information about doing, living, and thinking (Wallace & Wood, 2003).

There are four different levels of inquiry and each successive level comes with students' independence. The first level is confirmation inquiry, where students are given most of the information including the question, procedure, and what the results should be (Banchi & Bell, 2008). Teachers can implement level one as a final activity by wrapping up a concept that has already been learnt. The second level is structured inquiry where students are given a question and a prescribed procedure to answer it. Moving up, the next level is guided inquiry where students are only given the question leaving a lot of room for student ownership to answer it (Bell, Smetana, & Binns, 2005). The final level is open inquiry where learners create their own questions and have the freedom to decide on what to undertake to undermine the problem (Banchi & Bell, 2008). Each of these levels build on one another which requires teachers to take inquiry learning step-by-step and complete each level before moving on. In 2000, inquiry and the national Science education standards declared five main characteristics of inquiry-based Science teaching without any classification as pointed out by NRC (2000).

1. Learners are engaged in lessons by probing scientifically oriented questions.
2. Learners give priority to evidence which allow them to develop and evaluate explanations that address scientifically oriented questions.
3. Learners formulate explanations from evidence to address scientifically oriented questions.
4. Learners evaluate their explanations in light of alternative explanations particularly those reflecting scientific understanding.
5. Learners communicate and justify their proposed explanations.

Within IBL, students analyze their results and come up with their own conclusions in order to answer a research question (Bell, Smetana, & Binns, 2005). Employing traditional teaching methodologies cause rote learning of Science since they regard students as having knowledge holes that need to be filled with information. In short, the traditional teacher views that it is the teacher that causes learning to occur (Novak, 1998). IBL can be implemented at different levels. These levels are constructed inquiry, guided inquiry, and free inquiry (Colburn, 2000). In a guided-inquiry IBL model, the teacher provides guidance for the construction of questions, students plan their own questions and processes, and they generate new concepts by creating connections between prior knowledge and new information (Colburn, 2000). IBL provides students with knowledge and skill development, increased intrinsic motivation, development of expertise, self-efficacy, task commitment, positive attitudes about learning, competence or expertise, and greater creativity (Saunders-Stewart, Gyles, & Shore, 2012). Inquiry, as an instructional model, focuses on the process of learning and solving problems using hands-on approach that involves reflection and evaluation in a cyclical manner (Spring, 2005; Van Deur, 2010).

In numerous studies, it was found that the inquiry-based teaching (IBT) is much more efficient in improving students' performance than traditional teaching methods (Celik & Cavas, 2012), students laboratory skills and Science process skills (Ozdemir & Isik, 2015), their ability to remember the content of the course (Schneider & Rener, 1980), favors every sex, and positive attitudes towards Science and scientific activities (Arslan et al., 2014). Ergul, Simsekli, Calis, Ozdilek, Gocmencelebi, and Sanli (2011) carried out a study with elementary students about how inquiry-based Science learning changes their Science process skills and attitudes towards it and found that inquiry-based Science learning significantly influenced their Science process skills and attitudes towards it. Studies have indicated that inquiry-based Science learning increased students' Science process skills, achievement and attitudes towards Science and technology than traditional learning (Hmelo-Silver, Duncan, & Chinn, 2007; Tatar, 2012) with statistical significance whereas a study found that there is no effect of inquiry-based Science teaching learning on students' Science process skills, achievement and attitudes towards Science and technology compared with traditional learning (Yildirim & Berberoglu, 2012).

Minner, Levy, and Century (2009) reviewed a total of 138 studies on the effects of IBL in Science education on students' achievement and their conceptual comprehension. They found that the IBL method had significant effects on the students' academic achievement and their conceptual comprehension. Maxwell *et al.* (2015) found that IBL increases critical thinking skills as compared to traditional teaching. Duran and Dokme (2016) conducted a study by comparing the effectiveness of traditional lecture and the IBL to gauge critical thinking skills of students. Their results revealed an increase in critical thinking skills in students taught using the IBL than their counterparts taught by the traditional lecture approach.

Buchanan, Harlan, Bruce, and Edwards (2016) pointed that allowing students to complete an investigation may lead them to fail which then requires them to rethink their previous knowledge and learn from their mistakes. They further asserted that IBL is the approach that leads students to possibly fail and re-do thus, allowing them to learn from their mistakes which help a person to recognize what went wrong and inherently remember the content later next time.

New knowledge is acquired as students collect data, analyze data, and solve problems. Memorizing facts does not promote or develop problem-solving skills but when students are allowed to investigate, reason, and organize knowledge, they are able to incorporate new knowledge into their understanding (Miller, McNeal, & Herbert, 2010). Students' scientific understanding is supported through the expansion of habits of the mind and using problem solving skills. Using prior knowledge, students make connections with their new knowledge. IBL is seen as a system of learning that supports the development of students' problem solving and critical thinking skills which is important for them in everyday activities. Maxwell *et al.* (2015) assertioned that through IBL, students learn not only how to ask questions and figure out the answers, but they also learn what questions are important for them to ask and reiterated that a learning environment that supports this kind of cognitive skills enables students to assimilate these skills in other areas of learning (p. 3).

Aydeniz, Cihak, Graham, and Retinger (2012) reported that students' knowledge of electricity improved from a baseline of 4.7% to 76% after the implementation of the IBL activity. IBL has a positive impact on students' attitudes toward learning in Science when Watters and Ginns (2000) stated that IBL gave teachers greater confidence in their ability to teach Science and facilitate strategies for student-centered activities which made their students show a deeper understanding of contents in Science. Kazempour (2009) recommended that IBL should be encouraged in classrooms since it enhances deeper understanding of Science than traditional methods.

Drake and Long (2009) stated the curriculum centers around problems rather than disciplines and concluded that the IBL group showed an increase in on task behavior (68.72%) over the comparison group (58.75%) in addition to significant growth in the IBL groups' content knowledge. Branch and Solowan (2003) opined that inquiry focus on the asking of questions, critical thinking, and problem solving which enables students to develop skills needed throughout their whole lives. Inquiry methods of learning provide opportunities for students to focus on the process of how they learn through questioning and reflection skills (Littky & Grabelle, 2004; Wiggins & McTighe, 1998). Samuel (2016) investigated into the impact of inquiry on High School students' academic outcomes in New Jersey and found that the pretest revealed no statistically significant difference between the experimental and control group students but the experimental group students attained a high mean score than their counterparts in their controls. Inquiry skills are aligned with methods of learning that have been referred to as problem-based learning, authentic learning experiences, investigative processes, learning through lenses, and other activities that immerse students and teachers in making personal connections and well-thought out choices (Harvey & Daniels, 2009; Jacobs, 2010). Inquiry allows students' to make determinations about problems, challenges and issues they investigate, and help to move students' into a meaningful engagement and deeper learning (Buchanan, Harlan, Bruce, & Edwards, 2016).

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Limitations of Inquiry Approach

Bailey (2018) asserted that inquiry-based instruction and learning is affected by influences that comes without the right guidance and support, lack of resources or multiple perspectives, no enough time to plan and properly implement inquiry lessons and assessments, the ease of direct instruction over inquiry instruction, limiting classroom disruptions, and the attitudes of teachers and students in the inquiry process. Having limited resources and perspectives for students to view hinders their ability to historically think about information. This historical thinking encompasses the interconnected dimensions of historical comprehension, chronological thinking, historical analysis and interpretation, historical research capabilities, and historical issues analysis and decision-making. Students must move beyond the facts in the course textbook and examine "documents, journals, diaries, artifacts, historic sites, work of art, quantitative data, and other evidence from the past" (Prokes, 2009, p. 16). The use of multiple resources and perspectives is important in classes that stress skills for life-long learning, communication, and critical thinking (Scott, 2015). "An important restriction of this strategy is that, teachers cannot simply transmit knowledge to students but the students need to actively construct knowledge in their own minds" (Olusegun, 2015).

Another challenge is the impact of teacher and student attitudes on the inquiry process. Teachers that have never taught with a constructivist approach believe they have never been opened to the learning theory due to "rigid curriculums, unsupportive administrators, and inadequate pre-service and in-service educational experiences downplaying students' acquisition of scientific knowledge" (Brooks & Brooks, 2001, p. 101). Numerous students, on the other hand, have more frequently been exposed to more teacher-centered instruction and have little to no experience in inquiry (Pahomov, 2014).

2.6.2 Concept Mapping Approach

A concept map is a multi-dimensional representation of the relationship between key ideas. At first glance, a concept map looks like a flow chart in which key terms are placed in boxes connected by directional arrows (Ajaja, 2009). The principle of a concept map is that it provides a visual means of showing connections and relationships between a hierarchy of ideas ranging from the very concrete to the abstract (Bennett, 2003). The concept mapping strategy in education is based on Ausubel's assimilation theory of cognitive learning (Ausubel, Novak, & Hanesian 1978). According to this theory, meaningful learning facilitates high-level learning and occurs when students learn by self-discovery (Ausubel, 1968). Concept mapping is a learning strategy that helps learners to organize various concepts (Liu, Chen, & Chang, 2010).

Ajaja (2011) stated that concept maps help in understanding ideas by showing the connections with other ideas. The benefits of concept mapping are mainly to the individual making the map. The process of simplifying concepts and arranging them on a page compels the learner to think about what is most important. In this approach, teachers' present concepts in a hierarchical manner; the most general are positioned in the superior part of the map, while the specific concepts are positioned in the lower part of the map. The reason why concept mapping is powerful for the facilitation of meaningful learning is that it serves as a kind of template or scaffold to help to organize knowledge and to structure it (Emmanuel, 2013).

Ajaja (2011) further stated that the development of concept mapping as an instructional tool can be traced to the early work of Ausubel and others in the 1970s and added that since its introduction, concept mapping has become a very useful tool in teaching and learning and particularly in Science education. Literature on concept mapping indicates that when it is being employed for instruction, it has relevance in improving the cognitive and affective aspects of learners (Johnson & Raven, 1998; Trowbridge, Bybee, & Powell, 2000).

Kinchin (2000a) found a significant impact of concept mapping on students achievement among Secondary School Biology students and found a statistically significant difference between the sores of students exposed to the teaching strategy than the controls. Kinchin (2000b) in a study compared the effect of the use of concept mapping as a study skill on students' achievement and found a positive effect on students who used concept maps to revise and summarize the materials given along with other instructional strategies. Okebukola (1989) investigated whether concept mapping alone as an instructional strategy in Biology would enhance meaningful learning when he compared concept mapping and cooperative learning groups. The study found a significantly higher achievement scores in Biology among students in the concept mapping group than those in class taught with cooperative learning technique.

Jegede, Alaiyemola, and Okebukola (1992) compared the effectiveness of concept maps as teaching strategy in Nigeria and found it to be an effective teaching methodology that improves students' academic outcomes. Ezeudu (1998) examined the effect of concept mapping on students' Chemistry achievement in Enugu and Nsukka educational zones and found out that students taught with concept mapping significantly performed better on achievement tests than those in the control group. Mensah, Otuka, and Ernest (1995) in a study in Senior Secondary Schools in Ghana recommended that concept mapping can be used as a pre-instructional and post-instructional tool in Biology classrooms to enhance conceptual meaning among students.

Markwo and Lonning (1998) investigated the use of students' constructed maps and the effects the maps on students' conceptual understanding of Chemistry experiment that they performed. They found that the construction of the pre and post instruction concept maps did help students understand the concepts in the experiments they performed. Ezeudu (1998) studied the interaction effect between concept mapping and sex on achievement in Chemistry and found that the methodology was effective when it comes to meaningful learning among students. Obianor (1997) found a significant impact of concept mapping in boosting students' academic achievement but found no statistically significant difference in achievement between males and females taught with concept mapping. To effectively teach and meaningfully learn genetics, concept mapping strategy has been recommended as a vital tool to improve students' performances in Biology (Agboghoroma & Oyovwi, 2015). Adlaon (2002) in his work discovered that concept map is a tool that enabled students to summarize texts and identify main ideas as well as provide useful ways to assess student understanding of a topic.

Limitations of Concept Mapping Approach

Bennett (2003) identified two major limitations of the use of concept mapping in instruction. First, concept mapping is not easy to construct, and respondents require training and practice in producing maps. Second, there are difficulties with the interpretation of concept maps in particular with devising appropriate ways of scoring to enable valid comparisons to be made. Peg (n.d) purported these as the limitations in using concept maps; difficult for students to interpret sometimes and asserted that one type of concept map known as the spider map may distort the importance of relationships and become difficult to read, hierarchical maps showing the progression from general to specific may lack connections among ideas. Finally, concept maps or graphic organizers may offer limited benefits if instructors introduce them at the wrong times. Concept maps work most efficiently at the University level. Therefore, introducing them to lower learners may yield disappointing results.

Hay (2008) asserted that the method does not fully acknowledge that interactions between mind and language are mediated through various symbolic structures and traditional concept-mapping theory does not easily accommodate the multiple perspectives encountered in University settings (Vosniadou, 2007).

2.6.3 Lecture/Traditional Approach

Lecture method is a teacher-centered approach where all the activities in class is centered on the instructor/teacher. Lecture is the oldest teaching method applied in educational institutions. This teaching method is one-way channel of communication of information. Learners/students involvement in this teaching method is just to listen and sometimes write down some notes during lecture, combine information, and organize it. Onwuka (1996) stated that, the traditional view of teaching is that the instructor knows everything and that the learner is blank. The instructor uses this method to impart knowledge to the learner by merely telling them. The instructor talks or addresses the learners by means of reading his notes, while learners silently and passively listen (Amina & Ester, 2017).

Lectures also may be used to introduce a topic or complete a training program. Lectures may be combined with other teaching methods to give added meaning and direction (CTL, 2006). There are several types of lectures such as the illustrated talk where the instructor relies heavily on visual aids to convey ideas to the learners. During a formal lecture, the instructor's purpose is to inform, persuade, or to entertain with little or no verbal participation by the learners. When using a teaching lecture, the instructor plans and delivers an oral presentation in a manner that allows some participation by the learners and helps direct them toward the desired learning outcomes. Killen (2007) asserted that lectures are good for teaching specific facts and basic skills, factual material are presented in a direct and logical manner which is very essential for introduction of new subject or topic to learners. It is used to present new material not yet available in print or books. Freiberg and Driscoll (2000) pointed that it is an efficient method to transmit content to a large group of learners, since it is the best method to use when the facts or problems are conflicting or confusing in nature and when there is shortage of time (p. 25).

The traditional view of teaching and learning sees teachers as passing over their knowledge to their pupils (Bennett, 2003; Trowbridge, Bybee, & Powell, 2000). This view is strongly linked to expository teaching; teachers standing at the front telling their pupils about scientific ideas. The transmission view implies that the pupil's role in the learning process is largely passive, and that a pupil's mind is a "tabula rasa"-a blank state onto which knowledge can be written. Ramsden (2003) further described this didactic method as education through the transmission of information and suggests that the theory underlying this teaching methodology assumes that students are passive recipients of knowledge transmitted by instructors. Lecturing, as Charlton (2006) claimed is the best teaching method in many circumstances and for many students especially for communicating conceptual knowledge and when there is a significant knowledge gap between lecturer and audience. In addition, lectures, as Carpenter (2006) opined are very adaptive to time tables, other courses, different audiences and new cognitions, and they play a valuable part in the social life of students.

Students' involvement in this teaching method is mainly to listen, jot down some notes during the lecture, combine the information and organize it (Marmah, 2014). Huxham (2005) maintained that students who are auditory learners find that lectures appeal to their learning style more than to other students. A good lecture always offers a point of view and an avenue of entry into a field of study. In addition, a lecturer may focus students' attention to help them identify and remember central points of lessons. The lecture method, therefore, emphasizes the role of the lecturer in communicating knowledge to students (Davis, 2009). The latter role is mainly to take notes during the lecture and repeat whatever students have learnt on exam papers. Students are often passive learners who can most of the time depending on the lecturer and their learning (Brookfield, 1995). Nonetheless, lectures are effective educational tools as Wood, Sadhbh, Petocz, and Rodd (2007) pointed out that if the instructors involved in the lesson delivery are skillful, competent, clear and enthusiastic voice, good eye contact, and appropriate gestures, they could be good mainly for auditory learners and those who are aware of different modes of presentation.

Teaching methods that enhance engagement and encourage self-directed learning is effective in delivering core knowledge and explaining difficult concepts leading to increased learning (Wolff, Wagner, Poznanski, Schiller, & Santen, 2015). Traditional didactic lectures were perceived by students as the least effective method used yet involves students actively within the lecture time and regarded as a more effective teaching and learning tool (Butler, 1992). Lectures have the advantage of sharing information with a large number of students and it can be effective in transmitting factual information (McKeachie, 1994).

Lecture is an effective teaching method when the lecture is given as large-group interactive learning sessions with discussion and frequent questions to students who have prepared in advance (Schwartzstein & Roberts, 2017). In interactive lecture, students are asked to actively participate and process knowledge throughout the lecture. They also take an active part in contextualizing the content and directing the focus of the lecture towards areas they find difficult to understand (Fyrenius, Bergdahl, & Silen, 2005). Therefore, teachers can use the lecture to encourage students to construct their own understanding of concepts, relationships, and enhance application of theories by choosing suitable student-centered learning approaches (Powell, 2003).

Chilwant (2012) compared structured interactive lectures with conventional lectures in two groups of second year medical students by giving questionnaire and multiple-choice questions (MCQs). Although their results showed no significant difference in average MCQ marks of two groups, students in the interactive group enjoyed being actively involved in the lecture which increased their engagement, attention during the lecture and stimulated their critical thinking. Domitrovich-Cortis and Greenberg (2007) noted that the lecture method is associated with the telling or didactic teaching method which results in allowing students to learn numerous concepts at a go making teachers to be able to complete the curriculum within the speculated time. This means that the teacher centered teaching happens in a highly teacher dominated environment in order to meet the demands of the curriculum (Egbo, 2008).

Teachers using the lecture method have very limited concern about student’s ideas and reasoning when they prepare their lessons (Olulube, 2006). Kirk (2000) noted that lecture method allows easy control over students thus their actions are more on helping students to develop understanding of subject matter. In other words, the teacher gives more attention to students, cognitive knowledge, and also use assessment as a tool to assign grades.

Researchers, especially in Africa and Asia, see lecture method as a valuable tool for effectively teaching and high student academic performance (Obanya, 2012) cited in Obunadike, 2011). Lecture employs the application of contemporary knowledge and ideas, effective use of appropriate questioning, time management and the arrangement of the classroom, proper curricular development, the statement of the instructional objective, and mastering of subject matter which makes it an effective instructional method (Creemers, 1994).

Hegarty (2000) asserted that instructional competence is needed to do well in the use of the lecture method and stated that having quality teachers in institutions enable high-quality teaching and learning critical to the welfare of the nation's education system and the young people it serves. Miranda and Landmann (2011) supported by pointing out that if teachers can be trained to provide an enriched environment and teach effectively during lectures, it ensures the completion of a curriculum which challenges every child is challenged to perform far above grade level.

Limitations of Lecture Method

Amina and Ester (2017) pointed the following to be the drawbacks of this teaching methodology as follows:

1. Learners frequently forget or never learn much of the materials taught.
2. Learners are placed in passive rather than active role which hinder learning and learners' attention may be lost.
3. Instructor cannot interact with all learners on each point.
4. Instructors find it difficult to hold the attention of learners.
5. Instructors cannot estimate learners' progress before examination (p. 21).

2.6.4 Computerized Assisted Instruction (CAI)

The term Computerized Assisted Instruction (CAI) as the name suggests is the use of a computer to provide instruction. The use of technology in education provides students with a more suitable environment to learn, serve to create interest and a learning centered-atmosphere, and helps to increase students' motivation. The use of technology in this way plays an important role in the teaching and learning process (Isman, Baytekin, Balkan, Horzum, & Kiyici, 2002). CAI makes teaching techniques far more effective than those of the traditional teaching methods as it is used for presenting information, testing and evaluation, and providing feedback (Ozmen, 2004). It makes a contribution to the individualization of education. It serves to control a lot of variables having an impact on learning which cannot be controlled by means of traditional educational techniques (Chang, 2002; Kasli, 2000). CAI allows learners to be able to take increasingly more responsibility to choose, control, and evaluate their own learning activities which can be pursued at any time, at any place, through any means at any age. Simply put, learners can decide what they want to learn and in what order (Pilli, 2008). Liao (2007) found out that computer assisted instruction (CAI) had a positive effect on individuals by comparing 52 research studies carried out in Taiwan in his meta-analysis study.

In CAI, rote learning is minimized and meaningful learning can occur (Renshaw & Taylor, 2000). Schank (2001) summarized the benefits of CAI in classroom practice. First, it gives opportunities to both students and teachers to be quicker in instruction, promote student engaged learning, increase learners' motivation, provide learners with abundant sources of information and support collaborative learning. Ozmen (2008) alluded that use of computer technology enables learners be active in the learning process, to construct knowledge, to develop problem solving skills and to discover alternative solutions.

Efe and Efe (2011) examined the effectiveness of CAI compared to the traditional teaching in the implementation of cells and found that the pupils who were taught by CAI software which contained a large number of simulations were more successful in solving problems in six cognitive domains. Senteni (2004) found out that CAI enabled the students to increase their motivation and achievements and to develop positive attitudes. Berger, Lu, Belzer, and Voss (1994) and Geban (1995) found out that CAI increase students' attitudes and achievements significantly. Atif (2014) examined the effects of the computer-assisted learning on the achievements and problem-solving skills on Educational Science students. The result revealed that experimental group students with computer-assisted learning methods increased their problem-solving level, achievement, and showed a higher performance more than the control group students.

Dukuzumuremyi (2014) reported the use of computer supported collaborative learning is a resourceful way of developing collaborative skills among students. Kareem (2015) investigated the effects of introduction of CAI in Biology by comparing it to the conventional method of teaching on Senior Secondary School students' achievement and found that improvement in students' academic achievement in Biology resulted from the use of CAI.

Olakanmi, Gambari, Gdodi, and Abalaka (2016) in their study found that Nigerian Secondary School students who were taught Chemistry with CAI had higher extrinsic and intrinsic motivation as well as achievement than those in conventional teaching methods. Jesse (2012) in a study on enhancement of Science performance through CAI

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in Kenya noted that the improvement in Science performance by the experimental group was as a result of the application of CAI in Science. Charagu (2015) in a study assessed the effects of computer-based learning on Kenyan Secondary School students' achievement in Chemistry and indicated that the significant improvement in Chemistry performance for students from the experimental group was attributed to the effectiveness of CAI. Hancer and Tuzeman (2008) found that CAI is more efficient than the traditional methods concerning the increase of academic achievement of students in the realization of lessons.

Limitations of CAI

Wehrle (1998) also stated "the pre-computer age generation envisions designing computer technologies that still take into account the emotional needs of the students" (p. 5). The main argument against computers in the classroom is that teachers do not take into account the importance of student emotions.

Mahvish, Showkat, and Mudasir (2017) established the following as the limitations associated with CAI:

1. It is not an integral part of the education but a novelty.
2. It is expensive.
3. Some of the content in a CAI package can be out-dated.
4. CAI courseware lacks specificity on students' existing learning difficulties.
5. The increasing development in hardware makes selection of a system difficult for CAL as the system may become obsolete (p. 257).

2.6.5 Demonstration Approach

Demonstration method refers to the type of teaching in which the teacher is the principal actor while the learners watch with the intention to act later. Here the teacher does whatever the learners are expected to do at the end of the lesson by showing them how to do it and explaining the step-by-step process to them (Ameh, Daniel, & Akus, 2007). Mundi (2006) described it as a display or an exhibition usually done by the teacher while the students watch with keen interest. The role of the teacher is to illustrate how to do something or illustrate a principle first by explaining the nature of the act verbally, followed by exhibiting the act in a systematic manner and later the students repeat the act. Through demonstrations, students are exposed to physical materials that will illustrate meaning to their cognitive framework. Dorgu (2015) asserted that demonstration is useful mostly in imparting psychomotor skills and lessons that require practical knowledge. The gains of using demonstration method in teaching lies in the fact that it bridges the gap between theory and practice, enables learners to become good observers, and generate their interest whereas students see immediate progress as a result of a correct effort and which enable teachers to teach manipulative and operational skills. Furo, Abdullahi, and Badgal (2014) suggested that demonstration is appropriate for teaching students of primary and secondary schools because it encourages adequate participation of students in the learning process. Demonstration strategy is effective for long-term memory retention and appropriate to college students' study skills (McCabe, 2014).

Classroom demonstrations help students meaningfully comprehend most Science courses in schools and universities and to stimulate student interest (Crouch, Adam, Fagen, Callan, Mazur, 2004). Most students get a great deal more out of visual information than verbal information (spoken and written words and mathematical formulas) which favours visual learners (Felder, Woods, Stice, & Rugarcia, 2000). Demonstrations provide a multi-sensory means to describe a concept and an idea or product that may otherwise be difficult to grasp by verbal description alone (Cabibihan, 2013). Demonstration strategy has emerged to become an instructional approach that is gaining rising interest within the Engineering Education community (Hadim & Esche, 2002). Carrier (2005) supported this by reiterating that research had found that diverse students benefit vastly when they have the opportunity to participate in activities, interact with materials, and manipulate objects and equipment. Similarly, an earlier work that made use of demonstrations in Engineering Education reported an increase in student attendance from thirty percent to eighty percent (Kresta, 1998).

Cabibihan (2013) used working models for in-class demonstrations and reported that a multi-background, multidisciplinary, and multinational student audience had responded favorably to the in-class demonstrations. It was also reported that the students' academic achievement was as a result of the immediate appreciation of concepts from the practical examples that the students experienced from the demonstrations.

Jaksa (2009) utilized a number of demonstration models in his teaching in Geotechnical Engineering. In conclusion, the author reiterated the effectiveness of demonstration models as a tool to improve learning and engaging students' attention. Adekoya and Olatoye (2011) and Daluba (2013) studied the effect of demonstration using working models in an aspect of Agricultural Science and reported that this teaching strategy brought about significant positive impact on the students' academic achievement. Maizuwo (2011) investigated the effectiveness of demonstration strategy on students' misconceptions of concepts in Organic Chemistry and academic achievement of Chemistry students and reported a significant difference in academic achievement of students when they were exposed to teaching strategy.

Similarly, Ikitde and Edet (2013) reported a high achievement in Biology students' scores when they were subjected to demonstrations. Udo (2010) investigated into the effects of demonstration on Secondary School students' achievement in Chemistry and found that the method was very influential in enhancing the students' achievement.

Ogologo and Wagbara (2013) purported that the achievement of students assigned to the demonstration method group was significantly better than that of their counterparts assigned to the traditional method group. Abdulhamid (2010) found that demonstration approach developed and sustained students' learning interests which led to the better performance of students. Auwal (2013) found that demonstration improved students' knowledge retention in Agricultural Science. Adekoya and Olatoye (2011) asserted that demonstration approach raise students' interest and reinforce memory retention because they provide connections between facts and real-world applications of those facts. Ekeyi (2013) studied the effect of demonstration method and the conventional method on students' achievement in Agricultural Science in Secondary Schools of East Kogi Education Zone. The results showed that demonstration method had a significant effect on students' achievement on the students exposed to it than their counterparts taught by the conventional lecture.

According to Chiappetta and Koballa (2002), well prepared and properly presented demonstrations have the potential to enhance students' understanding of Chemistry concepts. Hofstein and Lunetta (2004) in their comprehensive reviews came to the conclusion that demonstrations have the potential to enhance learning, motivation, and attitudes. Buncick, Betts, and Horgan (2001) found that demonstration encourage generalization because they promote active participation on the part of all students. Meyar, Schmidt, Nozawa, and Paneee (2003) found that demonstrations encourage student involvement since they are less teacher oriented and give students an opportunity to ask questions and to become more active in the learning process.

Limitations of Demonstration Approach

Alyce (2008) identified the following as the limitations to demonstration.

1. High capacity students might be bored with demonstration because they already know what the teacher is demonstrating.
2. Continuous talking during demonstration makes some students uninterested.
3. Using demonstrations in large classes may lead to the inability on part of some students not to see what the teacher is demonstrating.
4. It is very challenging for teachers to watch and control students whilst he/she is focusing on the demonstration.
5. Demonstrations require planning and this takes a lot of teachers' time schedule.

2.7 Misconceptions about Genetics Concepts

Enormous studies have been done in Science education focusing on identifying, analyzing, understanding, and mapping the concepts students hold before and after instruction (Wanderse, Mintzes, & Novak, 1994). Learning Science is a cumulative process and when new a piece of information is added to what students already know (or believe) about the topic at hand, it enhances easier understanding. If students have a solid foundation, the new pieces fit together more easily. However, if the students' preparation is incomplete, they may find it challenging to grasp the new material. The National Academy Press (2016) asserted that when a new material conflicts with earlier information or a firmly held idea, students may ignore or distort the new information. According to constructivist theory of learning, knowledge is constructed by each learner and learners actively construct knowledge to make sense of the world and interpret new information in terms of their existing cognitive structure. The knowledge that is constructed by a learner affects his/her prior knowledge, experience, and the social context in which learning take place (Grayson, 2001).

Hewson and Hewson (1984) opined that most students construct prior ideas which ideas which are not scientific of natural phenomena before instruction which in turn hinder effective teaching and learning of Science during instruction. Students' knowledge, however, can be erroneous and illogical or misinformed. These erroneous understandings are termed alternative conceptions or misconceptions, (or intuitive theories) (Burgoon, Heddle, & Duran, 2010).

Ezechie (2018) opined that these prior conceptions filter through ways which new information is processed and understood. When she investigated students understanding of Science, the study revealed that children have different ideas which are un-harmonized with scientific knowledge. These create confusion and barriers on how to handle those erroneous problems in the classroom practice since students bring to school learning ideas, expectations, and beliefs concerning natural phenomena which they have developed prior to their school learning which on numerous occasions is are deeply rooted within them hindering effective teaching and learning. Ilo (2018) supported the claim by pointing that, the implication is that students' alternative conceptions may influence their observations, inferences they draw, and what they understand from a formal learning situation in Biology. According to Erol, Salih, and Erdem (2012), when new concepts are compatible with previous concepts, meaningful learning occurs therefore it is important for instructors to examine the prior knowledge students bring to a learning environment in order to help them construct new knowledge.

Various types of genetics misconceptions exist. To begin with, preconceived notions are popular conceptions rooted in everyday experiences (NRC, 1997). For example, a student who thinks that women should be blamed when she continually delivers children of a particular sex does not understand that women are homogametic. This misconception usually originates from the intuitive ideas usually from parents and or their cultural beliefs. In addition, nonscientific beliefs include views learned by students from sources other than scientific ones, such as religious or mythical teachings. An example of this is when a student attests to the fact that blood transfusion is a sinful act due to his or her religious beliefs do not understand the tremendous role this action plays in saving the lives of people. In the same vein people who think that albinism and sickle cell inheritance is as a result of punishment from the gods do not understand the mechanisms of pedigree analysis.

Conceptual misunderstandings make up the third type of misconceptions. In this situation, scientific information is presented to students in a way that does not require them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs. A typical example is when numerous textbooks and teachers refer to co-dominance and incomplete dominance to be the same not pointing out that co-dominance is as a result of the purple flower color from the cross between the white and red flower whereas the incomplete dominance is as a result of the allele A and the B being expressed equally when it comes to the ABO blood group system. In this instance, students may find it challenging to have a conceptual understanding in order to distinguish clearly between the two concepts.

Vernacular misconceptions may also arise among students. These types of misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context (NRC, 1997). For example when students are told “sex” during genetics lessons, it could be misinterpreted by students that it means sexual intercourse as they are aware of in their everyday life which they in turn equate it with a meaning they had learned in Social Studies regarding early sex amongst adolescents likewise "sex" in Christian Religious Studies though the concept is referring to whether the individual is either a male or a female.

Vernacular misconceptions include problems with vocabulary and symbols as well as analogy and metaphor used in the subject matter which confuses students when learning. For instance, one symbol, word(s) may be used for different purposes across different disciplines or even within one discipline (e.g. the letter "XX" may stand for "female" in Biology during genetics, and "twenty" (Roman numeral) in Mathematics, and "alphabets" in English Language). Even in the same Biology, when one is not referring to genetics but a different topic, the word has a different meaning with regards to the context one is examining.

The final misconceptions are factual misconceptions. These are falsities, often learned at an early age and retained unchallenged into adulthood (NRC, 1997). An example is when a student thinks that that all mutations are harmful since it involves the change in the genome of an organism when it was pointed to him/her at an early stage in life lacks an in-depth knowledge about mutation since not all mutations are harmful especially transition (when a purine is replaced by a purine or a pyrimidine for a pyrimidine. In this case, some of the changes at times are not harmful to the organism). Since the genetic code is redundant, the change can even result in the same amino acid. A student who does not understand this mechanism generalizes all mutations as being harmful to organisms.

Misconceptions do not only arise from primitive worldviews or daily life experiences but also as a result of both formal and informal education (Gniffithi & Grant, 1985).

NRC (2012) stated that inaccurate Science concepts come from adults, media, and other educators. Textbooks used in formal education are considered to be important sources of most students' misconceptions (Dikmenli, Cardak, & Oztas, 2009). Most textbooks give misleading information either through illustrations or written text. An example could be when textbooks provide incorrect written information such as referring to phenotype "the outward appearance of an organism as a result of the genotype". Most students in most Senior High Schools and Universities in Ghanaian classrooms hold unto this misconception. In this case, a clarification of outward traits and inward traits needs to be addressed, as the former in genotype refers to physical traits and the latter internal traits such as blood groups and color blindness which are also genotypes but cannot be seen.

Sirhan (2007) alluded that the principal sources of misconceptions are overloading the learner's short-term memory and wrong mental strategies (teaching with the use of algorithms and hastily covering too much material).

Ramorogo and Wood-Robinson (1995) opined that most students' use their own intuitive ideas to explain some aspects of inheritance even before they receive tuition on these subjects and by the time they receive formal Science education, their preconceptions are already well established and problems arise when these "naive" theories disagree with the present Science concepts in the classroom. These preconceptions then interfere with new learning and lead to the establishment of misconceptions or alternative conceptions and these can be very stable and highly resistant to change (Arnaudin & Mintzes, 1985; Fisher, 1985).

Ezechie (2018) purported that a typical Igbo culture in southeastern Nigeria, recurrent infant mortality in a specific family is attributed to spiritual phenomenon referred to as "Ogbanje spirit." It is believed that a demon spirit "Ogbanje" possessed the children and causes them not to want to live on earth. As a result, the first child to die will reincarnate in a subsequent child, who in turn dies, and so on. Such deaths are believed to reoccur except when the parents perform some rites in order to appease the gods. These rites are believed to stop further deaths. This is what a scientific explanation will refer to as sickle cell phenomenon. She further found that students were holding this idea due to their lack of understanding concerning how traits are transferred and found during the interview sessions that students held such previous knowledge from their parents and their cultural background with some students even possessing a wrong notion that albinism is as a result of punishment from the gods (p. 17). In addition, ignorance of facts about sex determination made some of the students to believe that woman should be blamed especially if she continually deliver baby of a specific sex more especially females (p. 18).

Cisterna, Williams, and Merritt (2013) explored students' ideas about cells and inheritance. Students tended to struggle in distinguishing genes, chromosomes, and DNA and had some difficulties connecting the cell division process with the inheritance of genetic material due to how it has been explained in textbooks. Kilic and Saglam (2014) ascertained the effect of reasoning ability and learning approaches on students´ understanding of genetics concepts using two-tier genetic concept test. On significant influence of reasoning ability, misconceptions was revealed as students held alternate views about the phases of meiosis, sex linkages, and genes.

Kibuka and Sebitosi (2007) focused on understanding genetics and inheritance in rural schools. Their results showed insufficient distinguishing between concepts gene and chromosome among students. Also, students understanding of the concept of inheritance and Mendelian genetics were confusing. Dikmenli (2010) reported that studies conducted on problem-solving related to genetics revealed that students have

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some misconceptions regarding the stages of meiosis. However, accurate organization of many concepts in cell Biology perhaps is dependent on the degree of understanding of cell division. He stressed that students possess misconceptions and inadequate knowledge about the behavior of chromosomes and the transfer of genetic material during cell division (p. 43). Saka, Cerrah, Akdeniz, and Ayas (2006) found that Science student teachers have misconceptions, particularly regarding the concepts of gene and chromosome in accordance with their findings obtained from written responses and drawings.

Jallinoja and Aro (2000) focused their study on selected Finnish students' attitudes about gene testing and the influence of their knowledge on this testing. Study results showed approval of gene testing among majority of the population. Subsequently, it was indicated that over half of the respondents consider genetic testing as a realistic possibility. Many of them were afraid and worried with genetic testing due to the notions they hold regarding it. Chabalengula, Mumba, and Chitiyo (2011) published research concerning people's attitudes towards biotechnological processes among American elementary education middle school teachers. Authors used questionnaires and surveys utilizing the Likert scale. Majority of these pre-serviced teachers approved of the genetic modification of microorganisms and plants. The few ones left thought of GM organisms as against their culture and religion.

Jurkiewicz, Bujak, Lachowski, and Florek-Luszczki (2014) researched into people's emotional perception based on young people who completed Secondary School and specialized in the Genetic Modification of Organisms (GMOs) and Genetically Modified Foods (GMFs). Authors were alerted lack of knowledge pertaining GMOs. Most students were against the cultivation of GM plants and the breeding of GM animals on their own personal farms and land. GMOs mean big business for schools and large populations but regrettably, students did not see the obvious benefits when it comes to its tremendous roles it plays within large populations but rejected its sustainability due to certain cultural beliefs they hold. Prokop, Kubiatko, and Diran (2007) found a significant positive correlation between attitudes and the level of knowledge among Slovakian University students. Females in the research showed poorer knowledge and lower acceptance of GE products than did males. Overall, Slovakian students have poor knowledge and numerous misconceptions about what GE means.

Usak, Erdogan, Prokop, and Ozel (2009) examined statistically significant correlation between the level of Biotechnology knowledge and the sub-dimensions of attitudes toward Biotechnology. They found no statistically significant difference between High School and University students' knowledge of Biotechnology. In contrast, University students showed more positive attitudes toward biotechnology than did High School students. They attributed it to their prior notions they hold concerning the discipline. Bal, Samanci, and Bozkurt (2007) examined students' knowledge and attitude when faced with GE. Students expressed adjustable attitudes to GE depending on the species of organism and the objectiveness of the study. Furthermore, most students' negative perceptions and risky attitudes changed as they became educated on the matter. Overall students' attitudes to GE were positive. Most of the respondents regarded GE as an opportunity. Animal GE was seen as a positive opportunity for people and the future of civilization. In spite of these possible benefits, students did not want to agree with animal GE. Students revealed positive attitudes to planned GE when medical professionals were present. In contrast, students had negative attitudes to other type biological plant engineering.

Lewis and Wood-Robinson (2000) investigated the knowledge and understanding of genetics among Secondary students in the UK and they found that secondary school students have little understanding of the process of information transfer. In addition, they found that students have misconceptions about the basic knowledge of genes, chromosomes, and cells. Chattopadhyay (2005) also studied Indian High Secondary School students' understanding of genetics information related to cells and the transmission of genetic information during reproduction. Using the questionnaire developed by Wood-Robinson (2000) for the collection of data, the results indicated that students lacked the basic understanding of genetics. He argued that Indian students' misconception of genetics is related to the way Biology subjects are taught in schools requiring students only to memorize concepts and factual information rather than meaningfully understanding them.

Min-Nan, Kun-Chang, and Ti-Chu (2007) investigated the effect of grade level, sex, and school location factors on Taiwanese High School students' conceptual learning of genetics. To fulfil this goal, 4,537 students were randomly selected from ten districts in Taiwan and a questionnaire on biological concepts was applied to the sample students. The one-way ANOVA and t-Test analysis of the data showed that students in the urban areas had clear and better genetics conceptions than students in eastern Taiwan and other distant districts. Ninth grade students performed better than 8th grade students since most of them were holding misconceptions. Shahrani (1995) and Nashiri (2008) pointed out that despite the existence of global and local studies about genetics and inheritance, students hold alternative conceptions when they pointed in their separate study that there is still a great need to see how Arab students understand concepts related to genetics. They hold held alternate views about blood transfusion and sex determination. Several students opined that blames should go to women when they frequently deliver children of a particular sex.

A study was conducted by Mustafa (1996) on the patterns of alternative conceptions about meiosis held by 10th grade students. Students have views in the understanding of the stages of meiosis and chromosomes. They referred to chromosomes as particles in the nucleus that carry genetic information. He found that textbooks, teachers, and the surrounding environment are among the main sources of such misconceptions. Shahrani (1995) concentrated on 11th grade Saudi Arabian students understanding of concepts related to inheritance and found that students' understanding of inheritance is poor and they held many alternative conceptions about the inheritance of characteristics that are acquired from the environment.

Shaw, Horne, Zhang, and Boughman (2008) observed and reported that students had knowledge, personal interests, and bias as their Biology teachers. They identified major misconceptions in 55.6% of students' writings about genetics even after corrections performed by their Biology teachers and reported that prospective teachers did not see themselves as sufficiently capable teachers to conduct conceptual teaching for their students. Tekkaya (2002) studied the misconception possessed by 9th grade students relating to cell division and found that most of the students held different views about the stages of meiosis. He suggested conceptual teaching as an effective method for understanding the concepts related to cell division and for elimination of misconceptions.

Lewis (2000) examined students' level of understanding with regard to mitosis, meiosis, and fertilization and found out that students possess inadequate knowledge and numerous misconceptions related to the physical relationships between the genetic material, chromosomes, relationships between the behavior of the chromosomes, and continuity of genetic information. Ishaya, Mallam, Ezekiel, and Williams (2017) investigated the level of alternative conceptions of genetics held by selected Senior Secondary School Biology students in Jos North Lga of Plateau State and found misconceptions among students concerning genetics concepts such as students using gene and an allele interchangeably, some classifying genes as particles, phenotype as only outward traits, meiosis as the only mode of reproduction, and problems with the structure of the genetic material and pointed out that out that there was a significant relationship between students' alternative conceptions and their performance.

Lewis (2004) reviewed two research studies on Secondary students' (ages 14-18 years) understanding of genetics and found that students attempted to explain genetics in terms of everyday notions and conceptual frameworks. In the first study including 10 German Secondary School students that were asked to explain genetics terms used descriptors of genes as 'small trait bearing particles' and using terms like gene and character equally. Additionally, students thought of heredity as the transfer of these passive particles from parent to offspring via reproduction. In the second study of 482 English Secondary School students they held the notion of heredity as a transfer of trait bearing particles.

In a cross-sectional study observing the differences in understanding among 175 Turkish students across various age ranges, Saka *et al.* (2006) found that all students at least provided a functional explanation to define a gene rather than a structural definition. This suggests that students think of the structure of genes as different from that of DNA and its relation to where genes are located on a chromosome.

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Marbach-Ad (2001) found similar results in how High School students drew relationship between genes, DNA, and chromosomes. Specifically, students appeared to characterize genes, DNA, and chromosomes differently in both structures even though each served similar functions. For example, both 9th grade and 12th grade students defined genes as being composed of traits and DNA as being composed of nucleotides. However, when 9th grade students were asked about the structure and function of genes and DNA they compartmentalized the concepts separately. Lewis et al. (2000) found that most students fail to link concepts of genes and chromosomes. Even though some students were able to characterize chromosomes containing DNA, only 10% of students identified genes being located on a chromosome. Bahar, Johnstone, and Hansell (1999) used word association tests to identify conceptual problems of first-year Biology students. Specifically, the authors examined the ideas student generated using the words such as gene, mutation, chromosome, phenotype, and GE and found out that majority of the students held alternative views concerning these concepts making them unable to make the appropriate connections between these words.

Newman, Catavero, and Wright (2012) also investigated freshmen college students' conceptions pertaining to genes, chromosomes, and chromosomal behavior within a cell. The authors assessed 71-college freshman enrolled in an introductory Biology course and sophomores enrolled in a cell Biology course using targeted questions on genetics taken from various assessment instruments. In addition, the researchers conducted interviews and collected drawings students developed during the interviews to illustrate their understanding. Overall, students at both levels understand basic chromosome structure and were able to identify the relationship between DNA and chromosomal structure. The authors noted during interviews that students identified genes as directly relating to traits or phenotypes. These students shared similar misconceptions of genes demonstrated by K-12 students whose ideas were analogous to classical models of gene function indicating that students have an incomplete understanding of other molecular processes related to gene expression.

Marbach-Ad (2001) further found that pre-service teachers and 12th grade students shared a common naive view regarding the relationships between genes and traits rather than between genes and DNA. Lewis and Kattmann (2004) also observed that students had difficulties with the concept of gene regulation (different cell types contain the same DNA but turn on or off certain genes). In other words, the genetic information in a cell determines its phenotype rather than the differential expression of certain genes determining a phenotype. Lewis *et al.* (2000) found that students had difficulties in distinguishing between genes and genetic information. According to the authors, no student explicitly linked a gene with a gene product. However, when they were asked about DNA, they were able to distinguish between DNA and its role in providing information for the production of proteins.

Findings from Marbach-Ad and Stavy (2000) also revealed that students' lack a solid conceptual understanding in the function of RNA related to concepts about genes. The authors also suggest that because of this, students have difficulty linking the molecular process of gene function to cellular process and structures. They further examined the difficulty in swapping between different levels of organization and found out that students described relationships between ideas in a "structure or function" (either and or) dichotomy. Because of this, 12th grade students showed difficulty in their ability to link concepts of a gene and DNA to a protein product.

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Santos, Joaquim, and El-Hani (2012) study revealed that students superimpose ideas of a gene as a unit of information to a classical model of gene function. This means that in some cases students might combine historical gene function models that result in hybrid gene models in which genes are defined as units of information that determine a trait or characteristic. Saka et al. (2006) found that while University students used a greater amount of genetics terminologies, both pre-service and Biology student teachers still lacked a clear understanding. In some cases, grade eight students scored higher in conceptual understanding compared to grade twelve and University students. This suggests that as students grow older and acquire increasingly more complex knowledge, they may forget content that was previously learned making them unable to construct the appropriate connections between concepts as a result of developing alternative conceptions and or synthetic models which hinder meaningful conceptual meaning.

Jensen, Kummer, and Banjoko (2013) assessed college students' ideas pertaining to gene expression (concepts on the molecular basis of gene expression). More specifically, the authors examined the effects of prior conceptions on learning the process of central dogma in both University Biology majors, non-majors, and community college Biology majors. The results showed that both non-majors and community college Biology majors outperformed University Biology majors since they lacked conceptual understanding of the roles of tRNA, mRNA, rRNA, and the mechanisms of the genetic code. This suggests that prior conceptions can serve as barriers to effective learning. In other words, prior conceptions lead to the uptake of learned information without the consideration of meaningful conceptual understanding which can result in learning challenges.

2.8 Why Genetics Learning Challenges

Lerner (2000) defined learning challenge as a dynamic and expanding condition that makes it difficult for one to absorb, retain, and bring back to memory what is absorbed. He stated that learning difficulty does not include learning problems which are primarily the result of visual, hearing, motor handicaps, mental retardation, emotional disturbance, environment, cultural, and economic disadvantages. In this respect, learning difficulties are presumed to be intrinsic to the individual and the result of central nervous system dysfunction.

Inhelder and Piaget (1958) pointed out that students' ability to deal with concepts such as genetics in a meaningful manner is correlated with their level of cognitive development thus, unless students have reached the Piagetian level of formal operational thinking, they will not be able to cope adequately with these ideas. In view of this, Shayer and Adey (1981) posited that only some of fourteen-year-old students have reached this level yet they need to be able to understand the concepts of mitosis and meiosis in order to comprehend topics such as Mendelian genetics. Therefore, one can conclude that students' difficulties in dealing with scientific ideas originate from the abstract level of the concepts as well as the students' cognitive developmental stages (Yu-Chien, 2008).

Genetics requires a certain level of abstract thought and this is one of the reasons accounting for the difficulty of understanding genetics since formal operational thinking is required to be able to think of reality in a multivariate way to make a general or abstract formulation of a relationship (Banet & Ayuso, 2000). In Science Education, many researchers have noted that, when concepts and processes in a subject belong simultaneously to several levels of organization, considerable challenges are encountered when learning (Bronsan, 1990). Knowledge in Biology is being structured around different organizational levels and those particularly important in genetics are, according to Knippels (2002), population, organism, cell, gene, and molecule making it challenging for students when learning. Lemke (2001) opined that some features of language used in Biology education including words (gene or allele), grammar (nominalizations), and thematic patterns (parts versus wholes, and organizational levels), have a great impact on how the content is understood thereby causing learning students learning challenges.

According to Duncan and Reiser (2007), genetics is challenging for students to learn because of the invisibility and inaccessibility of genetic phenomena which they referred to as the molecular and micro level in genetics knowledge. They pointed out that when concepts belonging to this level of organization are understood by students they face no challenges when learning Mendelian genetics. Knippels, Waarlo, and Boersma (2005) reviewed studies in the field of genetics education and revealed some major difficulties experienced by students when learning genetics concepts as (a) the domain-specific vocabularies and terminologies (genes, proteins, cells, tissues, organs, etc.) belonging to different levels of a biological organisation (macro, micro, and molecular levels), (b) the mathematical content of Mendelian genetics tasks, (c) the cytological processes, and (d) the abstract and complex nature of genetics.

Bahar (2002) supported this claim that the main genetics concepts which were challenging to learn by students were gene, gamete, allele, gene, mitosis and meiosis, monohybrid and dihybrid crosses, and linkage since they all belonging to different levels of organization. Marbach-Ad and Stavy (2000) on students' explanation of cellular and molecular explanations of genetic phenomena distinguished the macroscopic, microscopic, and sub-microscopic level in genetics from a population comprising of 9th graders, 12th graders, and pre-service Biology teachers. Their findings revealed that for students to overcome these learning challenges in genetics, they should be first exposed to various phenomena in human beings or higher organisms, in macro terms only so that in dealing with the micro level (chromosomes) they may be able to link them together to enhance better understanding of the concept.. Bahar et al. (1999) applied a three model to the subject of genetics and asserted that the complexity in learning genetics is connected with the occurrence of ideas and concepts on these different levels of thought; the macro (plant or animal) the micro (cell) and biochemical level (DNA). They explained that a lot of processes at the micro level elucidated at the sub-macro (micro) level (e.g. genes and chromosomes) are represented by symbols such as *Aa* and *//*. With these symbols, students have to calculate ratios and probabilities and they have to reason back from this level of representation to the macro level for instance when they have to determine the probability of a certain genotype and translate it into a phenotype answer making it challenging for them in terms of learning. The study also revealed that problems such as difficulties in understanding concepts such as genetic crosses, genetic terms, cell division, and mutation were hurdles for students in learning the topic due to the various levels of organizations each belongs to.

Pearson and Hughes (1988a) asserted that there are many terms which look-alike and sound-alike in genetics and there are many synonymous words in genetic terms and this leads to students' confusions when dealing with these terms which poses challenges to them when learning. Bahar et al. (1999) supported by stating that one source of confusion and errors in genetics education is the extensive and complex vocabulary of genetics and found that students were not confident with the definitions of the genetics-related words therefore, confusion arises among students because the terms look alike and sound very similar e.g. homologue, homologous, homozygous, homozygotes, co-dominance, incomplete dominance, antigen, antibody, genotype, and phenotype.

Pearson and Hughes (1988b) further found out in their study that the challenges students face in learning genetics are related to the use of terminologies in genetics education and classified them into three different types as; misuse of terms, existence of synonyms, and obsolete terminology. An example of the misuse of terms is the incorrect use of the terms "gene" and "allele" as synonyms which is written in various textbooks which makes numerous Biology s teachers use these two words interchangeably during instruction. Errors arise when these sources of phrases such as the gene for "red colored flowers" instead of the allele for "red colored flowers" or a "lethal gene" instead of a "lethal allele" are used. Due to the misuse of these genetics terms as synonyms, it creates a lot of confusion among students when learning.

Existences of synonyms occur when students find it challenging on which kind of genotype to employ in crosses especially when it is not defined in a given situation. A typical example is when a student is learning on the ABO blood group but his/her teacher told him/her that the genotypes of blood group A, B, AB, and O assuming the teacher in that situation was referring to homozygotes only would be I^AI^A, I^BI^B, I^AI^B, and I^OI^O respectively. In this situation, when the teacher does not further give the phenotypes for the heterozygotes, when the student comes across a genotype like I^AI^o and I^BI^o when learning might think of them as different traits resulting in all sorts of learning challenges. Finally obsolete terminology refers to the use of words that were used during several years ago but have been replaced with another word. An example is the replacement of "element" as proposed by Mendel by "gene". Due to these, when these terms are used as synonyms, students are confronted with all sorts of challenges when learning.

Albaladejo and Lucas (1988) buttressed this when they found besides the misuse of terms and disassociation of terms in genetics, there are obsolete or redundant terms

(terms which no longer have any real meaning) which are principal sources of students' learning difficulties. For instance, the word "element" used by Mendel has been replaced by the term "factor" and since 1909 by "gene". These terms can confuse students especially when they are familiar with one of the term in a particular context and exposed to another one. They further pointed that genetics terms may have different meanings depending on the context of use. Mutation, for example is strongly associated with the idea of change and some students consider the term synonymous with biological developmental changes and opined that in Catalan language, the term mutation has a range of meanings in everyday language making conceptual meaning of the statement challenging to students. Longden (1982) also supported the assertion by purporting that "chromatid" is a redundant term because, it adds nothing to the understanding of the processes of cell division and DNA replication and is a potential source of confusion among students which in turn leads to learning difficulties.

Bahar et al. (1999) found that the mathematical expressions used in genetics such as XX, XY, I^AI^A and I^AI^O and the likes which are not used consistently by teachers and textbook writers' probes problems to students when learning. Although students often understand the probabilistic nature of real-life problems and have no difficulties in determining the chances, they fail when they have to apply the same chance events in the context of genetics. The authors purported most that students have difficulties in transferring the mathematical knowledge and insights from one context to another. The mathematical symbols which are expressions are symbolic and cause the problems students face and indicated that students opined that in genetic crosses, a lot of symbols are used and that they do not understand the crosses because they are not good at Mathematics. They concluded that the upper cases and lower cases, subscripts and superscripts, different combinations of letters, how the symbols are related to the concepts of symbolism, and mathematical calculations make Mendelian genetics abstract and difficult for students to learn because they are often not able to relate these features to real biological phenomena like the underlying process of meiosis.

Lewis et al. (2000) found in their study with 14-16-year-old students indicated that the main source of difficulties students experience with genetics is due to their difficulties in understanding mitosis and meiosis. Students understanding of cell division appeared to be limited, confused, and inconsistent. Students made little distinction between mitosis and meiosis and had poor understanding of the purpose, processes, and products of cell division probing numerous learning challenges.

Stewart et al. (1990) found that the alternative views of meiosis that students hold and use in solving traditional classroom genetics tasks lead to an underestimation of their knowledge or thinking ability and to an overestimation of the genetics knowledge of other students when only correct answers are taken into account resulting in numerous learning challenges. Kinfield (1994) reported that students do not understand that meiosis consists of sub-processes and that each specific event occurs at a unique time with students misunderstanding related to time of replication, crossing-over, alignment, and segregation and concluded that since mitosis and meiosis comprehension is a major backbone for understanding Mendelian genetics, these misunderstandings makes it very challenging for them to learn.

Chattopadhyay (2012) observed in his study that the understanding of cell division was limited, confused and inconsistent among students. The students had no coherent conceptualization of cell division processes, no understanding of how mitosis and meiosis took place, and were not clear about the nature of differences between mitosis and meiosis. They further opined that students were confused by the similar words 'mitosis and meiosis' and concluded that since this topic plays a tremendous role in enhancing students understanding of genetics, holding an alternative view about it resulted in their learning challenges.

Bahar et al. (1999) coined that the reasons behind students learning challenges in learning genetics is due to the conceptual organization of most High School Schools textbooks and the curriculum of numerous countries which tend to discuss or treat meiosis before genetics and in numerous occasions the two treated as separate topics. Moreover, the topic of meiosis is usually isolated from that of heredity and Mendelian genetics being discussed within the chapter heredity resulting in students' germane cognitive load. Kingfield (1994) supported when he found out in his study that the challenges students encounter in learning genetics are due to the separation of these topics in isolation in textbooks and the time it is treated by instructors owing to the fact that it is fixed at the tail end of numerous Biology curriculum in most countries.

Lewis and Wood-Robinson (2000) investigated English students' (aged 14-16) knowledge and understanding of genetics concepts (n= 482). Findings revealed that students lacked of basic knowledge regarding genetics such as chromosomes, genes, and cell structure. For instance, majority (73%) were able to define characteristics of genes, only 11% correctly identified the location of genes. Their results indicated that students' major problems were due to the abstract nature of the concepts and little time allotted for genetics lessons which have resulted in all sorts of misconceptions amongst them posing all sorts of learning challenges. Tekkaya et al. (2001) investigated Turkish High School students' difficulties in Biology concepts and whether sex differences influence these perceptions. A total of 368 High School students were surveyed. The results revealed that High School students mostly perceived the concepts in Mendelian genetics, meiosis and mitosis, genes, and chromosomes as difficult to learn. In addition, the researchers revealed sex difference favoring male students thus, male students perceived the Biology concepts easier to learn when compared to female students. Moreover, the researchers interviewed 14 Biology teachers in order to get a deeper understanding of the reasons behind these difficulties. The interview results revealed that teachers were aware of their students' difficulties. The researchers attributed these difficulties to Biology curriculum, insufficient teaching and learning strategies, and laboratory conditions.

Topcu and Sahin-Pekmez (2009) investigated Turkish middle school students' difficulties in learning genetics concept by using qualitative approach. In first step, an open-ended questionnaire was administrated to 128 students. Then, semi-structured interviews with low, moderate, and high achiever students (3 students for each) who completed the questionnaire were conducted in order to get deeper insights about their difficulties. The results revealed that while majority of students correctly identified the characteristics of genetic structures as cell, nucleus, chromosome, DNA, and gene, they have difficulties in explaining their functions. For instance, more than half of participants correctly defined cell concepts (62.5%). However, only 14% of them correctly explained the functions of cell. Similarly, while majority of students correctly defined somatic and sex cells, more than a quarter correctly explained their functions in reproduction and growth. Overall, these findings indicated that students did not have deep understanding in genetic structures. Semi-structured interviews revealed that students were not pleased about their textbooks as they indicated that they could not get conceptual knowledge from textbooks. Moreover, students expressed that they had difficulties in mathematical expressions used in genetics such as monohybrid and dihybrid linkages. The researchers attributed the students' difficulties to being invisible and inaccessible concepts in genetics referred as "micro-level concepts in genetics" and recommended that cell division topics which are visible and referred as “macro level” should be first taught to students which may help students to understand other genetics concepts easily.

Sesli and Kara (2012) investigated Turkish High School students’ learning difficulties in cell division and reproduction by using open-ended questions and semi-structured interviews (n= 403). The researchers developed a two-tier multiple-choice diagnostic test for assessing students’ understanding and identifying students’ challenges in cell division and reproduction concepts. The questionnaire consisted of 14 items with average item discrimination index of 0.46 and item difficulty index of 0.50. The findings revealed that students lack conceptual understanding regarding reproduction and cell division. In particular, most students had difficulties in understanding reproduction of sex cells, fertilization, genetic variation, and genetic information. In addition, some students tended to use theological explanations to transmission and appearance of characteristics. The researchers attributed the existing students’ difficulties to abstract nature of genetics concepts and facts as well as difficulty in making distinction between scientific and theological explanations.

Fonseca, Costa, Lencastre, and Traves (2012) explored Portuguese High School students’ understanding of biotechnology who enrolled in three different curricula as Science students comprising Biology students (n= 225), non-Biology students (n= 210) and non-Science students (n= 263). Findings indicated that only 36% of students correctly answered the questions related to biotechnology implying a relatively low level of knowledge. While students were more knowledgeable in medicine and vaccine production as well as disease resistance enhancement of plants, only more than a quarter were knowledgeable in genetically modified foods and genetically modified bacteria (31% and 35% respectively). The students asserted that the underlying principles of biotechnology are challenging and requires an abstract way of reasoning making its learning very challenging to them.

Chu (2008) explored problem of genetics learning and developed test ways by which the situation might be improved and pointed out that due to the nature of the subject matter, the way learning processes occur, and the way genetics is being taught causes the understanding of genetics ideas of the majority of students in Taiwan to be very poor and full of confusion and alternative views. Furthermore, she explored learners' prerequisite knowledge about genetics and found out that those essential foundation concepts such as structure and function of cell and its organelles were not understood and attributed these learning difficulties to the alternate conceptions students hold as a result of the textbooks they use and the mathematical nature of genetics concepts.

Knippels et al. (2005) investigated teaching and learning difficulties in genetics in the Netherlands. In that study, focus group interviews with teachers, student interviews, and content analysis of school genetics textbooks were used to collect data. The study found that Dutch teachers and students had difficulties in teaching and learning genetics as a result of the abstract and complex nature of genetics. The researchers also found out that the separation of inheritance, reproduction, and meiosis in the Dutch Biology curriculum also accounted for the problem.

In genetics, many researchers have shown that numerous students have serious misunderstandings even after instruction concerning the basic scientific content related to biological inheritance. For instance, research has shown that students do not fully understand chromosomes, genes, and alleles (Collins & Stewart, 1989), cannot adequately interpret some concepts such as homozygous or heterozygous (Slack &

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Stewart, 1990), alternative views of some processes such as mitosis and meiosis (Kindfield, 1994), and not understanding the meanings of probability in relation to genotype and phenotype frequencies in offspring (Browning & Lehman, 1988) which in turn pose all sorts of learning challenges to them.

A study by Adelana (2018) reported the followings as factors contributing to students learning challenges in genetics:

Inadequate explanation: Most students attributed their challenges in learning genetics to teachers' inability to explain genetics concepts adequately during lessons. They further reported that the topic was not well presented for them to be able to get the concepts.

Topic not taught: Another reason given by students was that the topic was not taught to them at all and indicated that instead of being taught, they were required to read on their own from the notes given to them without any explanation. One teacher explained that some teachers themselves do not understand the subject matter because in Colleges the topic was either not taught or not properly taught to them hence most teachers tend to shun the topic when they for the fear of embarrassing themselves in front of students.

Speed of lesson presentation: The fast rate at which some teachers presents lessons on genetics was pointed by students as a reason for their difficulties they face in learning the topic. Students further reported that a teacher who is too fast while teaching the topic makes them not to be able grasp something reasonable from the lesson.

Unfriendly teachers: Students purported that some teachers never liked to be asked questions by learners on issues students did not understand during the lesson. Hence, the unfriendly nature of the teacher made students not to ask questions about concepts they found confusing.

Scheduling of the topic: Most students opined the topic is usually taught nearly at the end of the year when examinations are around the corner and by that time, most of them had lost concentration to learn. Hence, the late introduction of the topic make them to lose concentration in it because they are busy preparing for their examinations. Some teachers also reported that genetics is taught towards the end of the term when students' are about to write their final examinations and do not have enough time to read and understand the concepts presented to them.

Negative attitude: Teachers indicated that most students perceive genetics as a difficult topic and that this made them not to put any effort in learning the topic. Some students also have negative attitude towards genetics because their seniors commented that it was difficult and due to this when they are being taught never concentrates.

Poor mathematical knowledge: Another factor given by teachers for learners having difficulties in genetics was their inability to carry out mathematical calculations involving probability. For example, one teacher who had been teaching Biology for 24 years reported that poor mathematical background of some students makes it difficult for them to change even the four possible combinations to percentages.

Lack of learning resources: Students cited lack of appropriate reading and learning materials as factors which contribute to learning difficulties in genetics. Teachers purported that lack of teaching and learning aids such as video tapes, computer programs, charts etc. to illustrate what was being taught was a hindrance to learning of genetics.

Too many terms: Students advocated that there were many new and similar terms in the topic that confused them. They cited terms such as phenotype, genotype, heterozygous, homozygous, allele, alleles, antigens, antibodies and the likes.

2.9 Summary of Literature

Cognitivist theory of learning purports that learners construct and build their knowledge about the world around them (Driver, 1988; Piaget, 1970; Vygotsky, 1978). Teachers who are constructivists are aware of the role of prior knowledge in students' learning (Mohan, 2010; Creswell, 2003) making them to employ learner centered strategies (Jones, 2002; Yu-Chien, 2008). Academic achievement deals with the numerical scores of a students' knowledge which measure the degree of the individuals' adaptation to school work and to the educational system (Kobaland & Musek, 2001) Academic outcomes in Science is not sex sensitive (Olasehinde & Olatoye, 2014), in favor of either male or female students across various Science subjects (Abu-Hola; 2005; Bamidele et al., 2006; Raimi & Adeoye, 2002; Yoloyo, 1994). Classroom discussions has tremendous role on learners academic outcomes (Abdulhamid, 2010; de Grave et al., 2008; Falode et al., 2015; Gillies & Boyle, 2010; Harton et al., 2002). Apart from classroom discussion, there are numerous ways of teaching genetics which has yielded merits on academic outcomes of students. These include; IBT, concept mapping, lecture, CAI, and demonstration.

Misconceptions originate as a result of both formal and informal education (Gniffithi & Grant, 1985), adults, media, and other educators NRC (2012), textbooks (Dikmenli, Cardak, & Oztas, 2009) and overloading the learner's short-term memory (Sirhan, 2007). Students have wrong notions about genetics (Chabalengula et al., 2011; Dikmenli, 2010; Ezechie, 2018; Nashiri, 2008). Students find genetics challenging to learn (Banet & Ayuso, 2000; Marbach-Ad & Stavy, 2000; Pearson & Hughes, 1988a; Stewart et al., 1990).

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CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter presents the research paradigm, research approach, population, sample and sampling techniques, instrumentation, piloting, validity and reliability of instrument. It also considers the procedures of data collection, its analysis, and ethical considerations.

3.2 Research Paradigm

A paradigm is a shared belief system that influences the type of knowledge researchers seek to obtain and how they interpret any research evidence they may collect (Morgan, 2007). It deals with the beliefs one holds about the action to take in the quest for reality in a given situation. The study adopted the positivist paradigm. This paradigm was proposed by a French philosopher, Auguste Comte (1798-1857) who defined a worldview to research which is grounded in what is known in research methods as the scientific method of investigation. Comte (1856) postulated that experimentation, observation, and reason based on experience ought to be the basis for understanding human behaviour making it the only legitimate means of extending knowledge and human understanding. Positivism is regarded as "scientific method" or "Science research" and is "based on the rationalistic, empiricist philosophy that originated with Aristotle, Francis Bacon, John Locke, Auguste Comte, and Emmanuel Kant" (Mertens, 2005 p. 8). Furthermore, it reflects a deterministic philosophy in which causes determine effects or outcomes (Creswell, 2003).

Positivist paradigm takes realism (naive realism) as its ontological stance assuming that reality exists and is driven by immutable natural laws and mechanism (Guba & Lincoln, 1994). For a positivist, reality is "out there" in the world independent of the researcher

(Pring, 2000a p. 59) and essentially discovered through scientific and conventional methodologies (Bassey, 1990; Guba & Lincoln, 1994).

Positivist researchers perceive the world as an external and objective reality where observers are independent and detached (Cohen, Manion, & Morrison, 2000) and their philosophical treatise is that the world is knowable which could be explored through quantitative methodologies. Further, positivists see the world as a meaningful object once the conscious beings engage with it and make sense of it thus, researchers' "claim that human beings could be studied as a scientific entity in a world that exists independent of human consciousness" (p. 177).

They further pinpointed the originality about this quest of evidence by establishing determinism, empiricism, parsimony, and generalizability about positivism. An unpacking of each of these help researchers understand better the meaning and expectations of research conducted within this paradigm. Determinism means that the events we observe are caused by other factors. Therefore, if one wants to understand casual relationships among factors, there is the need for the follow to be able to make predictions and to control the potential impacts of the explanatory factors on the dependent factors.

Empiricism on the other hand alludes that one is able to investigate into a research problem when the individual gathers evidence using his/her sense organs. Parsimony refers to a researcher's attempt to explain a phenomena under study in the most economic ways as possible purporting that researchers should try as much as possible to cater for issues that pertain them to sacrifice their time or bear a cost when the need arises in order to enable them to attain the exact data they seek to ascertain in order to find true reality. Finally, generalizability deals with the manner in which the results obtained from a researcher conducted within one context will be applicable to other situations by inductive inferences. This means that positivist researchers observe occurrences in the particular phenomenon they have studied and be able to generalize about what can be expected elsewhere in the world (Cohen *et al.*, 2007). Because of these, the positivist paradigm advocates the use of quantitative research methods as the bedrock for the researcher's ability to be precise in the description of parameters and coefficients in data that are gathered, analyzed, and interpreted so as to understand relationships embedded in the data analyzed.

Fadhel (2002) as cited in Cohen et al. (2007) asserted that due to these foundational elements of the positivist paradigm, its epistemology is said to be objectivist, its ontology naive realism, its methodology experimental, and its axiology beneficence. The objectivist epistemology holds that human understanding is gained through the application of reason. This implies that through research one can acquire knowledge which increasingly approximates the real nature of what it is that a researcher investigates into. Thus, adopting the positivist paradigm makes one to gain knowledge which helps one to become more objective in understanding the world around them.

3.1 Research Design

Zohrabi (2013) defined research design as the procedures, methods used to gather data, and the instruments used for the collection of data by a researcher. The Solomon four experimental group design was employed for the study. Experimental design is a research design in which a variable is manipulated in order to determine its effect(s) on another variable(s). The Solomon four-group design is a research design that attempts to take into account the influence of pretesting on subsequent posttest results (Kelly, 2018). It employs a combination of pretest-posttest design and posttest-only design to

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combat threats to internal and external validity that are present in less complex designs (p. 1). The design is illustrated below.

R	O_1	X	O_2
R	O_3		O_4
R		X	O_5
R			O_6

Where R = Random Assignment X = Treatment O_1 = Experimental Group Pretest O_2 = Experimental Group Posttest O_3 = Control Group Pretest O_4 = Control Group Posttest O_5 = Experimental Group Posttest O_6 = Control Group Posttest

The quantitative approach was employed for the study. Bryman (2012) defined quantitative research as, "a research strategy that emphasizes quantification in the collection and analysis of data" meaning that quantitative research denotes numerical values (p. 35). Payne and Payne (2004) stated that, "quantitative methods (normally using deductive logic) seek regularities in human lives by separating the social world into empirical components called variables which can be represented numerically as frequencies or rate whose associations with each other can be explored by statistical techniques and accessed through researcher-introduced stimuli and systematic measurement (p. 180)." Quantitative approach to research is advantageous since its findings are likely to be generalized to the whole population or a sub-population because it involves a larger sample which is randomly selected (Carr, 1994). Besides sampling, its data analysis is less time consuming as it uses the statistical software such as SPSS (Connolly, 2007). It also establishes correlation between given variables and outcomes.

3.3 Population

Kusi (2012) defined population as a group of individuals or people with the same characteristics which a researcher is interested in (p. 8). The study population consisted of all Biology students in Winneba Senior High School in the Central Region, Ghana. The target population consisted of all Senior High School two (2) Biology students. The accessible population was form two Science One (1) and Science Two (2) students class. A class was assigned as either an experimental and control through a balloting technique by their respective class prefects. Through the technique, Science One (1) class was used as the experimental group whereas the Science Two (2) was used as the control.

3.4 Sample and Sampling Techniques

Ary, Jacobs, and Sorensen (2010) defined sample as a subset or collection of some units of the universe or population (p. 9). Simple random sampling without replacement was employed to select the research participants for the study. Simple random sampling is a type of probability sampling technique in which individuals comprising a population are assigned numbers and the units having those numbers are included in the sample (Babbie, 2004). The "lotto" technique was employed. This was done by dividing the students in the classes under investigation into two with regards to their sex. A paper with a statement depicting "Yes" or "No" was created by the researcher corresponding to the number of students to be involved in the study in each class and mixed evenly before the selection of participants. It was subjected differently to the males and females on the same occasion in each class. Students were allowed to pick from the papers. This was to ensure that the number of students in either class shall be equal likewise the number of students to be chosen with regards to their sex. This was to ensure that each member of the population is likely to be chosen and included in the study sample. A

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total of thirty-two (32) students were chosen comprising of sixteen (16) students in each class.

3.5 Research Instrument

Research instrument is a measurement tool (test, questionnaire, etc.) subjected to research participants to obtain data. The research instrument employed for this study is test. A test is an evaluative device used to measure an examinees behaviour in a specified domain and scored using a standardized process (SEPT, 1999). Standardized Genetics Achievement Tests (SGATs) were designed by the researcher and administered to the participants (appendices A and B). McMillan (2008) purported that test is a significant tool because effective teaching decisions are based on the ability of teachers to understand their students and to match actions with accurate assessments. Tests are also essential for generating information used for making educational decisions such as; grading, identification of students with special learning needs, motivating students, clarification of students' achievement expectations, and monitoring instructional effectiveness (Ohlsen, 2007; Stiggins, 2001) and are also essential for conveying expectations that can stimulate learning (Wiggins, 1998). Finally, data obtained from tests are very easier to analyze since it is susceptible to software such as SPSS.

3.6 Pilot-Testing

Baker (1994) explained piloting as pretesting a particular research instrument to give the researcher advance warning on where the main research project might fail and to guide the development of the research plan (Prescott & Soeken, 2009). Johnson and Christiansen (2012) opined that it is always essential to pilot test a research instrument before administering to research participants to eliminate ambiguities and errors that may arise during data collection and or to ascertain validity and reliability of research instrument(s). Accidental sampling was employed to select students at Winneba Senior High School of Business; an institution that shares similar features with that of the study area and the instrument was piloted on them. This was to make the researcher aware of the drawbacks that may arise in the main study. Their result obtained was used to improve upon the instrument by making the necessary corrections to increase its level of validity and reliability.

3.7 Validity and Reliability of Research Instrument

3.7.1 Validity

Validity means "an instrument measuring what is intended to measure" (Field, 2005). Face validity was ensured by discussing the relevance of the research instrument with my supervisor before administering them to the research participants. Content validity was ensured by handing my instrument to my supervisor and two other experts in the study area to make the necessary corrections. This helped the researcher to construct the SGAT items to be in line with the content requirements of the syllabus.

3.7.2 Reliability

Reliability refers to the consistency on the part(s) of a measuring instrument (Huck, 2007). Moser and Kalton (1999) opined that an instrument is reliable when repeated measurements undertaken by it under constant conditions yield similar results. Reliability of the test was obtained using the split-half technique. The test items were constructed to measure knowledge and comprehension and application of knowledge profile dimension with each half matched in terms of item difficulty to enable its discrimination. Part I was scored by the researcher but part II were scored by the researcher and two other Biology instructors to prevent halo effect the former whereas the items in part II of each of the SGATs were evaluated item by item to reduce carry-over effects the latter. The mean score of each participant from the raters after piloting was recorded to ascertain the reliability between the two dimensions by employing Spearman-Brown formula: Reliability = 2r/1+r where r = the actual correlation between the halves of the instrument. By using the formula, the correlation coefficient was computed as 0.701. The instrument is therefore reliable enough for data collection in the study since it is within the acceptable standard of all reliable instruments (Borich, 2004; Johnson & Christensen, 2000).

3.8 Data Collection Procedures

Data collection is the process of gathering and measuring information on variables of interest in an established systematic manner that enables a researcher to answer stated research questions, hypotheses, and to evaluate outcomes (Kabir, 2016). According to Creswell (2002), gaining permission before entering the site where a researcher is willing to investigate into a problem is very paramount in research. Due to this, an introductory letter was obtained from the Department of Science Education at University of Education, Winneba which stated clearly the aims and purpose of the study and the need for each concerned participant to give his/her honest consent and co-operation (Appendix E). A copy of the letter was given to the Head of the school under investigation likewise the head of Biology department in the school. An SGAT designed by the researcher was administered to one of the experimental (O_1) and one of the control group (O_3) on his second visit to the school (Appendix A). The treatment was employed for six weeks.

3.8.1 Treatment

The Experimental Group: Activities involving classroom discussion were used to teach the experimental group. The control group was exposed to lecture method. The treatment that was administered to the subject involved teaching the concept of genetics by the researcher using cooperative approach (classroom discussion) based on the constructivist theory of learning lasting a total period of eighteen hours with six periods per week.

The Control Group: Lesson notes were prepared for each topic for a teaching period of 80 minutes per lesson for each group; lasting a total period of eighteen hours. The group had six lessons over a period of six weeks. The lessons were taught to each group during school hours to enable all the study samples to participate actively in the study. The subjects in each group had contact with the researcher once a week. The researcher personally taught all the groups in order to reduce intervening variable of teacher factor, that is, to ensure that each student has the opportunity of participating actively in the study and to avoid bias. The same teaching and learning materials, contents and evaluation questions were used throughout the lessons.

3.8.2 Administration of Treatment

Week 1

Topic: Basic concepts in genetics

Instructional Materials: Diagram showing a chromosome, DNA molecule, and a chromatid.

Specific Objectives: At the end of the lesson, a student will be able to:

1. Explain genetics.

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2. State four reasons why Mendel used peas to study inheritance.
3. Explain and describe what a chromosome and chromatids are.
4. Describe DNA structure and outline how bases are sequenced in the molecule.
5. Explain basic genetics concepts such as alleles, gene, homozygous, heterozygous, dominant, recessive genotypes, phenotypes, test crosses, back crosses etc.

Previous Knowledge: Students are familiar with DNA structure and replication and cell division.

Presentation: Presentation of lesson to the experimental group with classroom discussion is as follows:

The teacher starts the lesson by soliciting for their previous knowledge by asking them some questions concerning the diagram such as what they can observe from the charts. Afterwards the teacher engages the class in discussions to come out with the explanation of genetics. Instructor put students into group of fives and engages them in discussions to make students to come out with the reasons why Mendel choose peas over other plants for his studies. Using the same groups, students were asked: Do all the structures on the chart look exactly identical? Is there any difference? How can you describe these diagrams? Afterwards, they were asked to present a write-up on what they had observed in groups for the instructor to have a look at it. Afterwards, the instructor discussed the chromosome and the chromatids structure and functions with them and allowed them to discuss to come out with the structure and how its bases are sequenced in the molecule. Finally, the students were engaged in whole group discussion to come out within the explanation of the basic concepts in genetics.

Week 2

Genetics Topic: Mendel's laws of inheritance

Behavioural Objective: At the end of the lesson, a student should be able to:

1. State Mendel's laws of inheritance.
2. Perform genetics crosses on questions relating to the laws.
3. Determine the genotypic and phenotypic ratio of progeny.
4. Predict the genotype(s) of an organism when one is given.

Materials: Pieces of papers, chart showing the various shapes and colors of Mendel's peas.

Previous Knowledge: Students have been taught basic genetics concepts and also familiar with the colors and shapes of fruits and seeds.

Presentation: Presentation of lesson to the students as follows: The teacher starts the lesson by asking some questions: 1. Name different shapes of fruits and seeds you have seen before. 2. What can you observe from the chart?

Afterwards, the teacher engages students in whole class discussion to come out with Mendel's first law and its justification. The process continued by the teacher posing a problem about the law concerning the shapes and colors of the seeds on the chart for the students to discuss in groups to come out with the answers. They were also given a problem in groups on papers where the teacher goes around to watch them. Regarding the second law, the teacher explained the scenario to them. This was followed by whole classroom discussion to help students to come out with the possible genotypes. The students were made to come out with the genotypic and phenotypic ratio of the resulting progeny in groups. Finally, the teacher explained vividly the mechanisms of a testcross.

The teacher posed a problem concerning the concept for whole class discussion for students to come out with the right answer.

Week 3

Genetic Topic: Mendelian Extensions

Previous Knowledge: Students have learnt Mendel's laws of inheritance and are also familiar with genetic crosses.

Instructional Materials: A chart showing incomplete dominance.

Behavioural Objectives: By the end of the lesson, a student will be able to:

1. Explain incomplete dominance.
2. Explain co-dominance.
3. Explain multiple alleles.
4. Explain antigens and antibodies.
5. Explain ABO blood group and their respective antigens and antibodies.

Presentation: Teacher starts the lesson by asking students to state Mendel's laws. Afterwards, they were asked to observe what is on the chart and were questioned to explain the situation. The teacher explained the phenomenon to them afterwards as to why it deviated from Mendel's law using the chart. This was followed by whole classroom discussion concerning incomplete dominance. The teacher asked students whether they are familiar with their blood groups and that of their parents. This was followed by whole class discussion concerning multiple alleles. This led to ABO blood group system where students were enlightened on the possible genotypes of a person belonging to a particular blood group. Students were grouped into five and were brainstormed to come out with the meaning of antigens and antibodies and the roles

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they play. The teacher discusses the antigens and antibodies of the various blood groups.

Week 4

Genetics Topic: Mendelian extensions (ABO blood group)

Behavioural Objectives: At the end of the lesson, a student will be able to:

1. Perform genetic crosses concerning the ABO blood group.
2. Determine the possible genotypes and probabilities of an offspring when the blood group of the parents are given.
3. Explain why a man should accept paternity or not when the issue is based on blood group.
4. Explain the mechanisms involved in blood transfusion.
5. Explain agglutination of blood.
6. Explain why a woman with negative Rhesus factor should not marry a woman who is positive.

Previous Knowledge: Students are familiar with homozygosity and heterozygosity and genetic diagrams.

Presentation: Teacher starts the lesson by asking students whether they have witnessed cases whereby some men have denied paternity of a child whose blood group does not match with him nor his wife in their communities. After responding to the situation, the teacher posed a question concerning ABO genetic crosses for discussion. Afterwards, students were given a problem compelling them to determine the possible genotypes of an offspring by giving them the blood group of the parents in groups to discuss as the teacher goes around supervising their work. They were also brainstormed to come out with the probabilities of the genotypes they have arrived at. Teacher poses a problem and using genetic diagrams and whole class discussion, the issue as to whether a man should accept paternity or not when his child's blood does not match with that of his/her wife. Teacher discusses the mechanisms involved in blood transfusion with students and brainstormed them to come out with the explanation of agglutination of blood. Tutor engages students in discussion concerning Rhesus factor and students were put in groups afterwards to come out as to why a woman with negative Rhesus factor should not marry a woman who is positive.

Week 5

Genetics Topic: Sex linkages and inheritance of disorders

Specific Objectives: At the end of the lesson, will be able to:

1. Explain sex linkages
2. Perform genetic crosses on sex linked traits.
3. Explain why sex linked traits are prevalent in males.
4. Explain sex determination in humans.
5. Analyze why blames should not be placed on women when they continually give birth to a child of a particular sex.
6. Perform crosses concerning inheritable disorders such as albinism and sickle cell traits.

Previous Knowledge: Students already have the knowledge of how characters are transmitted from parents to offspring.

Presentation: The teacher starts the lesson by asking some questions; 1. How are characters transmitted from parent to offspring? 2. Should women be blamed for giving birth to a female baby?

The teacher after soliciting for their views cleared their misconceptions by engaging them in whole class discussion on the explanation to sex linkages. The teacher posed a question concerning color blindness and instructed students to discuss it in groups to arrive at the answer whilst the teacher goes around to supervise them. Teacher engages students in whole group discussion as to why sex linked traits are prevalent in males. Tutor puts students in focus groups to share their views about how sex is determined in humans and as to why blames should not be placed on women when they continually give birth to a child of a particular sex whilst the teacher goes around supervising students. Questions concerning crosses on albinism and sickle cell traits were raised whilst teacher engages students in whole group discussion to arrive at the answers.

Week 6

Genetics Topic: Variation.

Instructional Materials: Charts showing 3 different families.

Specific Objectives: At the end of the lesson, a student will be able to:

1. Explain variation and its types.
2. Give examples of morphological and physiological variation.
3. Explain the causes of variation.
4. Explain the consequences of variation.

Previous Knowledge: Students are familiar with variation in the physical appearances within families and between individuals.

Presentation: Presentation of lesson to the experimental group is as follows: The teacher starts the lesson by asking some questions: 1. Are all the children in the families similar to all their siblings and parents? 2. Why is it not so?

Teacher engages students in discussion to come out with the reasons why they vary from each other. Teacher asks students to point out observable differences such as height, skin color and the likes where the teacher discusses those traits as morphological traits. Teacher groups students into fives and made them to perform genetic cross with a married couple heterozygote for sickle cell anemia and the resulting genotypes. When the answer was given by students, teacher explains to them that those are variations but cannot be seen (physiological) like blood groups and the likes. Teacher instructs students to brainstorm and come out with other examples of the two types of variation. Teacher engages students in whole group discussion about the causes and explanation of variation. Teacher put students in focus groups to brainstorm to come out with to come out with the explanation of consequences of variation.

Immediately after the sixth week, another SGAT was administered (Appendix B) to each of the two groups in both the experimental (O_2 and O_5) and control group (O_4 and O_6) with each SGAT scored out of 40. In each of these cases, the scores of students were recorded separately in each group likewise the scores of the males and females.

3.9 Data Analysis Procedures

Data analysis is the process of systematically applying statistical and or logical techniques to describe, illustrate, condense, recap, and evaluate data. Statistical Package for Social Sciences (SPSS) was used to analyze the data obtained from. The posttested scores were used for analysis by comparing the scores of the experimental and control group students as illustrated in Table 3.1.

3.1: Posttest of Experimental and Control Group

	Experimental Group	Control Group
Pre-tested Scores	O_2	O_4
Post-tested Scores	O_5	O_6

Inferential statistics and descriptive statistics (means, standard deviations, minimum, and maximum values) were used to analyze the data obtained from the scores. All the inferential statistical tools were tested at a significance level of 0.05. 2X2 factorial ANOVA was used to compare the scores of the experimental and control group students since it is one of the appropriate statistical tools in analyzing Solomon four group data (Thayer & Martha, 2009). When the pretest revealed test revealed a significant difference, t-Tests were carried out to cater for the second and third hypothesis by comparing the scores, O_2 and O_5 and O_4 and O_6 respectively to ascertain whether all the groups or a single group pretest was sensitive. The interaction between the two variables (pretest and treatment) was also compared. T-test was carried out to cater for the final hypothesis to ascertain which sex scored attained high marks in the tests. Finally, researcher elaborated his views based on the data analysed and backed it with related literature.

3.10 Ethical Considerations

Research ethics are the norms for conduct that distinguish between acceptable and unacceptable behavior in research. Fouka and Mantzorou (2011) opined that research ethics are essential since it enables a researcher to protect the dignity of their subjects and publish well the problem that has been investigated into. To avoid a deceptive practice such as plagiarism, all the sources the researcher obtained information from were duly acknowledged. Participants informed agreement to partake in the study or

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not was considered during sampling by giving them the freedom to choose to participate or not in the study. The researcher arranged with the participants before the administration of the instrument on each occasion. Anonymity refers to keeping secret by not identifying the ethnic or cultural background of respondents, refraining from referring to research participants by their names, and divulging any other sensitive information about them (Mugenda, 2003). This variable was catered for by using numbers to represent the respondents when recording their scores. Participants' information were neither given nor disclosed to other students or other instructors within the institution to cater for their confidentiality.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

This chapter deals with the results and discussion of the research questions and its related hypotheses of the data obtained from the research participants.

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Analysis of Research Questions

4.2 Research Question One: What are the Genetics Pretest Scores of Experimental and Control Group Students?

This research question and its associated hypotheses sought to find out whether significant differences exist between the pretest scores of experimental and control group students. In order to determine it, inferential and descriptive analyses were carried out. The descriptive analysis of the scores is indicated in Table 4.1.

Table 4.1: Descriptive Analysis of Pretest Scores of Experimental and Control Group

Groups	N	M	SD	Minimum	Maximum
EXPERIMENTAL	8	20.03	3.13	12.6	22.4
CONTROL	8	18.35	2.63	13.3	20.4
Total	**16**				

Source: Researcher's Fieldwork Data (2020) M= Mean SD=Standard Deviation

It can be inferred from the data in Table 4.1 that the pretest mean scores of students was 20.03 and 18.35 for the experimental and control group respectively. The control group had the lowest SD of 2.63 whilst the experimental group students had SD of 3.13. In addition, the experimental group obtained the highest maximum score of 22.4 and a lowest minimum score of 12.6. Finally, the control group obtained the lowest maximum score of 20.4 and a highest minimum score of 13.3.

However, in order to ascertain whether there is any statistically significant difference among these mean scores, t-test was carried out to claim the fact in order to buttress its related hypothesis and is indicated in Table 4.2.

Table 4.2: t-test Analysis of Pretest Scores of Experimental and Control Group

Groups	N	df	t	p	Remark
EXPERIMENTAL	8	14	1.76	0.27	Not Significant

CONTROL	8
Total	**16**

Source: Researcher's Fieldwork Data (2020)

Data in Table 4.2 spells out clearly that [df=14, p=0.27 > 0.05] suggests no statistically significant difference so the null hypothesis is maintained. The scores of students in the experimental and control group was similar. This clarifies that before the study, students in the two classes held similar views in terms of their intellectual ability levels in genetics concepts depicting that they are suitable for the study because it shall enable the researcher to obtain real effects of the treatment.

4.3 Research Question Two: What is the effect of Classroom Discussion on Academic Outcomes of Experimental and Control Group Students in Genetics?

This primary intent of this research question and its associated hypothesis was to find out whether significant difference exists between the posttest scores of experimental and control group students. In order to determine it, 2X2 ANOVA and descriptive analysis were carried out on their scores. The descriptive analysis of the scores is indicated in Table 4.3.

Table 4.3: Descriptive Analysis of Posttest Scores of Experimental and Control Group

Groups	N	M	SD	Minimum	Maximum
EXPERIMENTAL	16	29.17	2.40	20.7	32.4
CONTROL	16	19.93	5.29	12.3	30.4
Total	**32**				

Source: Researcher's Fieldwork Data (2020) M=Mean SD=Standard Deviation

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It can be deduced from the data in Table 4.3 that the pretest mean score of students was 29.17 and 19.93 for the experimental and control group respectively. The experimental group had the lowest SD of 2.40 whilst the control group students had SD of 5.29. In addition, the experimental group obtained the highest maximum score of 32.4 and a highest minimum score of 20.7. Finally, the control group obtained the lowest maximum score of 30.4 and a lowest minimum score of 12.3.

However, in order to ascertain whether there is any statistically significant difference among these mean scores, its related hypothesis was tested by employing 2X2 ANOVA to claim the fact as indicated in Table 4.4.

Table 4.4: 2x2 ANOVA Analysis of Experimental and Control Group Scores

Sources of Variation	SS	df	Mean Square	F	p
Corrected Model	765.221	3	255.074	17.23	.000
Intercept	19252.125	1	19252.12	0.003	.000
Pretest	64.695	1	64.695	4.371	.046
Treatment	676.200	1	676.200	45.68	.000
Pretest * Treatment	24.325	1	24.325	1.643	.210
Error	414.444	28	14.802		
Total	**20431.790**	**32**			

Source: Researcher's Fieldwork Data (2020) SS =Sum of squares

Data from Table 4.4 points that [$F(1,32)=45.68$, $p=0.020 < 0.05$] reveals a statistically significant difference so the null hypothesis is rejected. The scores of the experimental and control group are not the same. Each of the groups scores yielded different results. This eludes that the result obtained was not as a result of chance but as a result of the treatment (instructional methodology) subjected to the students. This verifies that the methodology is very powerful thus, had the potentials in clearing misconceptions students hold thereby enabling them to conceptually understand the topic which in turn led to an increase in their academic performance. This was so because they were able to elaborate on issues, share their opinions, and argue on concepts they find it challenging when the methodology was employed which enabled the instructor to diagnose their learning challenges.

The finding corroborates de Grave et al. (2001) who reported a positive effect of classroom discussions on medical students. Similarly, Ebrahim (2012) on Kuwait students' achievement in Science testified that students in experimental group taught through the use of classroom discussion showed a significant academic achievement.

Finally, Reza et al. (2013) study reported effectiveness of the approach on academic success on students in the experimental group than the controls.

It was revealed from Table 4.4 that [$F(1,32)=4.37$, $p=0.046 < 0.05$] implies a statistically significant difference so the null hypothesis is rejected. This verifies that the pretest was very sensitive by playing a tremendous role in determining the posttest scores of the research participants. This opines that pretests are very crucial in enabling students to increase their academic outcomes in a hierarchical manner in subsequent tests. This finding agrees with Kelly (2018) who reported that pretest has an influence of on subsequent posttests.

Though the pretest revealed a statistically significant difference, but was it sensitive for both group and or one of the groups? Perhaps, one of the groups can or not be sensitive to the action of the pretest with regards to [$F(1,32)=4.37$, $p=0.046 < 0.05$]. In statistical studies, when a **p** value nears the confidence level in comparison between groups requires further analysis to find out whether both groups were sensitive to the pretest or one of the groups (experimental or control) was sensitive to it. Inferential and descriptive analysis were carried out to compare the scores of each group by comparing O_2 and O_5 and O_4 and O_6 respectively to ascertain the effects of the pretest posed in the experimental and control group. As a result, third and fourth research question and their related hypotheses were tested in order to substantiate the claim.

4.4 Research Question Three: What are the Potentials of Pretesting on Academic Outcomes of Control Group Students in Genetics?

The aim of this research question and its related hypothesis was to ascertain whether pretesting has a significant influence on the control group students' academic outcomes.

In verifying the fact, t-test and descriptive analyses were carried out on their scores. Descriptive analysis of the scores is outlined in Table 4.5.

Table 4.5: Descriptive Analysis of Posttest Scores of Control Group

Groups	N	M	SD	Minimum	Maximum
PRETESTED GROUP	8	22.23	5.33	14.9	30.4
POSTTESTED GROUP	8	17.64	4.23	12.3	24.3
Total	**16**				

Source: Researcher's Fieldwork Data (2020) M= Mean SD=Standard Deviation

It can be deduced from the data in Table 4.5 that the pretested group obtained a high mean score of 22.23 as compared to their colleagues who received only the posttest whose score was 17.64. Nonetheless, the SD of their scores followed the reverse of their mean scores with the pretested group obtaining 5.33 whilst the posttested group obtained 4.23. The Table further pointed that the pretested group obtained a high maximum score of 30.4 whereas the posttested group obtained 24.3. Finally, the data verified that the pretested group obtained a high minimum score of 14.9 whereas their posttested counterparts obtained 12.3.

In order to establish whether there is any statistically significant difference between these mean scores, to cater for hypothesis underlying it, t-test analysis was carried out to buttress the fact as indicated in Table 4.6.

Table 4.6: t-test Analysis of Posttest Scores of Control Group

Groups	N	df	t	p	Remark
PRETESTED GROUP	8	14	1.87	0.04	Significant
POSTTESTED GROUP	8				
Total	**16**				

Source: Researcher's Fieldwork Data (2020)

From the data in Table 4.6, it can be verified that [df=14, t=1.87, $p=0.04 < 0.05$] illustrates a statistically significant difference so there the null hypothesis is rejected.

The posttest scores of the control groups yielded different results. The pretested group performed better than the other spelling out clearly the significant role the pretest played in determining the academic performance of students' within this group. It can therefore be established that pretest is very essential since it enables students to increase their scores in subsequent tests.

In addition, though the teaching strategy was very effective in enabling the experimental group to perform better than their counterparts in the control but it can be construed from Table 4.5 that the pretest played a major role in enabling the pretested group to obtain a posttest mean score which is above average when evaluating any SHS student in any given test according to the WASSCE grading system in Ghana. The finding corroborates Robert (2018) who reported that students pretested on Mathematics who received no feedback from teachers recognized what they need to learn which led to an increase in their performance in subsequent ones

4.5 Research Question Four: What is the effect of Pretesting on Academic Outcomes of Experimental Group Students in Genetics?

The aim of this research question and its related hypothesis was to ascertain whether pretesting has a significant influence on experimental group students' academic outcomes. In verifying the fact, t-test and descriptive analyses were carried out. The descriptive analysis of the scores is presented in Table 4.7.

Table 4.7: Descriptive Analysis of Posttest Scores of Experimental Group

Groups	N	M	SD	Minimum	Maximum
PRETESTED GROUP	8	29.76	2.14	25.8	31.8
POSTTESTED GROUP	8	28.80	2.65	20.7	32.4
Total	**16**				

Source: Researcher's Fieldwork Data (2020) M= Mean SD=Standard Deviation

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It can be inferred from the data in Table 4.7 that the pretested group obtained a high mean score of 29.76 as compared to their colleagues who received only the posttest whose score was 28.80. In addition, the SD of their scores followed a favor pattern where the pretested group obtained 2.14 whilst the posttested group obtained 2.65. The Table further pointed that the pretested group obtained a low maximum score of 31.8 whereas the posttested group obtained 32.4. Finally, the data verified that the pretested group obtained a high minimum score of 25.8 whereas their posttested counterparts obtained 20.7.

In order to test its related hypothesis to determine whether there is any statistically significant difference between these mean scores, t-test analysis was carried out to ascertain it as indicated in Table 4.8.

Table 4.8: t-test Analysis of Posttest Scores of Experimental Group

Groups	N	df	t	p	Remark
PRETESTED GROUP	8	14	0.99	0.34	Not Significant
POSTTESTED GROUP	8				
Total	**16**				

Source: Researcher's Fieldwork Data (2020) df=degrees of freedom

It can be deduced from the data in Table 4.8 that [df=14, t=0.99, p=0.34> 0.05] suggests no statistically significant difference so the null hypothesis is maintained. The test scores of the experimental group was randomly distributed thus, similar despite the tremendous roles pretest play in predicting the posttest scores of participants in Solomon four group designs. Phenomenon of this kind use to happen only when there is an independent variable strong enough to undermine the action of the pretest. This authenticates that it was the treatment that was efficacious in undermining the action of the pretest in this group. The finding agrees with Oyedeji (1996) who stated that since classroom discussions work on the principle that the knowledge and ideas of several people are more likely to find solutions or answers to specified problems in the classroom setting, all students subjected to it achieve high academic outcomes.

Table 4.4 finally revealed that [$F(1,32)=1.64$, $p=0.21 > 0.05$] suggests no statistically significant difference so the null hypothesis is maintained. There is no interaction between the pretest conducted and the treatment. The two factors yielded effective results confirming there was no association between the treatment the pretest since each variable revealed significant results. This verifies that internal and external validity is being catered for since the teaching strategy was having a direct bearing on the scores of the students whereas the various groupings made it eligible to generalize the finding to the whole students' population and other population of similar settings.

4.6 Research Question Five: What is the effect of Classroom Discussion on Academic Outcomes of Male and Female Students in Genetics?

This research question and its related hypothesis sought to find out the effects of classroom discussion on academic outcomes of male and female students academic outcomes of the experimental group students.

In ascertaining the claim, inferential and descriptive analyses were carried out. The descriptive analysis of the scores is outlined in Table 4.9.

Table 4.9: Descriptive Analysis of Males and Females Test Scores

Sex	**N**	**M**	**SD**	**Minimum**	**Maximum**
MALES	8	27.62	6.28	20.7	32.4
FEMALES	8	26.97	6.06	21.2	30.4
Total	**16**				

Source: Researcher's Fieldwork Data (2020) M= Mean SD=Standard Deviation

It can be deduced from the data in Table 4.9 that males obtained a high mean score of 27.62 as compared to their female counterparts score was 26.97. In addition, the SD of their scores followed a favor pattern for females who obtained 6.06 whilst males obtained 6.28. The Table further pointed that males obtained the high maximum score of 32.4 whereas females obtained 30.4. Finally, the data verified that females obtained a high minimum score of 21.2 whereas males obtained 20.7.

Inferential statistics (t-Test) was carried out to test its related hypothesis to determine whether there is any statistically significant difference between these mean scores, t-test analysis was carried out to bolster the claim as indicated in Table 4.8.

Table 4.10: t-Test Analysis of Males and Females Test Scores

Sex	N	df	t	p	Remark
MALES	8	14	2.04	0.27	Not Significant
FEMALES	8				
Total	**16**				

Source: Researcher's Fieldwork Data (2020)

It can be deduced from the data in Table 4.10 that [df=14, t=2.04, p=0.27 > 0.05] suggests no statistically significant difference so the null hypothesis is maintained. The test scores of males and females were similar. Neither sex outperformed the other despite the perceptions most people hold with regards to sex as a determinant of students' academic outcomes in Biology and other Science related disciplines. This means that the teaching methodology employed was powerful enough to favor both sex.

This finding corroborates Smith (2004) who reported no statistically significant difference in achievement of male and female students. Similarly, Mobark (2014) reported no statistically significant difference in academic performance of male and female graduate. Furthermore, Ogunkola and Bilesanmi-Awoderu (2000) found in their study that students' achievement in Biology was not sensitive to the sex of the students. Moreover, Pandian (2004) on the effects of cooperative computer-assisted learning on male and female students' academic outcomes in Biology indicated that sex did not

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express any statistically significant influence on students' academic achievement in Biology. Bayerbach and Smith (2002) reported no statistically significant difference between male and female students test scores in genetics. In contrast, Hashim et al. (2015) found that inquiry-based Science teaching was significantly in favor of male students.

Table 4.9 revealed the mean score of males and females to be 27.62 and 26.97. The finding contradicts Samuel and John (2004) who found that females had a slightly higher mean score than males in Chemistry. Similarly, Nnorom (2015) found that females had a greater mean score than their male counterparts in Biology.

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CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDIES

5.1 Overview

This chapter presents the summary of the study, main findings, conclusions, recommendations, and other suggested areas to be studied.

5.2 Summary

The study investigated the effect of classroom discussion on academic outcomes of second year Biology students in genetics at Winneba Senior High School, Central Region.

The objectives of the study were to:

1. determine the genetics pretest scores of experimental and control group students.
2. determine the effect of classroom discussion on academic outcomes of experimental and control group students in genetics.
3. ascertain the potentials of pretesting on academic outcomes of control group students in genetics.
4. determine the effect of pretesting on academic outcomes of experimental group students in genetics.
5. determine the effect of classroom discussion on academic outcomes of male and female students in genetics.

Five hypotheses and assumptions guided the study. Constructivists' theory of learning was adopted for the study. The study adopted positivist paradigm and quantitative approach. Solomon four group design was employed for the study. The study population consisted of all Biology students in Winneba Senior High School with the target and accessible population being all Senior High School Two students and Science One and Two students respectively. Simple random sampling (lotto) technique was used to draw thirty-two (32) students with sixteen (16) students each from Science One (1) and Science Two (2) as the experimental and control group respectively. SGAT was the instrument employed to gather data for the study. SPSS was used in analyzing the data obtained using descriptive analysis (means, standard deviations, minimum and maximum values) and inferential statistics (2x2 ANOVA and t-Tests).

5.3 Key Findings

Significant findings were revealed by the study was that no statistically significant difference existed between the experimental and control group students during the pretest [df=14, $p=0.27 > 0.05$]. In addition, the ANOVA analysis unveiled that students in the experimental group performed better than their counterparts in the control [$F(1,32)=45.68$, $p=0.020 < 0.05$]. Furthermore, it was established by the ANOVA analysis that the pre-SGAT was sensitive [$F(1,32)=4.37$, $p=0.046 < 0.05$] in the control group [df=14, t=1.87, $p=0.04 < 0.05$] but not in the experimental group [df=14, t=0.99, $p=0.34 > 0.05$]. The ANOVA Table further established no interaction between the pretest conducted and the treatment [$F(1,32)=1.64$, $p=0.21 > 0.05$]. Finally, it was found that neither sex outperformed each other academically [df=14, t=2.04, $p=0.27 > 0.05$].

5.4 Conclusions

Genetics, the biological Science that deals with how traits are transferred from parents to their offspring plays a tremendous role in the lives of individuals in this 21st century so it is very essential for instructors in Ghanaian Senior High School classrooms to pay greater attention to it as a result of the merits associated with its literacy. The finding revealed that because no treatment was meted out to the experimental and control group before the pretest, they all held similar intellectual ability levels in genetics concepts. In addition, the finding revealed that because the strategy gave students' opportunities to elaborate their views concerning genetics concepts during lessons, it enhanced deeper understanding amongst them which made it eligible for them to outperform their control counterparts academically. Furthermore, the finding unearthed that owing to the fact that the instructional approach was potent in clearing students' misconceptions when they discussed genetics concepts in class made it influential in undermining the action of the pre-SGAT in the experimental group. The findings depict further that because students who received the pre-SGAT in the control group learnt from their mistakes they committed, it played a significant role in increasing their post-SGAT scores compared to their own counterparts. Finally, for the reason that both male and female students were subjected to the same instructional strategy that was efficacious, non-sensitive to sex, and tested on the same occasion made their scores non-significant.

5.5 Recommendations

The following recommendations were made based on the conclusions:

1. Classroom discussion should be employed predominantly by Biology teachers at Winneba Senior High School when teaching abstract topics such as genetics to enable conceptual understanding of the concepts among students the former and to increase their academic outcomes the latter.
2. Biology instructors at Winneba Senior High School Senior High School classrooms should organize tests for their students on regular basis since most students learn from their mistakes in previous tests and are eager to perform better in subsequent ones.
3. GES should workshops for Biology teachers at Winneba Senior High School on regular intervals on the need not to be sex sensitive in Biology classes and

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other Science-related discipline classes to favour each sex to achieve outcomes at his/her desirable level.

4. Administrative heads and Science teachers at Winneba Senior High School should scrutinize Biology textbooks thoroughly before they are being sold or distributed to students since it is a principal source of most students' misconceptions which result in student's declines in performance in genetics.

5.6 Suggestions for Further Studies

The following areas can be investigated into:

1. A study should be conducted to ascertain teachers' perceptions about genetics among selected Senior High Schools in Effutu Municipality, Central Region, Ghana.
2. Another educator should investigate into the correlation between students learning styles and their academic outcomes in genetics among Uncle Rich Senior High School students, Central Region, Ghana.
3. Finally, a study should be conducted to compare the effectiveness of activity-based learning and 5E learning model on academic outcomes of students in cell division in two Senior High School classrooms in Effutu Municipality.

REFERENCES

Abdulhamid, D. (2010). Effect of lecture and classroom discussions teaching method on Secondary School students Agricultural Science Performance in Bauchi Metropolis, Nigeria. *Journal of Research in Education and Society, 1*(1), 35–54.

Adekoya, Y., & Olatoye, R. (2011). Effect of demonstration, peer-tutoring, and lecture teaching strategies on Senior Secondary School students' achievement in an aspect of Agricultural Science. *The Pacific Journal of Science and Technology, 12*(1), 321.

Adelana, O. P. (2018). *Development and Validation of Multimedia Self-Learning Package on Genetics for Senior Secondary Students.* Unpublished Master Thesis, Department of Educational Foundations and Instructional Technology, Tai Solarin University of Education, Ijebu-Ode, Nigeria.

Adesoji, F. A., & Olatunbosun, S. M. (2008). Student, Teacher and School Environment Factors as Determinants of Achievement in Senior Secondary School Chemistry in Oyo State, Nigeria. *The Journal of International Social Research, 1*(2), 13–34.

Adigun, J., Onihunwa, J., Irunokhai, E., Sada, Y., & Adesina, O. (2015). Effect of Gender on Students' Academic Performance in Computer Studies in Secondary School in New Bussa, Borgu Local Government of Niger State. *Journal of Education and Practice, 63*(3), 17-31.

Adlaon, R. B. (2002). *Assessing effectiveness of concept map as instructional tool in high school Biology*. Masters' Thesis: Louisiana State University.

Agboghoroma T. E., & Oyoywi, E. O. (2015). Evaluating effect of students, academic achievement on identified difficult concepts in Senior Secondary Schools Biology. *Journal of Education and Practice, 4*(3), 233–246.

Ajaja, O. P. (2009). *Teaching methods across disciplines*. Ibadan: Bomn Prints.

Ajaja, O. P. (2011). Concept mapping as a study skill: Effects on students' achievement in Biology. *International Journal of Educational Sciences, 3*(1), 49–57.

Akinleye, G. A. (2010). *Enhancing the quality of life in this complicated but dynamic world.* 25th Inaugural lecture. University of Ado-Ekiti, April 6th 2010.

Albaladejo, A., & Lucas, A. M. (1988). Pupils' meanings for mutation. *Journal of Biological Education, 22*(3), 215–219.

Albion, P. R., & Gibson, I. W. (2000). Problem-based learning as a multimedia design framework in teacher education. *Journal of Technology and Teacher Education, 8*(4), 315–326.

Aliyu, A. A., Muhammad, U. B., Rozilah, K., & David, M. (2014). Positivist and non-positivist paradigm in Social Science Research: Conflicting Paradigms or Perfect Partners? *Journal of Management and Sustainability, 4*(3), 79–87.

Alyce, H. (2008). *Strengths and limitations of the demonstration approach.* Retrieved on March 12th 2020fromhttps://alyceeduproject.wordpress.com/2-strengths-and-limitations-of-demonstration/

Amadi, C. C. (1992). *Cultural Implication of Cultural Education in Nigeria.* Theory and Perspective Benin City. Institute of Education University of Benin.

Ameh, I-Ei, Daniel, B. P., & Akus, Y. (2007). *Research and Methods in the Social Sciences*. Ankpa: Rowis Press.

Amina A. S., & Ester A. M. (2017). The effect of lecture and discussion methods of teaching on learner's performance in Social Studies in Continuing Education Institution Borno State, Nigeria. *International Journal of Education and Educational Research, 11,* 1–40.

Amogne, A. E. (2015). Analysis of gender disparity in regional examination: Case of Dessie Town; Ethiopia. *Basic Research Journal of Education Research and Review, 4*(2), 29-36.

Amosa, I. M., & Olubode, C. (2013). Effectiveness of video based cooperative learning strategy on high, medium and low academic achievers, African Symposium. *Journal of the African Educational Research Network*, *13*(2), 77–85.

Ankomah, A. Y. (2002). The success story of private basic schools in Ghana: The case of three schools in Cape Coast. *Journal of Educational Management, 4,* 1–4.

Arends, R. I. (1997). *Classroom Instruction and Management*. Boston: McGraw Hill.

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions: A cross age study. *Science Education*, *6*(9), 721–733.

Applebee, A. N., Langer, J. A., Nystrand, M., & Gamoran, A. (2003). Discussion-based approaches to developing understanding: Classroom instruction and student performance in middle and high school English. *American Educational Research Journal, 40*(3), 685–730.

Ary, D., Jacobs, L., & Sorensen, C. (2010). *Introduction to Research in Education.* Wadsworth: Cengage Learning.

Ashelford, S. (2008). Genetics in the national curriculum for England: Is there room for development? *School Science Review*, *90*(3), 95–100.

Atif, B. T. (2014). The effects of computer-assisted learning on the achievement and problem-solving skills of the educational statistics students. *European Scientific Journal, 28*(10), 271–277.

Atwood, S., Turnball, W., & Carpendale, J. I. M. (2010). The construction of knowledge in classroom talk. *Journal of the Learning Sciences, 19*(3), 358–402.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart & Winston.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). *Educational psychology: A cognitive view* (2nd ed.). New York: John Wiley & Sons, Inc.

Auwal, A. (2013). Effects of teaching method on retention of Agricultural Science knowledge in Senior Secondary Schools of Bauchi Local Government Area, Nigeria. *International Journal of Science and Technology Education Research, 4*(4), 63–69.

Aydeniz, M., Cihak, D., Graham, S., & Retinger, L. (2012). Using inquiry-based instruction for teaching Science to students with learning disabilities. *International Journal of Special Education, 27*(2), 189-206.

Babatunde, M. M. & Olanrewaju, M. K. (2014). Class size and school climate as correlate of secondary school students' scholastic achievement in Itesiwaju Local Government Area of Oyo State, Nigeria. *Global Journal of Human Social Science, 14*(3), 14–21.

Babbie, E. (2004). *The Logic of Sampling. The Practice of Social Research* (10th ed.). Belmont: Hadsworth/Thomson Learning.

Bahar, M., Johnstone, A. H., & Hansell, M. H. (1999). Revisiting learning difficulties in Biology. *Journal of Biology Education*, *33*(2), 84–86.

Bahar, M. (2002). Students' learning difficulties in reasons and solutions. *Journal of Kastamonu Faculty Education, 10*(3), 73–82.

Bailey, L. A. (2018). *The Impact of Inquiry-Based Learning on Academic Achievement in Eighth-Grade Social Studies*. (Doctoral dissertation). Retrieved on April 4th 2019 from https://scholarcommons.sc.edu/etd/4481

Baker, T. L. (1994). *Doing Social Research* (2nd ed.). New York: McGraw Hill.

Bal, S., Samanci, N. K., & Bozkurt, O. (2007). University students' knowledge and attitude about genetic engineering. *Eurasia Journal of Mathematics, Science & Technolog Education*, *3*(2), 119–126.

Banchi, H., & Bell, R. (2008). The many levels of inquiry. *Science and Children, 46*(2), 26–29.

Banet, E., & Ayuso, E. (2000). Teaching genetics at secondary school: a strategy for teaching about the location of inheritance information," *Science Education*, *84*(3), 313–351.

Banet, E., & Ayuso, E. (2003). Teaching of biological inheritance and evolution of living beings in secondary school. *International journal of Science Education, 25*(3), 373–407.

Bangbade, J. O. (2004). Effects of subject matter knowledge in the teaching and learning of Biology and Physics. *Teaching and Teacher Education, 2*(6), 109–102.

Barnes, D. (1992). *From Communication to Curriculum* (2nd ed.). Portsmouth, NH: Boynton/Cook-Heinemann.

Bassey, M. (1990). On the nature of research in education. *Research Inelegance, 3*(6), 35–38.

Bayerbach, B., & Smith, J. (2003). Itcing a computerized concept mapping programme to access the service teachers' thinking about effective teaching. *Journal of Research in Science Teaching, 2*(7), 961–972.

Bell, P. (2004). On the theoretical breadth of design-based research in education. *Educational psychologist, 39*(4), 243–253.

Bell, R., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction: Assessing the inquiry level of classroom activities. *The Science Teacher, 72*(7), 30–33.

Bennett, J. (2003). *Teaching and learning science.* London: Continuum.

Berger, C. F., Lu, C. R., Belzer, J. B., & Voss, B. E. (1994). Research on the uses of technology in Science Education. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (177-210). New York: Simon and Schuster Macmillan.

Birney, R. & McKeachie, W. (1995). The teaching of psychology: A survey of research since 1942. *Psychological Bulletin*, *5*(2), 51–68.

Boerwinkel, D. J., Swierstra, T., & Waarlo, A. J. (2014). Reframing and articulating socio-scientific classroom discourses on genetic testing from an STS perspective. *Science & Education, 23*(2), 485–507.

Bolt, B. R. (1998). Encouraging cognitive growth through case discussions. *Journal of Teaching in Physical Education*, *1*(8), 90–102.

Borgerding, L. A., Sadler, T. D., & Koroly, M. J. (2013). Teachers' concerns about biotechnology education. *Journal of Science Education and Technology, 10*(7), 956–1012.

Borich, G.D. (2004). *Effective teaching method.* (5th ed.). New Jersey: Pearson Merrill Prentice Hall.

Bowling, B. V., Acra, E. E., Wang, L., Myers, M. F., Dean, G. E., Markle, G. C., & Huether, C. A. (2008). Development and evaluation of a genetics literacy assessment instrument or undergraduates. *Genetics*, *178*(1), 15–22.

Bronsan, T. (1990). Categorizing Macro and Micro Explanations of Material Change. In Lijnse PL, Licht P, Vos W and Vaarlo Az (Ed) *Relating Macroscopic Phenomena to Microscopic Particles.* Utrecht, Netherlands: CD-Press, 198–211.

Brookfield, S. D. (1995). *Becoming a critically reflective teacher*. San Francisco: Jossey.

Brooks, J. G., & Brooks, M. G. (1999). *In search of understanding: The case for constructivist classrooms, with a new introduction by the authors*. Alexandria: Association for supervision & curriculum development.

Brooks, J. G. & Brooks, M. G. (2001). *In search of understanding: The case for constructivist classrooms.* Upper Saddle River, New Jersey: Prentice-Hall.

Brown, I. J., & Inouye, D. K. (1978). Learned helplessness through modeling: The role of perceived similarity in competence. *Journal of Personality and Social Psychology*, *3*(6), 900–908.

Browning, M. E., & Lehman, J. D. (1988). Identification of student misconceptions in genetic problem solving via computer program. *Journal of Research in Science Teaching*, *2*(5), 747–761.

Bryce, T. & Gray, D. (2004). Tough acts to follow: the challenges to science teachers presented by biotechnological progress. *International Journal of Science Education*, *26*(6), 717–733.

Bryman, A. (2012). *Social research methods*. New York: Oxford University Press.

Buchanan, S., Harlan, M. A., Bruce, C., & Edwards, S. (2016). Inquiry based learning models, information literacy, and student engagement: A literature review. *School Libraries Worldwide, 22*(2), 23–39.

Buncick, M. C., Betts, P. G., & Horgan, D. D. (2001). Using demonstrations as a contextual road map: enhancing course continuity and promoting active engagement in introductory college Physics. *International Journal of Science Education, 23*(12), 1237–1255.

Bunton, R. (2001). *New Genetics and new publication Health.* London: Routledge.

Burgoon, J., Heddle, M., & Duran, E. (2010). Re-Examining the Similarities between Teacher and Student Conceptions about Physical Science. *Journal of Science Teacher Education, 21*(7), 859–872.

University of Education, Winneba http://ir.uew.edu.gh

Burns, S. N., & Grove, S. K. (2003). *Understanding nursing research* (3rd ed.). Philadelphia: Saunders.

Bush, G. (2006). Learning about learning: From theories to trends. *Teacher Librarian, 34*(2), 14–19.

Butler, J. A. (1992). Use of teaching methods within the lecture format. *Media Teaching, 14*(1), 11–25.

Cabibihan, J. J. (2013). Effectiveness of student engagement pedagogies in a mechatronics module: A 4- year multi-cohort study. *Journal of the NUS Teaching Academy, 3*(4), 125–149.

Capar, G., & Tarim, K. (2015). Efficacy of the cooperative learning Method on Mathematics achievement and attitude: A Meta-analysis Research. *Educational Sciences: Theory and Practice 15*(2), 553–559.

Carpenter, J. M. (2006). Effective teaching methods for large classes. *Journal of Family & Consumer Sciences Education, 24*(2), 13–23.

Carr, L. T. (1994). The strengths and weaknesses of quantitative and qualitative research: What method for nursing? *Journal of Advanced Nursing*, *20*(4), 716–721.

Carrier, K. (2005). Key issues for teaching learners in the classrooms. *Middle School Journal, 37*(4), 17–24.

Cary, J., Roseth, W. J., David, T., & Roger, J. (2008). Promoting early adolescents achievement and peer relationships: The effects of cooperative, competitive, and individualistic goal structures. *Psychological Bulletin, 134*(2), 223–246.

Caulfield, S. L., & Presnell, C. (2006). Teaching Social Science Reasoning and Quantitative Literacy: The Role of Collaborative Groups. *Teaching Sociology 34*(1), 39–53.

Cazden, C. B. (2001). *Classroom discourse: The language of teaching and learning* (2nd ed.). Portsmouth, NH: Heinemann.

Cazden, C. B., & Beck, S. W. (2003). Classroom discourse. In A. C. Graesser, M. A. Gernsbacher, & S. R. Goldman (Eds.), *Handbook of discourse processes* (pp. 165–197). New York: Routledge.

Celik, K., & Cavas, B. (2012). How does distance education compare with classroom instruction? A meta-analysis of the empirical literature. *Review of Educational Research, 74*(3), 349–361.

Centre for Teaching and Learning (2006). *Effective lecture Preparation and Delivery/Graduate School/Washington State University*. Retrieved on September 11th 2006 from gradschool.Wsu.edu/effective-lecture-preparation-an

Chabalengul, V. M., Mumba, F., & Chitiyo, J. (2011). American elementary education pre-service teachers' attitudes towards biotechnology processes. *International Journal of Environmental & Science Education*, *6*(4), 341–357.

Chang, C.Y. (2002). Does-computer-assisted instruction and problem solving improve Science outcomes? A pioneer study. *The Journal of Educational Research, 95*(3), 143–150.

Chang, Y. (2010). *Students' perceptions of teaching styles and use of learning strategies.* Retrieved from http://trace.tennessee.edu/utk_gradthes/782 on 22/9/2012

Chapin, S., O'Connor, C., & Anderson, N. (2003). *Classroom discussions: Using math talk to help students learn: Grades 1-6.* Sausalito, CA: Math Solutions Publications.

Charagu, S. N. (2015). *Effects of computer assisted learning on Secondary School students' achievement in Chemistry in Muranga South Sub-county, Muranga County, Kenya*. [Unpublished Med. Thesis]. Kenyatta University, Nairobi.

Charlton, B. (2006). Lectures are an effective teaching method because they exploit human evolved 'human nature' to improve learning. *Medical Hypotheses, 67*, 261–265.

Chattopadhyay, A. (2012). Understanding of mitosis and meiosis in Higher Secondary Students of Northeast India and implications for Genetics Education. *Cell Biology Education, 4*(7), 97–104.

Chiappetta, E. L., & Koballa, T. R. (2002). *Science instruction in the middle and secondary schools.* Upper Saddle River, NJ: Prentice-Hall.

Chika, P. O. (2012). The extent of students' responses in the classroom. *International Journal of Academic Research in Business and Social Sciences, 2*(1), 22–37.

Chilwant, K. (2012). Comparison of two teaching methods, structured interactive lectures and conventional lectures. *Biomedical, 23*(3), 363–376.

Christianson, R. G., & Fisher, K. M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms. *International Journal of Science Education*, *2*(1), 687–698.

Chu, P. (2008). Learning Genetics. *Journal of Biological Education, 33*(2), 84–86.

Cimer, A. (2012). What makes biology learning difficult and effective: Students views. *Educational Research and Reviews*, *7*(3), 61–71.

Cisterna, D., Williams, M., & Merritt, J. (2013). Students' misconceptions of cells and heredity: Patterns of Understanding in the Context of a Curriculum Implementation in Fifth and Seventh Grades. *The American Biology Teacher, 75*(3), 178–184.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research, 64*(1), 1–35.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education* (5th ed.). London. Routledge.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. London: Routledge.

Comte, A. (1856). *A general view of positivism*. London: Smith Elder & Co.

Connolly, P. (2007). *Quantitative data analysis in education: A critical introduction using SPSS*. London & New York, NY: Routledge.

Copeland, W. D., & Decker, D. L. (1996). Video cases and the development of meaning making in pre-service teachers. *Teaching and Teacher Education*, *1*(2), 467–481.

Cox, M. D., & Richlin, L. (1993). Emerging trends in college teaching for the 21st century: A message from the editors. *Journal on Excellence in College Teaching*, *4*, 1–7.

Creemers, B. (1994). *The effective classroom*. London: Cassell.

Creswell, J. W. (2002). *Research design: Qualitative, quantitative and mixed methods approaches*. London: Sage Publications.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed method approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Crone, J. A. (2001). Attaining more and greater depth of discussion in the undergraduate classroom: The seminar and seminar paper. *Teaching Sociology*, *2*(9), 229–236.

Crouch, C., Adam, P., Fagen, J., Callan, P., & Mazur, E. (2004). Classroom demonstrations: Learning tools or entertainment? *American Journal of Physics, 72*(6), 838–840.

Cummins, J. (2007). Pedagogies for the poor? Realigning reading instruction for low-income students with scientifically based reading research. *Educational Researcher, 36*(9), 564–573.

Curtin, E. (2005). Instructional styles used by regular classroom teachers while teaching recently mainstreamed ESL students: Six urban middle school teachers in Texas share their experiences and perceptions. *Multicultural Education, 12*(4), 36–42.

Daluba, N. E. (2013). Effect of demonstration method of teaching on students' achievement in Agricultural Science. *World Journal of Education, 3*(6), 1-7.

Davar, M. (2012). *Teaching of Science*. New Delhi: PHI Learning Private Limited.

Davis, B. G. (2009). *Tools for teaching*. San Francesco: Jossey-Bass.

de Grave, W. S., Schmidt, H. G., & Boshuizen, H. (2001). Effects of problem-based discussion on studying a subsequent text: A randomized trial among first year medical students. *Instructional Science*, *2*(9), 33–44.

Dikmenli, M. (2010). Misconception of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essay, 5*(2), 235–247.

Dikmenli, M., Cardak, O., & Oztas, F. (2009). Conceptual problems in biology–related topics in primary science and technology textbooks in Turkey. *International Journal of Environmental & Science Education*, *4*(4), 429–440.

Dimbisso, T. S. (2009). *Understanding Female Students' Academic Performance: An Exploration of the Situation in South Nations Nationalities and Peoples Regional State-Ethiopia.* A Research Paper Presented in Partial fulfillment of the Requirements for obtaining the degree of Masters of Arts in Development Studies, international Institute of Social Science. The Hague: The Netherlands.

Domitrovich, C. E., Cortes, R. C., & Greenberg, M. T. (2007). Improving Students Social and emotional competence in Textiles study: A randomized trial of the preschool "PATHS" curriculum. *Journal of primary prevention, 28*(2), 67–91.

Dorgu, T. E. (2015). Different Teaching Methods: A Panacea for Effective Curriculum Implementation in the Classroom. *Teaching Methods and Learning Styles in Education, 3*(6), 1–6.

Doyle, W. (2011). Classroom organization and management. In Mertin C. Wittrock (Ed.) *Handbook of Research on Teaching* (4th ed.). New York: MacMillan Publishing.

Drake, K., & Long, D. (2009). Rebecca's in the dark: A comparative study of problem-based learning and direct instruction/experiential learning in two 4th-grade classrooms. *Journal of Elementary science Education, 21*(1), 1–16.

Driver, R. (1988). *The pupil as scientist? Science Study and teaching*. Philadelphia: Open University Press.

Dukuzumuremyi, S. (2014). *The use of Technology to promote collaborative learning in inclusive Education in Primary School*. Retrieved September 20, 2016 from jultika.oulu.fi.nbnfioluolu-2014410221949

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.

Duncan, R. G., Freidenreich, H. B., Chinn, C. A., & Bausch, A. (2011). Promoting middle school students' understandings of molecular genetics. *Research in Science Education*, *41*(2), 147–167.

Duran, M., & Dokme, I. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills. *Eurasia Journal of Mathematics, Science & Technology Education, 12*(12), 2887–2908.

Ebrahim, A. (2012). The effect of Cooperative learning strategies on elementary students` Science achievement and social skills in Kuwait. *International Journal of Science and Mathematics Education, 2*(3), 293–314.

Eeds, M., & Wells, D. (1991). Talking, thinking, and cooperative learning: Lessons learned from listening to children talk about books. *Social Education*, *5*(5), 134–137.

Efe, H. A., & Efe, R. (2011). Evaluating the Effect of Computer Simulations on Secondary Biology Instruction: An Application of Bloom's Taxonomy. *Scientific Research and Essays, 6*(10), 2137–2146.

Egbo, H. (2008). *Effects of lecture versus demonstration method of teaching on students' clothing skill in college of education, Delta State*. [Unpublished Masters' degree thesis]. Delta State University Abraka.

Eggen, P., & Kauchak, D. (2001). *Educational psychology*: *Windows on classrooms.* New Jersey Prentice Hall, Inc.

Ehindero, O. J., & Ajibade, Y. A. (2000). What our students say about how we teach. *Ife Journal of Educational Studies. 7*(1), 1-9.

Eken, D. K. (2000). Through the eyes of the learner: Learner observations of teaching and learning. *ELT Journal, 53*(4), 66–80.

Ekeyi, D. N. (2013). Effect of demonstration method of teaching on students' achievement in Agricultural Science. *World Journal of Education 36*, 1–25.

Ekong, N. J., Akpan, G. A., Anongo, M. C., & Okrikata, E. (2015). Influence of Selected Variables on Students' Academic performance in Genetics and their Implications for Effective Application of Stem Education. *Journal of Emerging Trends in Educational Research and Policy Studies, 6*(4), 331–337.

Ellis, R. A., Calvo, R. L., David, P., & Tan, K. (2004). Learning through Discussions. *Higher Education Research and Development*, *23*(1), 73–93.

Emdin, C. (2010). *Dimensions of communication in urban science education*: *Interactions and transactions.* Tokyo: Wiley Periodicals, Inc.

Emmanuel, E. O. (2013). Effects of concept mapping strategy on students' achievement in difficult Chemistry concepts. *Educational Research, 4*(2), 182–189.

Ergul, R., Simsekli, Y., Calis, S., Ozdilek, Z., & Gocmencelebi, S. (2011). The effects of inquiry-based Science teaching on elementary school students' science process skills and science attitudes. *Bulgarian Journal of Science and Education Policy, 5*(1), 48– 68.

Erol, T., Salih, C., & Erdem, K. (2012). *The effects of web-supported and classical concept maps on students' cognitive development and misconception change*: *A case study on photosynthesis.* Retrieved 18 June 2016 from http://www.elainegalvin.ie/wpcontent/uploads/2014/09/The-effects-of-web-supported-and-classical.pdf

Etaga, O. H., Abidemi, K. A., Umeh, C., & Eriobu, N. (2017). Gender and Academic Performance. *International Journal of Mathematics and Statistics Studies, 5*(4), 6–17.

Ezechi, N. G. (2018). Alternative Conceptions as Determinant Factor for Students' Explanation of Biological Phenomena of Genetics. *Journal of Biology, Agriculture, and Healthcare, 8*(4), 17–20.

Ezeudu, F. O. (1998). The effect of concept mapping on students' achievement, interest and retention in selected units of Organic Chemistry. *Review of Education, 15*(1), 18–190.

Fadhel, K. (2002). Positivist and Hermeneutic Paradigm: A critical evaluation under their structure of scientific practice. *The Sosland Journal*, *3*(4), 21–28.

Falode, O. C., Adewale, I. A., Ilobeneke, S. C., Falode, M. E., & Robinson, A. O. (2015). Effects of discussion instructional strategy on achievement and retention of secondary school students in human geography in Minna, Nigeria. *Journal of Scientific and Engineering Research, 2*(4), 78– 84.

Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of Engineering Education II. Teaching methods that work. *Chemical Engineering Education, 34*(1), 26–39.

Field, A. P. (2005). *Discovering Statistics Using SPSS*. London: Sage Publications Inc.

Fonseca, M. J., Costa, P., Lencastre, L., & Tavares, F. (2012). Multidimensional analysis of high-school students' perceptions about biotechnology. *Journal of Biological Education*, *46*(3), 129–139.

Forum for African Women Educationalists (1998). *Teachers training qualification and working conditions.* Report no. 8, pp. 7–12. Nairobi: Kenya.

Fouka, G. & Mantzorou, M. (2011). What are the major ethical issues in conducting research? Is there a conflict between the research ethics and the nature of nursing? *Health Science Journal, 5*(1), 3–14.

Freiberg, H. J. & Driscoll, A. (2000). *Universities teaching strategies*. (3rd Ed.). London: Allyn & Bacon.

Froyd, J. E. (2007). *Evidence for the efficacy of student-active learning Pedagogies.* Retrieved on May 22nd 2009 from http://cte.tamu.edu/programs/flc.php on 22/9/2012

Fulya, O. & Haydar, O. (2016). What Beginner Biology Teacher Candidate know Genetics. *Journal of Research in Science Teaching*, *2*(2), 131–162

Furo, R. J., Abdullahi, Y., & Badgal, B. E. (2014). Effects of demonstration and lecture methods of teaching apiculture on achievement of agricultural students in Adamawa State University, Nigeria. *Scientific Papers Series-Management, Economic Engineering in Agriculture and Rural Development, 14*(2), 173–178.

Fyrenius, A., Bergdahl, B., & Silen, C. (2005). Lectures in problem-based learning-why, when and how? An example of interactive lecturing that stimulates meaningful learning. *Media Teaching, 27*(1), 55–61.

Gafoor, K. A., & Shilna, V. (2014). *Gender fair efficacy of concept mapping tests in identifying students' difficulties in High School Organic Chemistry.* Collaborative International conference on Learning Environment for Excellence in Education (January 24 & 25th 2014). SRM University Tamil Nadu India.

Gage, N. L., & Berlinar, C. D. (1988). *Educational psychology* (4th ed.). Boston: Houghton Mifflin.

Gall, M. D., & Meredith, D. G. (1990). Outcomes of the discussion method. In W. W. Wilen (Ed.) *Teaching and learning through discussion: The theory. Research and practice of the discussion method,* (pp. 25-44). Springfield, IL: Charles C. Thomas.

Gallagher, M. A., & Delisi, R. (1994). Gender difference in scholastic aptitude test-Mathematics problem solving among high-ability students. *Journal of Educational Psychology*, *86*(2), 2004–211.

Garside, C. (1996). Look who is Talking: A Comparison of Lecture and Group Discussion Teaching Strategies in Developing Critical Thinking Skills. *Communication Education*, *45*(3), 212–227.

Geban, O. (1995). The effect of microcomputer uses in a Chemistry course. *Hacettepe University Journal of Education, 11*, 25- 28.

Gherasim, L. R., Butnaru, S., & Mairean, C. (2013). Classroom environment, achievement goals and math performance: Gender differences. *Educational Studies, 3*(9), 1–12.

University of Education, Winneba http://ir.uew.edu.gh

Gillies, M. R. & Boyle, M. (2010). Teachers' reflections on cooperative learning, issues of, implementation. *Teaching and Teacher Education*, *26*(4), 933–940.

Glomo-Narzoles, D. (2015). Student Team Achievement Division (STAD), its effect on the academic performance of EFL learners. *American Research Journal of English and Literature*, *1*(4), 1–7.

Gniffithi, A. K., & ve Grant, B. A. C. (1985). High school students' understanding of food webs: Identification of a learning hierarchy and related misconceptions. *Journal of Research in Science Teaching*, *22*(5), 421– 436.

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education, 7*(2), 18–24.

Goldin, C., Katz, L., & Kuziemko, I. (2006). *The homecoming of American college women: The reversal of the college gender gap*. The National Bureau of Economic Research, NBER Working Paper No. 12139.

Grayson, D. (2001). A four-level framework for identifying and classifying student conceptual and reasoning difficulties. *International Journal of Science Education, 2*(3), 611–622.

Guba, E. & Lincoln, Y. (1994). Competing paradigm in qualitative research. In Denzin, N. & Lincoln, Y. (Eds.). *Handbook of qualitative research* (p. 99–136). Sage Publications.

Hadim, H. A. & Esche, S. K. (2002). *Enhancing the Engineering Curriculum through Project-Based Learning.* Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference. IEEE Press: Boston, MA.

Halverson, K. L., Freyermuth, S. K., Marcelle, A., & Clark, C. G. (2010). What Undergraduates Misunderstand About Stem Cell Research. *International Journal of Science Education*, *32*(7), 2253–2272.

Hancer, A. H., & Tuzeman, A. T. (2008). A Research on the Effects of Computer Assisted Science Teaching. *World Applied Sciences Journal, 4*(2), 199–205.

Hardman, F., & Mroz, M. (1999). Post-16 English Teaching: From recitation to discussion. *Educational Review*, *5*(1), 283–293.

Harton, H. C., Richardson, D. S., Barreras, R. E., Rockloff, M. J., & Latane, B. (2002). Focused interactive learning: A tool for active class discussion. *Teaching of Psychology*, *2*(9), 10–15.

Hashim, A., Ababkr, T. E., & Eljack, N. S. A. (2015). Effects of inquiry-based science teaching on Junior Secondary School Students' academic achievements: A case study in Hadejia zonal Education Area of Jigawa State, Nigeria. *SUT Journal of Humanities, 16*(1), 156–169.

Hay, D. B. (2008). Developing dialogical concept-mapping as an e-learning technology. *British Journal of Educational Technology, 39* (6), 1057–1060.

Hegarty, S. (2000). Teaching as a knowledge-based activity. *Oxford Review of Education, 26*(3 & 4), 451–465.

Henning, J. E. (2005). Leading discussion: Opening up the conversation. *College Teaching, 53*(3), 90–94.

University of Education, Winneba http://ir.uew.edu.gh

Henson, K. T. (2004). *Constructivist methods for teaching in diverse middle-level classrooms*. Boston, M.A: Allyn & Bacon.

Hewson, P. & Hewson, M. (1984). The role of conflict in conceptual change and the design of Science instruction. *Instructional science 13*(2), 121–124.

Hofstein, A. & Lunetta, V. N. (2004). The laboratory in science education: Foundation for the 21st century. *Science Education, 88,* 28–54.

Hott, A. M., Huether, C. A., & McDnerney, J. D. (2002). Genetics content in introductory biology courses for non-science majors: Theory and Practice. *Bio-Science*, *52*(11), 1024–1035.

Huck, S. W. (2007). *Reading Statistics and Research*. New York: Allyn & Bacon.

Huxham, P. (2005). *Teaching the large college class: A guidebook for instructors with multitudes*. San Francisco: Jossey-Bass.

Ikitde, G. A., & Edet, U. B. (2013). Influence of learning styles and teaching strategies on students' achievement in Biology. *Voice of Research, 1*(4), 5–13.

Ilo, F. I. (2018). *Effect of Conceptual Change Instructional Model and Expository Method on Students Alternative Conceptions and Achievement in Biology.* [Unpublished M.Sc. Thesis]. Chukwuemeka Odumegwu Ojukwu University.

Inhelder, B., & Paiget, J. (1958). *The Growth of Logical Thinking from Childhood to Adolescence*. New York: Basic Book.

Ishaya, L. M., Mallam, D. N., Ezekiel, D. P., & Williams, M. M. (2017). The relationship between types of misconceptions and achievement in genetics among Senior Secondary School Biology Students in Jos North Lga of Plateau State. *International Journal of Quantitative and Qualitative Research Methods, 5*(3), 1–26.

Isman, A., Baytekin, C., Balkan, F., Horzum, M. B., & Kiyici, M. (2002). Science education and constructivism. *The Turkish Online Journal of Educational Technology,1*(1), 25- 48.

Jaksa, M. B. (2009). *Use of Demonstration Models in Undergraduate Geotechnical Engineering Education.* Research Report No. R 177. November. University of Adelaide.

Jallinoja, P., & Aro, A. R. (2000). Does knowledge make a difference? The association between knowledge about genes and attitudes toward gene tests. *Journal of Health Communication*, *5*(1), 29–39.

Jana, V., Milan, K., & Muhammet, U. (2016). Czech High school students' Misconceptions about basic Genetic Concepts: Preliminary Results. *Journal of Baltic Science Education, 15*(6), 738–745.

Jegede, O. J., Alayemola, F., & Okebukola, P. A. (1992). The effect of concept mapping on students' anxiety and achievement in Biology. *Journal of research in science teaching, 27*, 951–960.

Jensen, J. L., Kummer, T. A., & Banjoko, A. (2013). Assessing the effects of prior conceptions on learning gene expression. *Journal of College Science Teaching, 42(*4), 82- 91.

Jesse, S. N. (2012). *Computer assisted instruction and conventional instructional techniques in relation to science performance among selected secondary schools in Embu District.* [Med. Thesis]. Kenyatta University, Kenya.

Johnson, B., & Christiansen, B. (2012). *Educational research: Quantitative, qualitative & mixed approaches.* Los Angeles: Sage Publications.

Johnson, D. W., Johnson, R. T., & Smith, K. (2007). The state of cooperative learning in post-secondary and professional settings. *Educational Psychology Review*, *1*(9), 15–29.

Johnson, B., & Christensen, L. (2000). *Educational research.* Boston: Allyn and Bacon.

Johnson, G. B., & Raven, P. H. (1998). *Biology: Principle and explorations*. Florida: Holt, Rinehart and Winston.

Johnston, J., Andermann, L., Milne, L., & Harris, D. (1994). *Improving civic discourse in the classroom*: Taking the measure of channel one (research report 4). Ann Arbor, MI: Institute for social research, University of Michigan.

Jonassen, D. H. (1994). Towards a Constructivist Design Model. *Educational Technology, 3*(4), 34–37.

Jones, J. (1998). *Lesson planning: Towards purposeful learning and effective teaching*. London: Kings College.

Josten, D. (1996). Students rehashing historical decisions-and loving it! *Journal of Adolescent & Adult Literacy*, *3*(9), 566–574.

Jurkiewicz, A., Zagorski, J., Bujak, F., Lachowski, S., & Florek-Luszczki, M. (2014). Emotional attitudes of young people completing secondary schools towards genetic modification of organisms (GMO) and genetically modified foods (GMF). *Annals of Agricultural and Environmental Medicine*, *21*(1), 205–211.

Kabir, S. M. S. (2016). *Basic Guidelines for Research*: *An Introductory Approach for All Disciplines.* Chittagong: Book Zone Publication.

Kacovsky, P. (2015). Grammar school students' misconceptions concerning thermal phenomena. *Journal of Baltic Science Education*, *14*(2), 194–206.

Kampourakis, K., Reydon, T. A., Patrinos, G. P., & Strasser, B. J. (2014). Genetics and society-educating scientifically literate citizens: Introduction to the thematic issue. *Science & Education*, *23*(2), 251–258.

Karen, B. (2008). Biology and society: A new way to teach tertiary science to non-science students. *Journal of Education*, *1*(2), 12–15.

Kasli, A. F. (2000). *Fundamentals of computer aided education*. Izmir: E.U. Faculty of Education.

Kaunang, E. (2014). The effect of cooperative learning model and belief about Science on the Biology learning achievement by controlling the initial ability of students experiment study on eighth grade students of public Junior High School in Minahasa. *Journal of Education and Practice*, *5*(7), 5–8.

Kazempour, M. (2009). Impact of inquiry-based professional development on core conceptions and teaching practices: A case study. *Science Educator, 18*(2), 56–67.

Kelchtermans, G. (2009). Who I am in how I teach is the message: Self-understanding, vulnerability and reflection? Teachers and Teaching. *Theory and practice*, *15*(2), 257–272.

Kelly, M. D. (2018). *Solomon Four-Group Design*. Thousand Oaks: SAGE Publications, Inc.

Kibuka K., & Sebitosi, E. (2007). Understanding genetics and inheritance in rural schools. *Journal of Biological Education, 4*(2), 56–61.

Kilic, D., & Saglam, N. (2014). Students understanding of genetics concepts: The effect of reasoning ability and learning approaches. *Journal of Biological Education, 48*(2), 63–70.

Killen, R. (2007). *Teaching strategies for quality teaching and learning*. Johannesburg: Shuman Printers.

Kim, D. R. (2010). High school students′ understanding of genetics concepts and their difficulties in learning genetics. *Korean Journal of Teacher Education, 26*(5), 17– 42.

Kinchin, I. M. (2000a). Using concept maps to reveal understanding: A two tie analysis. *School Science Review, 8*(1), 41–46.

Kinchin, I. M. (2000b). Concept mapping in Biology. *Journal of Biological Education, 3*(4), 61–68.

Kindfield, A. C. H. (1994). Understanding a basic biological process: Expert and novice models of meiosis. *Science Education*, *7*(8), 255–283.

Kingfield, A. C. H. (1994a). Assessing understanding of biological processes: Elucidating students' model of meiosis. *The American Biology Teacher, 56*(6), 367–371.

Kinnear, J. (1983). Identification of misconceptions in genetics and the use of computer simulations in their correction. In Helm, H. and Novak, J.D. (eds.), *Proceedings of the international seminar on misconceptions in Science and Mathematics.* (pp. 101 & 110) Ithaca, NY: Cornell University.

Kirk, A. J. (2000). *The peer effect on academic achievement among public elementary school students.* Research Education Centre for Data Analysis Report No. 62. Retrieved on 25th May 2009 from http://www.ncpublicschools.org/schoolimprovement/closingthegap/strategies/

movement

Knippels, P. J., Waarlo, A. J., & Boersma, K. T. (2005). Design criteria for learning and teaching genetics. *Journal of Biological Education*, *39*(3), 108–112.

Kobaland, D., & Musek, J. (2001). Self-concept and academic achievement: Slovenia and France. *Personality and Individual Differences, 30,* 887– 899.

Koschmann, T., Kelson, A. C., Feltovich, P. J., & Barrows, H. S. (1996). Computer-supported problem-based learning: A principled approach to the use of computers in collaborative learning. In T. Koschmann (Ed.), *Computer-supported collaborative learning: Theory and practice of an emerging paradigm*. New Jersey: Lawrence Erlbaum.

Kresta, S. (1998). Hands on demonstrations: An alternative to full-scale lab experiments. *Journal of Engineering Education, 87*(1), 7– 9.

Kumar, M. (2006). Constructivists' epistemology in action. *Journal of Educational Thought, 40*(3), 246–262.

Kusi, H. (2012). *Doing qualitative research: A guide for researcher.* Accra Newtown: Emmpong Press.

Kwon, H., & Chang, M. (2008). Technology teachers' beliefs about biotechnology and its instruction in South Korea. *The Journal of Technological Studies*, *35*(1), 67–75.

Lampert, M., & Ball, D. (1998). *Teaching, multimedia, and mathematics:* Investigations of real practice. New York, NY: Teachers College Press.

Larson, B. E. (2000). Classroom discussion: A method of instruction and a curriculum outcome. *Teaching and Teacher Education*, *1*(6), 201–217.

Lazarowitz, R., & Bloch, I. (2005). Awareness of Societal Issues among High School Biology Teachers Teaching Genetics. *Journal of Science Education and Technology*, *14*(5&6), 437–457.

Lederman, N. G., Antink, A., & Bartos, S. (2014). Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science & Education, 23*(2), 285–302.

Lee, C. (2001). Is October Brown Chinese? A cultural modeling activity system for underachieving students. *American Educational Research Journal*, *3*(8), 97–141.

Lee, Y., & Law, N. (2001). Explorations in promoting conceptual change in electrical concepts via ontological category shift. *International Journal of Science Education, 2*(3), 111–149.

Leedy, P., & Ormrod, J. (2001). *Practical research: Planning and design* (7th ed.). Upper Saddle River, NJ: Merrill Prentice Hall. Thousand Oaks: SAGE Publications.

University of Education, Winneba http://ir.uew.edu.gh

Leichnitz, R. (2006). *Self-identification of non-cognitive factors that lead to success.* PhD Dissertation. United States- Texas: University of the Incarnate Word.

Leitenberg, H. (1990). *Handbook of Social and Evaluation Anxiety*. New York: Plenum.

Lemke, J. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching, 38*(3), 296–316.

Lerner, J. (2000). *Learning disabilities*: *Theories, Diagnosis and Teaching Strategies* (8th ed). Boston. Houghton Mifflin Company.

Leslie, G. & Schibeci, R. A. (2003). What do Science teachers think Biotechnology is? Does it matter? *Australian Science Teachers' Journal, 49*(3), 16–21.

Levin, B. B. (1995). Using the case method in teacher education: The role of discussion and experience in teachers' thinking about cases. *Teaching & Teacher Education, 1*(1), 63–79.

Lewis, J. & Kattman, U. (2004). Traits, Genes, Particles, and Information: Revisiting student's understanding of genetics. *International Journal of Science Education, 2*(6), 195–206.

Lewis, J. & Wood-Robinson, C. (2000). Chromosomes the missing link: Young People Understanding of Mitosis, Meiosis, and Fertilization. *Journal of Biological Education, 34*(4), 189 – 200.

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., Driver, R., Leach, J., & Wood- Robinson, C. (1997). *Working paper 2- Understanding of basic genetics concepts and DNA technology, the young people's understanding of, and attitudes to, the new genetics project.* University of Leeds: CSSME.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000). What's in a cell? Young people's understanding of the genetic relationships between cells, within an individual. *Journal of biological education, 34*(3), 178–184.

Liao, Y. C. (2007). Effects of computer-assisted instruction on students' achievements in Taiwan: A meta-analysis. *Computer and Education, 4*(8), 216– 233.

Liu, P. L., Chen, C. J., & Chang, Y. J. (2010). Effects of a computer-assisted concept mapping learning strategy on EFL college students' English reading comprehension. *Computers & Education, 5*(4), 436–445.

Lord, T. R. (1999). A Comparison Between Traditional and Constructivist Teaching in Environmental Science. *Journal of Environmental Education, 30*(3), 22–

Lyon, D. C., & Lagowski, J. J. (2008). Effectiveness of facilitating small-group learning in large lecture classes. *Journal of Chemical Education*, *8*(5), 1571–1576.

Mahvish, H., Showkat, K., & Mudasir, A. M. (2017). Computer Assisted Learning. *International Journal of Computer Science and Mobile Computing, 6*(6), 254–258.

Maizuwo, A. I. (2011). *Effects of Demonstration Teaching Strategy in Remedying Misconceptions in Organic Chemistry among Students of Colleges of Education in Kano State*. [Unpublished M.Ed. Thesis]. Zaria: Ahmadu Bello University.

Marbach-Ad, G. & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenomena. *Journal of Biological Education, 34*(4), 200–205.

Marbach-Ad, G. (2001). Attempting to break the code in student comprehension of genetics concepts. *Journal of Biological Education, 35*(4), 183–189.

Markow, P. G., & Lonning, R. A. (1998). Usefulness of concept mapping in college Chemistry laboratories: Students perception and effects on achievement. *Journal of Research in Science Teaching, 35*(9), 1015–1029.

Marmah, A. A. (2014). Students' perception about the lecture as a method of teaching in tertiary institutions. *International Journal of Education and Research, 2*(6), 601–612.

Martinello, M. L., & Cook, G. E. (2000). *Interdisciplinary Inquiry in Teaching and Learning*. (2nd ed.). Upper Saddle River, NJ: Merrill.

Martins, U., & Fidelia, N. (2018). Classroom discussion approach and student's achievement in Sociology. *An International Multi-Disciplinary Journal*, *3*(3), 388–398.

Maxwell, D. O., Lambeth, D. T., & Cox, J. T. (2015). Effects of using inquiry-based learning on Science achievement for fifth-grade students. *Asia-Pacific Forum on Science Learning and Teaching, 16*(1), 2–31.

McCabe, J. A. (2014). *Learning and Memory Strategy Demonstrations for the Psychology Classroom.* Baltimore: Goucher College.

McCann, T. M., Johannessen, L. R., Kahn, E., & Flanagan, J. M. (2006). *Talking in class: Using discussion to enhance teaching and learning.* Urbana, IL: National Council of Teachers.

McKeachie, W. (1994). Learning and cognition in the college classroom. In: Teaching tips: strategies, research and theory for college and university teachers. Lexington. *Heatlh, 23*(6), 279–295.

McKeachie, W. (1988). Teaching thinking. *NCRIPTAL Update, 2*(1), 1–10.

University of Education, Winneba http://ir.uew.edu.gh

McKeown, M. G., Beck, I. L., & Blake, R. G. (2009). Rethinking reading comprehension instruction: A comparison of instruction for strategies and content approaches. *Reading Research Quarterly, 44*(3), 218–253

McMillan, J. M. (2008). *Assessment essentials for student-based education* (2nd ed.). Thousand Oaks: Crown Press.

Mercer, N., & Howe, C. (2012). Explaining the dialogic processes of teaching and learning: The value and potential of sociocultural theory. *Learning, Culture and Social Interaction*, *1*(3), 12–21.

Mertens, D. M. (2005). *Research methods in education and psychology: Integrating diversity with quantitative approaches.* (2nd ed.). Thousand Oaks: Sage.

Meyar, L. S., Schmidt, S., Nozawa, F. & Paneee, D. (2003). Using demonstration to promote student comprehension in Chemistry. *Journal of Chemical Education, 80*(4), 431–435.

Michaels, S., O'Connor, C., & Resnick, L. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in Philosophy & Education*, *2*(7), 283–297.

Midgley, C., & Edelin, K. C. (1998). Middle school reform and early adolescent well-being: The good news and the bad. *Educational Psychologist, 3*(3), 195–206.

Miller, H., McNeal, K., & Herbert, B. (2010). Inquiry in the Physical Geology classroom: Supporting students' conceptual model development. *Journal of Geography in Higher Education, 34*(4), 595– 615.

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science*, *13*(3), 273–294.

Min-Nan, M. W., Kun-Chang, W., & Tai-Chu, I. (2007). A study on factors affecting biological concept learning of Junior High School students. *International Journal of Science Education, 29*(4), 453–464.

Minner, D. D., Levy, A. J., & Century, J. R. (2004). *Describing Inquiry Instruction in Current Research: A Challenge for Synthesis*. Paper presented at the National Association of Research in Science Teaching Annual Conference, Vancouver, B.C.

Minstrell, J. (1989). Teaching science for understanding. In L. B. Resnick & L. E. Lopfer (Eds.), *Toward the thinking curriculum: Current cognitive research (1989 Yearbook of the Association for Supervision and Curriculum Development)* (p. 131–149). Alexandria, VA: Association for Supervision and Curriculum Development.

Miranda, E., & Landmann, R. (2001). Instructional system. *Roeper Review, 23*(4), 230–235.

Mitchell, I. (2010). The relationship between teacher behaviors and student talk in promoting quality learning in science classrooms. *Research in Science Education, 40*(2), 171–186.

Mobark, W. M. (2014). The effect of using cooperative learning strategy on graduate students' academic performance and gender differences. *Journal of Education and Practice, 5* (11), 64–70.

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research, 1*(1), 48–76.

Moser, C. A., & Kalton, G. (1999). *Survey methods in social investigation*. Aldershot: Gower.

Mugenda, A. G. (2011). *Social Science Research Methods*: *Theory and Practice*. Nairobi: ARTS Press.

Mugenda, A. G., & Mugenda, O. M. (2003). *Research Methods Quantitative and Qualitative Approaches.* Nairobi: Acts Press.

Mundi, N. E. (2006). The state of students' academic achievement in secondary school agricultural Science in Kogi State. *Teacher Education Journal, 12*(1), 14–19.

Muraya D. N., & Kimamo, G. (2011). Effects of cooperative learning approach on biology mean achievement scores of secondary school students in Machakos District Kenya. *Journal of Educational Research and Reviews*, *6*(12), 726–745.

Mustafa, M. N. (1996). Patterns of misunderstanding among students in the first row on the concept of secondary diversity in living organisms. *Journal of the Faculty of Education, 5*(5), 56–86.

Muzumara, P. M. (2008). *Becoming an effective Science Teacher* (2nd ed). Lusaka: Bhuta Publishers.

Nashiri, M. A. (2008). *Alternative scenarios for some of the concepts of genetics among students in third grade average Qunfudah province*. [Unpublished Master's Thesis]. College of Education, Umm Al-Qura University: Mecca.

National Center for History in the Schools (1996). *National Standards for History*. Retrieved on June 12th 2010 fromhttp://www.nchs.ucla.edu/history-standards/historical-thinkingstandards/overview

National Research Council (2012). *Students' misconceptions*. Washington, D.C.: National Academies Press.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: The National Academies Press.

Ndirangu, M. (2000). *A Study on the Perception of the Influence of Teaching Practice Projects on the Teaching of Science in Selected Secondary Schools in Kenya.* Egerton University, Njoro. Kenya.

Newman, D. L., Catavero, C. M., & Wright, L. K. (2012). Students fail to transfer knowledge of Chromosome structure to topics pertaining to cell division. *CBE Life Science Education, 11*(4), 425– 436.

Nnorom, N. R. (2015). Effect of cooperative learning instructional strategy on senior secondary school students' achievement in biology in Anambra State, Nigeria. *International Journal of Cross Discipline of Education, 5*(2), 42–57.

Nolen-Hoeksema, S. (2001). Gender differences in depression. *Current Directions in Psychological Science, 10*(5), 173–176.

Nystrand, M. (1997). *Opening dialogue: Understanding the dynamics of language and learning in the English classroom.* New York, NY: Teachers College Press.

Obanya, P. A. (1990). *General Method of Teaching*. Ibadan: Macmillan Publishers Limited.

Obianor, E. W. (1997). *The use of concept mapping to teach the concept of atom*. [Unpublished M.Ed. dissertation]. Nnamdi Azikiwe University, Awka, Nigeria.

Obunadike, J. C. (2011). *A Study of the Influence of Reciprocal Peer Tutoring and Lecture Method on Students Achievement in Clothing and Textiles*. A Ph.D. Thesis of Faculty of Education, Delta State University Abraka.

Odundo, P. A. (2003). *Impact of instructional methods on learners' achievement in business studies in Kenya's secondary schools.* [Unpublished Ph.D. Thesis]. University of Nairobi.

Ogologo, G., & Wagbara, S. (2013). Effect of demonstration, strategy on senior secondary school students' achievement in separation techniques in Chemistry in Bio/Akpor local government area, Rivers State. *Journal Vocational Education & Technology, 10*(2), 15–29.

Ohlsen, M. T. (2007). Classroom assessment practices of secondary school members of NCTM. *American Secondary Education, 3*(6), 4–14.

Okebukola, P. O. A. (1989). Concept mapping with co-operative learning flavor. *The American Biology Teacher, 54*(4), 218–221.

Olakanmi, E. E., Gambari, I. A., Gbodi, E. B. & Abalaka, E. A. (2016). Promoting intrinsic and extrinsic motivation among Chemistry students using computer assisted instruction. *International Journal in Education Science, 12*(2), 155–168.

Olasehinde, K. J., & Olatoye, R. A. (2014). Comparison of male and female Senior Secondary School students' learning outcomes in science in Katsina State, Nigeria. *Mediteranean Journal of Social Sciences, 5*(2), 517–523.

Oliver, K. M. (2000). Methods for developing constructivism learning on the web. *Educational Technology, 40*(6), 97–120.

Oludipe, D. I. (2012). Gender difference in Nigerian junior secondary students' academic achievement in basic science. *Journal of Educational and Social Research, 2*(1), 93–99.

University of Education, Winneba http://ir.uew.edu.gh

Oludipe, D. I. (2014). Gender and science anxiety as predictors of Nigerian Junior Secondary School Students' academic achievement in Basic Science. *Scholar Journal of Arts, Humanities and Social Sciences, 2*(2), 197–303.

Olulube, N. P. (2006). *A study of academic and professional qualification on teachers' job effectiveness in Nigerian Secondary Schools*. [Unpublished Dissertation]. University of Helsinki, Helsinki.

Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research and Method in Education, 5*(6), 66–70.

Onuka, U. D. (1996). *Curriculum Development for Africa.* Onitsha: Africana-Feb Publishers Ltd.

Orodho, J. A. (2008). *Techniques of Writing Research Proposals & Report in Education and Social sciences*. Maseno: Kanezja HP Enterprises.

Orora, W., Keraro, F. N., & Wachanga, S. W. (2014). Effects of cooperative e-learning teaching strategy on students' achievement in secondary school biology in Nakuru County, Kenya. *Sky Journal of Education Research*, *2*(1), 1–9.

Otagburuagu, E. J. (1997). *Educational Teaching and Communicative English Language Curriculum.* Onitsha: Cape Publishers.

Otoo, D. (2007). *Comparative study of academic performance of public and private JSS graduate: A case study of four selected senior secondary schools in the Kumasi Metropolis*. [Master's thesis]. Centre for Educational Policy Studies, University of Education, Winneba, Ghana.

Otuka J., & Uzoechi, B. (2009). *History and Philosophy of Science*. Keffi: Onavi Printing & Publishing Company.

Oyodeji, O. A. (1996). Assessing gender factor in some Science and Mathematics texts in Nigeria. *Journal of Education Research, 8*(1), 45–53.

Ozdemir, O., & Isik, H. (2015). Effect of inquiry-based Science activities on prospective elementary teachers' use of Science process skills and inquiry strategies. *Journal of Turkish Science Education, 12*(1), 45–63.

Ozmen, H. (2004). Learning theories in science instruction and technology assisted constructivist learning. *The Turkish Online Journal of Educational Technology, 3*(1), 45–54.

Ozmen, H. (2008). The influence of computer-assisted instruction on students' conceptual understanding of chemical bonding and attitude toward Chemistry: A case for Turkey. *Computers & Education, 51*(1), 423– 438.

Pahomov, L. (2014). *Authentic learning in the digital age: Engaging students through inquiry.* Alexandria, Virginia: ASCD.

Payne, G., & Payne, J. (2004). *Key concepts in social research*. London: Sage Publications.

Pearson, J. T., & Hudges, W. J. (1988a). Problems with the use of terminology in genetics: 1-A literature review and classification scheme. *Journal of Biological Education, 22*(3), 178–182.

Pearson, J. T., & Hudges, W. J. (1988b). Problems with the use of terminology in genetics: 2-some examples from published materials and suggestions for rectifying problems. *Journal of biological education, 22*(4), 267–274

Peg, E. (n.d). The Disadvantages of Concept Mapping. Retrieved from https://classroom.synonym.com/disadvantages-concept-mapping-6749212.html on March 12th 2020

Petty, G. (2009). *Teaching Today: A Practical Guide* (4th ed.). Cheltonham: Nelson Thornes.

Phan, H. P. (2012). Informational sources, self-efficacy and achievement: a temporally displaced approach. *Educational Psychology*, *3*(2), 699–726.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher, 24*(7), 5–12.

Piaget, J. (1970). *Science of Education and the Psychology of the Child*. New York: Orion.

Pilli, O. (2008). *The Effects of Computer-Assisted Instruction on the Achievement, Attitudes and Retention of Fourth Grade Mathematics Course.* [Unpublished PhD thesis]. Department of Educational Sciences, Middle East Technical University.

Powell, K. (2003). Spare me the lecture. *Nature, 42*(5), 234–246.

Powers, D. E., & Powers, A. (2015). The incremental contribution of TOEIC Listening, Reading, Speaking, and Writing tests to predicting performance on real-life English language tasks. *Language Testing*, *32*(2), 151–167.

Prescott, P. A., & Soeken, K. L. (2009). The potential uses of pilot work. *Nursing Research, 3*(8), 60–72.

Pring, R. (2000a). *Philosophy of educational research*. London: Continuum.

Prokes, C. R. (2009). Inquiry-based planning and teaching for the 21st century: Impacts of the 5E model in Social Studies. *Ohio Social Studies Review, 45*(1), 15–23.

Prokop, P., Leskova, A., Kubiatko, M., & Diran, C. (2007). Slovakian students' knowledge of and attitudes toward biotechnology. *International Journal of Science Education, 29*(7), 895–907.

Quist, H. O. (2003). Secondary Education: A Tool for National Development in Ghana. A Critical Appraisal of the Post-Colonial Context. *African Development, 3*(3 & 4), 188–191.

Raimi, S. A., & Adeoye, F. A. (2002). Sex differences among college students as determinant of performance in Integrated Science. *African Journal of Educational Research, 8*(1 & 2), 41-49.

Ramorogo, G., & Wood-Robinson, C. (1995). Botswana children's understanding of biological inheritance. *Journal of Biology Education*, *29*(1), 60–72.

Ramsdeen, P. (2003). *Learning to teach in higher education.* (2nd ed.), London, Routledge Falmer.

Ratanaroutal, T., & Yutakom, N. (2006). *Social Constructivist Teaching and Learning of genetics for Disadvantaged Students in Welfare Schools in Thailand*. Apera conference 2006, Hong Kong.

Renshaw, C. E., & Taylor, H. A. (2000). The Educational Effectiveness of Computer-Based Instruction. *Computers and Geosciences, 26*(6), 677– 682.

Reza, K. M., Abozar, H. R., Ali, E. N., & Akbar, H. (2013). The impact of cooperative learning on students` science academic achievement and test anxiety. *Journal of Educational Innovations, 11*(4), 83–98.

Robert, P. (2018). To pretest or not to pretest. *Biomedical Journal of Scientific & Technical Research, 5*(2), 4471– 4473

Robyn, M., & Adrian, F. (2003). *Co-Operative Learning, the Social and Intellectual Outcomes of Learning in Groups* (1st ed.). New York: Taylor and Francis.

Rocca, K. A. (2010). Student participation in the college classroom: An extended multidisciplinary literature review. *Communication Education*, *5*(9), 185–213.

Ross, J. A. & Bruce, C. (2007). Self-assessment and professional growth: The case of a grade 8 Mathematics teacher. *Teaching and Teacher Education, 23*(2), 146–159.

Rushton, S. P. (2003). Two pre-service teachers' growth in self-efficacy while teaching in an inner-city school. *The Urban Review, 3*(5), 167–189.

Rutherford, R. B., Mathur, S. R., & Quinn, M. M. (1998). Promoting social communication skills through cooperative learning and direct instruction. *Education & Treatment of Children, 21*(3), 354–369.

Saka, A., Cerrah, L., Akdeniz, A. R., & Ayas, A. (2006). A cross-age study of the understanding of three genetic concepts: How do they image the gene, DNA and chromosome? *Journal of Science Education and Technology, 15*(2), 192–202.

Samikwo, D. C. (2013). Factors Which Influence Academic Performance in Biology in Kenya: A Perspective for Global Competitiveness. *International Journal of Current Research, 5*(12), 4296– 4300.

Samuel, S. (2016). Effects of inquiry-based learning on High School students academic outcomes: An experimental study. *Bioscience, 3*(2), 90-115.

Santos, V. C., Joaquim, L. M., & El-Hani, C. N. (2011). Hybrid deterministic views about genes in Biology textbooks: A key problem in genetics teaching. *Science & Education, 21*(4), 543– 578.

Sava, F. A. (2002). Causes and effects of teacher conflict-inducing attitudes towards pupils: A path analysis model. *Teaching and Teacher Education, 18,* 1007–1021.

Schank, R. (2001). *Designing World Class e-learning*. New York: McGraw-Hill.

Schleppegrell, M. J. (2004). *The language of schooling: A functional linguistics perspective*. Mahwah, NJ: Erlbaum.

Schneider, L. S., & Rener, J. W. (1980). Concrete and formal teaching. *Journal of Research in Science Teaching, 17*(8), 503–517.

Schwartzstein, R. M., & Roberts, D. H. (2017). Saying goodbye to lectures in medical school-paradigm shift or passing fad*? England Journal of Medicine, 377*(7), 605– 617.

Scott, C. L. (2015). *The future of learning. What kind of pedagogies for the 21st century?* Education Research and Foresight: Working Papers. Retrieved on March 22nd 2016 from http://unesdoc.unesco.org/images/0024/002431/243126e.pdf

Senteni, A. (2004). Mathematics and computer-aided learning. *Academic Exchange Quarterly, 3*(7), 22–35.

Sesli, E., & Kara, Y. (2012). Development and application of a two-tier multiple-choice diagnostic test for high school students' understanding of cell division and reproduction. *Journal of Biological Education*, *46*(4), 214–225.

Seweje, R. O. (2010). *Defining issues in science education*. *24th Inaugural lecture,* University of Ado-Ekiti.

Shahrani, N. A. (1995). *Understanding Concepts of Inheritance among some 11th grade students in Riyadh and their false perceptions about them.* [Unpublished Master's thesis]. College of Education, King Saud University, Riyadh.

Shaw, K. R. M., Van Horne, K., Zhang, H., & Boughman, J. (2008). Essay contest reveals misconceptions of high school students in genetics content. *Genetics, 178*(3), 1157–1168.

Shemwell, J. T., & Furtak, E. M. (2010). Science classroom discussion as scientific argumentation: A study of conceptually rich (and poor) student talk. *Educational Assessment, 15*(3), 222–250.

Shih, S. S. (2008). The relation of self-determination and achievement goals to Taiwanese eighth graders′ behavioral and emotional engagement in schoolwork. *The Elementary School Journal*, *10*(8), 313–334.

Simon, M. K. (2011). *Dissertation and scholarly research: Recipes for success* (20th ed.). Seattle, WA: Dissertation Success, LLC.

Sirhan, G. (2007). Learning Difficulties in Chemistry: An Overview. *Journal of Turkish Science Education, 4*(7), 2–20.

Skryabina, E**.** (2000). *Student Attitudes to Learning Biology and Physics at School and University Levels in Scotland*. [PhD Thesis]. University of Glasgow.

Slack, S. J., & Stewart, J. H. (1990). High school students' problem-solving performance on realistic genetics problems. *Journal of Research in Science Teaching*, *2*(7), 55–67.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology, 2*(1), 43–69.

Smith, B. F. (2004). *A Study of Interrelationship among Organisms*. New York: McGraw-Hill Higher Education.

Smith, M. S., Hughes, E. K., Engle, R. A., & Stein, M. K. (2009). Orchestrating discussions. *Mathematics Teaching in the Middle School, 14*(9), 548–556.

Sohmer, R. (2000). *A page so big no one can fall off: Apprenticeship as the architecture of inter-subjectivity in an after-school science program for inner city middle school students* [Unpublished dissertation]. Clark University, Worcester, MA.

Standards for Educational and Psychological Testing (1999). *Working Papers in Education, 2*(9), 5.

Starman, A. B. (2013). The case study as a type of qualitative research. *Journal of Contemporary Educational Studies 1*(3), 28–43.

Steele, F., & Aubusson, P. (2004). The challenge in teaching biotechnology. *Research in Science Education*, *3*(4), 365–387.

Steen, S., Bader, C., & Kubrin, C. (1999). Rethinking the graduate seminar. *Teaching Sociology*, *2*(7), 167-192.

Stiggins, R. J. (2001). *Student-Involved Classroom Assessment* (3rd ed.). Upper Saddle River, NJ, Merrill: Prentice Hall.

Sturgis, P., Cooper, H., & Five-Schaw, C. (2005). Attitudes to biotechnology: Estimating the opinion of a better-informed public. *New Genetics and Society*, *24*(1), 31–56.

Sun, J., Anderson, R. C., Lin, T. J., & Morris, J. (2015). Social and cognitive development during collaborative reasoning. In C. S. Asterhan, S. N. Clarke, & L. B. Resnick (Eds.), *Socializing intelligence through academic talk and dialogue.* Washington, DC: American Educational Research Association.

Tatar, N. (2006). *Scaffolding and achievement in problem-based learning and inquiry learning*. [Unpublished Dissertation]. A Gazi University, Institute of Education Sciences.

Tekkaya, C. (2002). *Misconceptions as Barrier to Understanding Biology*. Retrieved June 12th 2016 from http://www.efdergi.hacettepe.edu.tr/yonetim/icerik/makaleler/971-published.pdf

Tekkaya, C., Ozkan, O., & Sungur, S. (2001). Biology concepts perceived as difficult by Turkish high school students. *Hacettepe University Journal of Education*, *2*(1), 145–150.

Thayer, W. M., & Martha, S. T. (2009). The use of the Solomon four-group design in nursing research. *Southern Online Journal of Nursing Research, 9*(1), 1-9.

The National Academy Press (2016). *Misconceptions as Barriers to Understanding Science*. Retrieved May 3rd 2016 from: https://www.nap.edu/read/5287/chapter/6

The National Foundation for Educational Research (2011). *Exploring young people's views on Science Education.* Report to the Wellcome Trust.

The West African Examinations Council (2017). *Chief examiners' report. Science programme: May/June West African senior school certificate examination.* Accra: WAEC.

Topcu, M. S., & Sahin-Pekmez, E. (2009). Turkish middle school students' difficulties in learning genetics concepts. *Journal of Turkish Science Education*, *6*(2), 55–62.

Tran, V. D., & Vietnam, A. G. (2014). The effects of cooperative learning on the academic achievement and knowledge retention. *International Journal of Higher Education, 3*(2), 131–140.

Trowbridge, L. W., Bybee, R. W., & Powell, J. C. (2000). *Teaching Secondary School Science*. Upper Saddle River, NJ: Merrill/Prentice Hall.

Tsui, S. Y., & Treagust, D. F. (2010). Evaluating secondary students' scientific reasoning in genetics using a two-tier diagnostic instrument. *International Journal of Science Education, 32*(8), 1073–1098.

Udo, M. E. (2010). Effect of guided-discovery, student-centred demonstration and the expository instructional strategies on students' performance in Chemistry. *African Research Review, 4*(4), 23–30.

Ugboaja, C. (2008). Teaching a Profession or Craft: An Art or Science: In Nworgu N.A (ed.) *Teacher and teaching in Nigeria: issues, challenges and Prospect* (2-18) Benin City: NAE.

Usak, M., Erdogan, M., Prokop, P., & Ozel, M. (2009). High school and university students' knowledge and attitudes regarding biotechnology. *Biochemistry and Molecular Biology Education*, *37*(2), 123–130.

Vedanayagam, E. G. (1994). *Teaching technology for college teachers*. New Delhi: Sterling Publishers.

Venville, G. J., & Treagust, D. F. (1998). Exploring conceptual change in genetics using a multidimensional interpretative framework. *Journal of Research in Science Teaching, 35*(9), 1031–1055.

von Glasersfeld, E. (1995). A constructivist approach to teaching. In L. P. Steffe & J. Gale (Ed.), *Constructivism in education* (p. 3-15). Hillsdale, NJ: Lawrence Erlbaum Associates.

Vosniadou, S. (2007). The cognitive-situative divide and the problem of conceptual change, *Educational Psychologist, 42*(1), 55–66.

Vygotsky, L. S. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Wade, R. C. (1994). Teacher education students' views on class discussion: Implications for fostering critical reflection. *Teaching and Teacher Education*, *10*(2), 231–243.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into Mathematics classrooms. *Review of Educational Research, 78*(3), 516–551.

Wandersee, J., Mintzes, J., & Novak, J. (1994). *Research on Alternative Conceptions in Science. Research on Science Teaching and Learning.* New York: Macmillan.

Warren, B., & Rosebery, A. (1996). This question is just too, too easy: Perspectives from the classroom on accountability in science. In L. Schauble & R. Glasser (Ed.), *Innovations in learning: New environments for education* (p. 97–125). Hillsdale, NJ: Erlbaum.

Watters, J., & Ginns, I. (2000). Developing motivation to teach elementary science: Effect of collaborative and authentic learning practices in pre-service education. *Journal of science Teacher Education, 11*(4), 301–321.

Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping in peer-directed groups. *International Journal of Educational Research*, *39*(1&2), 73–97.

Webb, N. M., Franke, M. L., Turrou, A. C., & Ing, M. (2015). Exploration of teacher practices in relation to profiles of small-group dialogue. In C. S. Asterhan, S. N. Clarke, & L. B. Resnick (Eds.), *Socializing intelligence through academic talk and dialogue.* Washington, DC: American Educational Research Association.

Wehrle, R. (1998). *Computers in education: The pros and the cons.* Retrieved on February 18th 2003 from http://www.edweek.org/sreports/tc98/intro/in-n.html

Westwood, P. (2008). *What teachers need to know about teaching methods*. Camber Well, Vic: ACER Press.

Wiggins, G. P. (1998). *Educative assessment*: *Designing assessments to inform and improve student performance.* San Francisco: Jossey-Bass Publishers.

Wilkinson, L. (2009). *Discussion method.* Retrieved on September 5, 2016 from education.com/reference/article/discussion-methods

Wilson, J. D. (1996). An evaluation of the field experiences of the innovative model for the preparation of elementary teachers for science, mathematics, and technology. *Journal of Teacher Education, 47*(1), 53–59.

Windschitl, M. (1999). Using small-group discussions in Science lectures. *College Teaching*, *4*(7), 23–27.

Wolff, M., Wagner, M. J., Poznanski, S., Schiller, J., & Santen, S. (2015). Not another boring lecture: engaging learners with active learning techniques. *Journal of Emergency Medicine, 48*(1), 85–93.

Wood, L. N., Sadhbh, J., Petocz, P., & Rodd, M. (2007). Learning in lectures: multiple representations. *International Journal of Mathematical Education in Science and Technology. 38*(97), 907–915.

Wood, W. B. (2003). Inquiry-based undergraduate teaching in life Sciences at large research universities: A perspective on the Boyer Commission Report. *Cell Biology Education, 2*(6), 112–116.

Yala, P. O., & Wanjohi, W. C. (2011). Performance Determinants of KCSE in Mathematics in Secondary Schools in Nyamira Division, Kenya. *Asian Social Science, 7*(2), 107–112.

Yildirim, A., & Berberoglu, G. (2012). Longitudinal impact of an inquiry-based Science program on middle school students' attitudes towards Science. *Science Education, 86*(5), 693-714.

Yoloyo, A. (1994). *Interventional strategy in promoting women participation. Science and Technology in Nigeria in perspective on women in science and technology in Nigeria* (SY Ed.). Ibadan SAM Bookman Education and Communication Services.

Yu-Chien, C. (2008). *Learning Difficulties in Genetics and the Development of Related Attitudes in Taiwanese Junior High Schools.* A thesis submitted to the Centre for Science Education, Educational Studies, Faculty of Education, University of Glasgow, United Kingdom.

Zakaria, E., & Iksan, Z. (2007). Promoting cooperative learning in Science and Mathematics Education: A Malaysian perspective. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(1), 35–39.

Zeeb, M. S. (2004). *Improving student success through matching learning and teaching styles.* Retrieved on November 15th 2004 from http//www.creativelearningcentre.codownloads/lsia/Zeeb%

20LSA%20research%20pilot%2edited%20US.pdfon 20/9/2012

Zeller, M.F. (1994). Biotechnology in the Curriculum: The future is here! *The American Biology Teacher*, *56*(8), 460–464.

University of Education, Winneba http://ir.uew.edu.gh

Zohrabi, M. (2013). Mixed method researcher: Instruments, validity, reliability and reporting findings. *Theory and Practice in Language Studies*, *3*(2), 12–26.

APPENDIX A

Standardized Genetics Achievement (SGAT) Pretest

Answer all questions on the answer sheet provided Duration: 45 minutes

1. A strand of DNA with the sequence ***AACTTG*** will have a complimentary strand with which of the following sequence?
   a. AACTTG.
   b. CCAGGT.
   c. TTCAAG.
   d. T.

2. Which of the following factors could lead to ***variations*** in the offspring of asexually reproducing organisms?
   a. Crossing over.
   b. Fertilization.
   c. Independent assortment.
   d. Mutations.

3. The cytoplasm of an animal cell is divided by means of
   a. a cell plate.
   b. a cell membrane formed within the cytoplasm.
   c. a cleavage furrow.
   d. mitosis.

4. The step of mitosis in which chromosomes line up along the equatorial plane of the cell is
   a. anaphase.
   b. metaphase.

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c. prophase. d. telophase.

5. Crossing over in diploid organism is responsible for
    a. dominance of genes
    b. linkage between genes.
    c. recombination of linked alleles
    d. segregation of alleles

6. A gene is said to be dominant if
    a. it never expresses its effect in any condition.
    b. it expresses its effect only in heterozygous condition.
    c. it expresses its effect only in homozygous state.
    d. it expresses its effect both in homozygous and heterozygous condition.

7. An example of an allele is
    a. AB and Tt. c. TT and Tt.
    b. T and t. d. X and Y.

8. An example of a genotype is
    a. a tall pea plant. c. R and r.
    b. hemophiliac. d. TtHH.

9. Which of the following gives information about the ***phenotype*** but not the ***genotype?***
    a. Female carrier for colour-blindness.
    b. Hemophiliac man.
    c. Tall pea plant.
    d. XHY.

10. Pea plants were particularly well suited for use in Mendel's breeding experiments for all of the following reasons except that

a. it is possible to completely control matings between different pea plants.

b. it is possible to obtain large numbers of progeny from any given cross.

c. peas have an unusually long generation time.

d. peas show easily observed variations in a number of characters, such as pea shape and flower colour.

11. What is the difference between a ***monohybrid cross*** and a ***dihybrid cross?***

a. A monohybrid cross involves organisms that are heterozygous for a single character whereas a dihybrid cross involves organisms that are heterozygous for two characters.

b. A monohybrid cross is performed only once whereas a dihybrid cross is performed twice.

c. A monohybrid cross involves a single parent whereas a dihybrid cross involves two parents.

d. A monohybrid cross produces a single progeny whereas a dihybrid cross produces two progeny.

12. A cross between homozygous purple-flowered and homozygous white-flowered pea plants results in offspring with purple flowers. This demonstrates

a. dihybrid cross.

b. dominance.

c. the blending model of genetics.

d. true-breeding.

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13. What is genetic cross between an individual showing a ***dominant phenotype*** (but of unknown genotype) and a ***homozygous recessive*** individual called?

a. A hybrid cross.
b. A self-cross.
c. A test-cross.
d. An F1 cross.

14. Mitotic cell division results in two cells that have

a. 2n chromosomes and are genetically different.
b. 2n chromosomes and are genetically identical.
c. n chromosomes and are genetically different.
d. n chromosomes and are genetically identical.

15. In tobacco, if the diploid number of chromosomes is 48, how many chromosomes will be found in a ***pollen grain***?

a. 12.
b. 24.
c. 48.
d. 96.

16. Which of the following statements about Mendel's breeding experiments is correct?

a. All of the F1 progeny resembled one of the parental (P) plants but only some of the F2 progeny did.
b. All of the F2 progeny showed a phenotype that was intermediate between the two parental (P) phenotypes.
c. Half of the F1 progeny had the same phenotype as one of the parental (P) plants and the other half had the same phenotype as the other parent.
d. None of the parental (P) plants were true-breeding.

17. The F1 offspring of Mendel's classic pea cross always looked like one of the two parental varieties because

a. each allele affected phenotypic expression.

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b. no genes interacted to produce the parental phenotype.

c. one allele was completely dominant over another.

d. the traits blended together during fertilization.

18. Which of the following is (are) ***true*** for alleles?

a. They can be dominant or recessive.

b. They can be identical or different for any given gene in a somatic cell.

c. They cannot represent alternative forms of a gene.

d. Only A and B are correct.

19. Which of the following is ***false*** regarding the law of segregation?

a. It can account for the 3:1 ratio seen in the F2 generation of Mendel's crosses.

b. It can be explained by the segregation of homologous chromosomes during meiosis.

c. It can be used to predict the likelihood of transmission of certain genetic diseases within families.

d. It states that each of two alleles for a given trait segregate into different gametes.

20. A 1:2:1 phenotypic ratio in the F2 generation of a monohybrid cross is a sign of

a. complete dominance.

b. incomplete dominance.

c. multiple alleles.

d. polygenic inheritance.

PART II
ANSWER ALL QUESTIONS

1. Define the following terms (3 marks each)

A. Chromosome
B. Meiosis

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C. Genetics

2. In humans, brown eyes are dominant over grey eyes. Suppose a man who is heterozygous for such trait marries a true breeding woman, determine with the aid of genetic diagrams the genotypic ratio of their off springs (5 marks).
3. Briefly explain how one can determine whether an individual is either homozygote or heterozygote for a given trait (6 marks).

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APPENDIX B

Standardized Genetics Achievement (SGAT) Posttest

Answer all questions. Duration: 50 Minutes

1. A plant with purple flowers is allowed to self-pollinate. Generation after generation, it produces purple flowers. This is an example of

a. hybridization.
b. the law of segregation.
c. incomplete dominance.
d. true-breeding.

2. Which statement concerning a pair of alleles for a gene controlling a ***single characteristic*** in humans is true?

a. Both genes come from the father.
b. Both genes come from the mother.
c. One gene comes from the mother and one gene comes from the father.
d. The genes come randomly in pairs from either the mother or father.

3. Mr. Kapoor has Bb autosomal gene pair and ***d*** allele which is sex-linked. What shall be proportion of ***Bd*** in his sperms?

a. 0.
b. 1/8.
c. 1/4.
d. 1/2.

4. The phenomenon in which an allele of one gene suppresses the activity of an allele of another gene is known as

a. dominance.
b. epistasis.
c. suppression.
d. inactivation

5. A common test to find the genotype of a hybrid is by

a. crossing of one F2 progeny with female parent

b. studying the sexual behaviour of F1 progenies

c. crossing of one F1 progeny with male parent

d. crossing of one F2 progeny with male parent.

6. Genetic traits of seeds are noted as follows: L = long, l = short W = wrinkled, w = smooth Y = yellow, y = white R = ribbed, r = grooved. Which of the following is the genotype for a ***short, wrinkled, yellow, grooved seed?***

a. LlWwyyrr.

b. llWwYYrr.

c. LLWWyYRr.

d. LlWwYYRr.

7. In pea plants, yellow colour is dominant over green and round shape dominant over wrinkled. A plant producing yellow round seeds is crossed with a plant producing green wrinkled seeds. F1 generation consists of ***yellow round, yellow wrinkled, green round and green wrinkled*** in the ratio of 1:1:1:1. Hence the genotype of the yellow round parent is

a. YYRR.

b. YyRR.

c. YYRr.

d. YyRr.

8. In Mendel's experiments with garden peas, round seed shape (RR) was dominant over wrinkled seeds (rr), yellow cotyledon (YY) was dominant over green cotyledon (yy). What are the expected ***phenotypes*** in the F2 generation of the cross RRYY x rryy?

a. Only round seeds with green cotyledons.

b. Only wrinkled seeds with green cotyledons.

c. Only wrinkled seeds with yellow cotyledons.

d. Round seeds with yellow cotyledons and wrinkled seeds with yellow cotyledons.

9. Which of the following is **accurate** about an X-linked trait?

a. There is 0% chance that a son inherits an X-linked trait from his father.

b. There is a 25% chance that a son inherits an X-linked trait from his father.

c. There is a 50% chance that a son inherits an X-linked trait from his father.

d. There is an 80% chance that a son inherits an X-linked trait from his father.

10. A child of O-group has B-group father. The genotype of father will be

a. $I^{\circ}I^{\circ}$

b. $I^{B}I^{B}$

c. $I^{A}I^{B}$

d. $I^{B}I^{\circ}$

11. A man heterozygous for blood type A marries a woman heterozygous for blood type B. The chance that their first child will have type O blood is

a. 0%.

b. 25%.

c. 50%.

d. 75%

12. If two white sheep produce a black offspring, the parent's genotypes for colour must be

a. heterozygous.

b. homozygous white.

c. homozygous black.

d. WW.

13. An extra finger in humans is rare but is due to a dominant allele. When one parent is normal and the other parent has an extra finger but is heterozygous for the trait, what is the probability that the first child will be ***normal***?

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a. 0%.
b. 25%.
c. 50%.
d. 75%.

14. In drosophila (fruit flies), eye colour is sex-linked and red eye colour is dominant to white eye colour. Which of the following are ***not*** possible in a cross between a red-eyed male and a heterozygous female?

a. Carrier female.
b. Homozygous white-eyed female.
c. Red-eyed male.
d. White-eyed male.

15. In pea plants, yellow seeds are dominant to green. If a heterozygous yellow seeded plant is crossed with a green seeded plant, what ratio of ***yellow and green*** seeded plants would you expect in F1 generation?

a. 1:1.
b. 1: 3.
c. 3: 1.
d. 9: 1.

16. People with sickle-cell trait

a. are heterozygous for the sickle-cell allele.
b. are usually healthy.
c. have increased resistance to malaria.
d. produce normal and abnormal haemoglobin.

17. Genes X and Y are

a. located far from each other on the same chromosome.

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b. located on different chromosomes.

c. located very near to each other on the same chromosome.

d. both A and B.

18. Males are more often affected by sex-linked traits than females because

a. female hormones such as estrogen often compensate for the effects of mutations on the X.

b. males are hemizygous for the X chromosome.

c. male hormones such as testosterone often exacerbate the effects of mutations on the X chromosome.

d. X chromosomes in males generally have more mutations than X chromosomes in females.

19. A recessive allele on the X chromosome is responsible for red-green color blindness in humans. A woman with normal vision whose father is color-blind marries a color-blind male. What is the probability that a ***son*** of this couple will be color-blind?

a. 1/4.

b. 1/2.

c. 3/4.

d. 1.

20. Mendel discovered principles of inheritance because he

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a. believed that the hereditary characteristics of two individuals became thoroughly blended in the offspring.
b. ignored all characteristics except a few markedly contrasting ones in which he studied.
c. Observed simultaneously all of the many characteristics in which the parents differed.
d. studied only the offspring obtained from a single mating.

PART II

ANSWER ALL QUESTIONS

1. Explain why a female with a negative rhesus factor should not marry a male who has a positive rhesus factor (5 marks).
2. A man of blood group A married a woman of an unknown blood group and had a daughter who belongs to blood group O. With the aid of genetic diagrams, illustrate the possible genotypes of the woman (10 marks).
3. Explain how biological sex is determined in humans (5 marks).

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APPENDIX C

MARKING SCHEME OF THE PRE-SGAT

PART I

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

Any correct option chosen (1 x 20 marks) =20 marks

PART II

1.A. chromosome refers to a thread-like structure (1 mark) found within the nucleus/genome/genetic material (1 mark) of organism that carry/transfer traits (1 mark) from parents to offspring/ progeny.

Any statement properly outlined (1 x 3 marks) = 3 marks

B. Meiosis refers to a reduction cell division (1.5 marks) that occurs in sex cells (1.5 marks).

Any statement properly stated (1 x 3 marks, 1.5 marks x 2) = 3 marks

C. Genetics refers to the study of heredity (1.5 marks) and variation (1.5 marks).

Any statement properly stated (1 x 3 marks, 1.5 marks x 2) = 3 marks

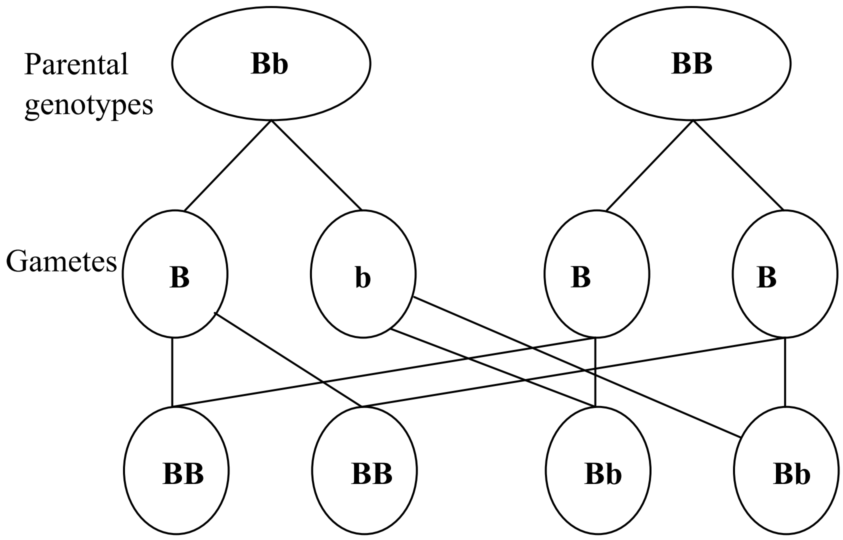
2. Let B=brown eyes (0.25 mark each)

Let b=grey eyes

Therefore the genotype of the man=Bb

Genotype of the woman=BB

Correct outline of the above = (0.25 mark x 4) =1 mark



Correct illustration of all gametes = (0.25 mark x 4) =1 mark

Correct crossing and arriving at the right genotype = (0.5 mark x 4) = 2 marks

Stating the right phenotypic ratio 1:1 = (1 mark x 1) =1 mark but stating it as 2:2 = (1 x 0.5 mark) =0.5 mark.

3. This is done by employing a testcross (1 mark). A **true** breeding/homozygote dominant organism for a given trait (1 mark) is crossed with another organism that is with an unknown genotype for such trait (1 mark). When the genotypic ratio ends in 4:0 in the F1 (1 mark) progeny, the person is homozygous recessive for such trait (1 mark) but when the genotypic ratio result in 1:1 or 2:2, such individual is heterozygote for the trait (1 mark).

Any statement(s) properly explained with the key words or ratios intact intact = (1mark x 6) = 6 marks.

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APPENDIX D

MARKING SCHEME OF THE POST-SGAT

PART I

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

Any correct option chosen (1 mark x 20) =20 marks

PART II

1. If a woman who is Rh negative and a man who is Rh positive conceive a baby, the foetus may have Rh-positive blood inherited from the father. Rh incompatibility usually isn't a problem if it's the mother's first pregnancy. That's because the baby's blood does not normally enter the mother's circulatory system during the pregnancy. During birth, though, the mother's and baby's blood can mix. If this happens, the mother's body recognizes the Rh protein as a foreign substance. It then might begin making antibodies (proteins that act as protectors if foreign cells enter the body) against the Rh protein. Rh-negative pregnant women can be exposed to the Rh protein that might cause antibody production in other ways too. These include: blood transfusions with Rh-positive blood miscarriage, and ectopic pregnancy. During the mother's second or later pregnancies. If she is ever carrying another Rh-positive child, her Rh antibodies will recognize the Rh proteins on the surface of the baby's blood cells as foreign. Her antibodies will pass into the baby's bloodstream and attack those cells making the baby's red blood cells swell and rupture.

Any statements properly explained taking into consideration the key words antigens, antibodies, and the baby's health status = 5 marks

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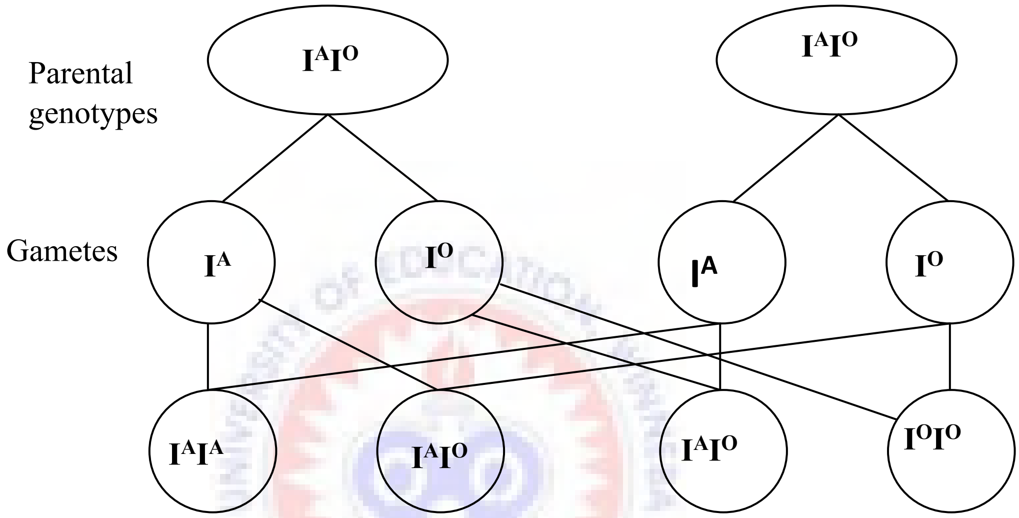
2. For the man to a child with blood group O means that the genotype of the man is I^AI^O.

Correct statement of genotype = 1 mark

Possible genotypes of the woman are:

1. I^AI^O

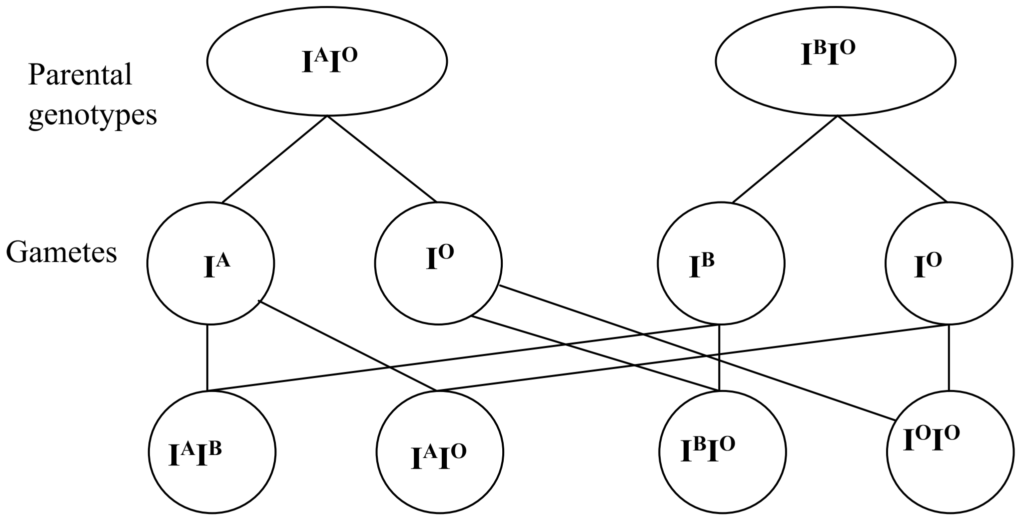
   Correct statement of this genotype = 1mark



Employing all the correct crosses and arriving at the above genotypes = 2.5 marks

2. I^BI^O

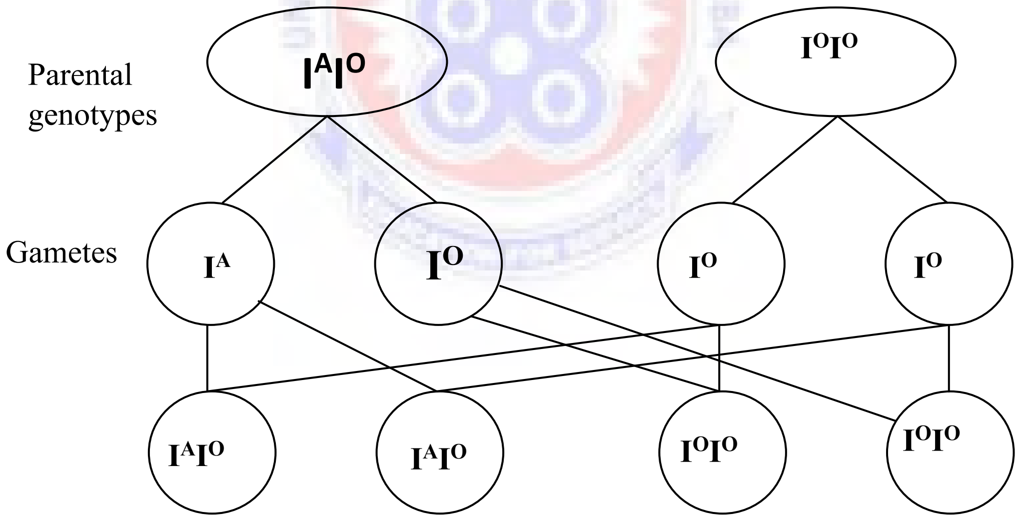
   Correct statement of genotype = 1mark



Employing all the correct crosses and arriving at the genotypes = 2 marks

3. I^OI^O

Correct statement of genotype = 1mark



Employing all the correct crosses and arriving at the genotypes = 2 marks

Therefore, the possible genotypes of the woman are I^AI^O, I^OI^O, and I^OI^O.

Correct outline of these genotypes = 1 mark.

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2. Human females have two X chromosomes (XX) and males have a single X and a single Y chromosome (XY). In humans, the male-specific Y chromosome plays a pivotal role in sex determination, and also bears genes that are required for spermatogenesis. 50% of the total sperm produced possess the X-chromosome and the rest 50% has Y-chromosome besides the autosome. There is an equal probability of fertilization of the ovum with the sperm carrying either X or Y chromosome. If ovum fertilizes with X type sperm, the zygote develops into a female but when fertilizes with X type sperm, the zygote develops into a male. Thus, genetic makeup of the sperm determines the sex of the child. It is also clear that in each pregnancy there is always 50% or 1/2 probability of either a male or a female child.

Any statements properly explained taking into consideration males being heterogametic and females being homogametic with the Y chromosome determining sex = 5 marks.

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APPENDIX E

Letter of Introduction

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF PHYSICS EDUCATION

DSE/M.../VOL.2/

March 10 2020

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

INTRODUCTORY LETTER

The bearer of this letter, *Maxwell Asare* with Index Number *8180130019*, is an M.Phil. student of the Department of Science Education in the above University.

He is conducting a research on "*Effect of Classroom Discussion on Academic Outcomes of second year Biology students in Genetics at Winneba Senior High School*" for his studies. We would be grateful if you could assist him collect data for his research.

Counting on your usual co-operation.

Thank you.

Yours faithfully,

HEAD
DEPARTMENT OF PHYSICS EDUCATION
UNIVERSITY OF EDUCATION
WINNEBA

PROF. VICTOR ANTWI, PhD
for: Head of Department

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