AN INVESTIGATION INTO STRATEGIES THAT MALAWIAN BIOLOGY TEACHERS USE TO ADDRESS TEACHING CHALLENGES IN GENETICS: A CASE STUDY

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Statement of Originality

The concept, research, organization, writing of this research report is entirely my own and has been carried out at Mzuzu University, Malawi, under the supervision of **Dr F.C. Lungu.** All quotations are distinguished and identified by reference.

Candidate's signature: ____

Thandeka Andreah Nkhonde

Dedication

I dedicate this piece of work to my parents Mr Hawkings Samuel Nkhonde and Effie Msachi (late) for inspiring me to this academic level.

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I would like to express my appreciation to my supervisor **Dr Foster C. Lungu** for his tireless effort in shaping this study to be what it is today. His guidance was significant to this project. Also, my special gratitude goes to Mrs Margret. Mdolo and Mr Friday.F.F Masumbu for their material and moral support rendered to me during this study.

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Abstract

Genetics is rated as one of the most difficult topics to teach at MSCE level in Malawi, yet it is a fundamental part of biology and is relevant to everyday life. Despite its importance to the individual and society at large, genetics teaching and learning at different levels of education and in different context is facing significant challenges such as vocabulary and terminologies, abstract nature, complex nature, mathematical problems and misconceptions in textbooks, teachers and learners. In Malawi, very little, if anything has been done to find out how biology teachers are addressing the teaching challenges in genetics.

This study investigated how Malawian senior secondary school biology teachers address the teaching challenges in genetics by identifying the challenging concepts, describing the strategies used to teach the identified concepts and explain the reasons for using the described strategy. A case study approach was used and data was collected through structured interviews and video observation of lessons. Data was analysed through content analysis in order to come up with categories and themes.

This study has revealed that Malawian biology teachers find teaching of some genetics concepts, mathematical aspects and drawing of crosses challenging. The study also found that teachers use group work, demonstration, question and answer and problem based learning to address the challenges. The study recommends that biology teachers should create opportunities for learners to construct knowledge individually and socially.

CHAPTER ONE: INTRODUCTION

1.0 Background

The Malawi School Certificate of Education (MSCE) biology syllabus contains five major topics: plant structure and function, animal structure and function, human and animal diseases, genetics and evolution and environment (MoEST, 2001). Genetics contains the following sub topics: variations among organisms of the same species, sources of variations, Mendelian inheritance patterns (monohybrid crosses), recessive genes, dominant genes, co-dominance and blood groups, sex determination, sex linked characteristics, mutations, genes , chromosomes and DNA, plant and animal breeding (MoEST, 2001).

From my experience as a biology teacher and in my capacity as a biology divisional trainer for the Strengthening of Mathematics and other Science Subjects in Secondary Education (SMASSE) project, I have observed during my participation in SMASSE workshops that genetics is one of the difficult topics to teach and learn. This observation was made by listening to the workshop participants concerning topics which are deemed difficult and where they need help.

SMASSE is an In-Service Education and Training (INSET) of science teachers. It is aimed at equipping Malawian biology, physical science, mathematics and home economics teachers with effective teaching strategies and subject matter knowledge. Trainings take place in designated centres during school holidays. Teachers in these centres share the knowledge on effective instructional techniques of science subjects with guidance from Divisional Trainers (DTs). It is through such meetings that teachers discuss the challenging topics at MSCE and Junior Certificate of Education (JCE) in their respective subjects as agendas for their next INSET. In the SMASSE Baseline Survey of 2009 and the National INSET of April 2011, biology teachers nationwide identified genetics as one of the most difficult topics to teach and learn at MSCE level. The teachers argued that it is hard to come up with meaningful activities and learner-centred lessons.

Furthermore, reports by biology chief examiners in MSCE theory papers indicate that learners have difficulties in answering genetic questions. For example, the chief examiner's report of 2012 states that candidates seemed to have problems to correctly draw genetic diagrams. It was also reported that students had little understanding for the identification of genotypes to use for drawing genetic diagrams (Malawi National Examinations Board, 2012).

Another report states that candidates were failing to apply their genetic knowledge in solving problems that demand higher order thinking skills especially in tracing the inheritance of sex linked characteristics in a family tree diagram (Malawi National Examinations Board, 2008).

My interest in teaching difficulties in genetics grew and prompted me to chat with some of the biology teacher educators at Mzuzu University. The aim of chatting with the educators was to find out their perception towards the teaching and learning of genetics at higher learning institutions. I also wanted to be enlightened if there was any study in the Malawi context that dealt with strategies in teaching challenging concepts in genetics. The biology teacher educators expressed the same feelings that genetics is difficult to teach and learn. They also said that studies on strategies for teaching challenging genetic concepts have never been published since the time when the studies were conducted in Malawi

My search through Google and Yahoo has revealed that little is known about the effective strategies to address the teaching challenges in genetics by Malawian biology teachers in secondary school education. In search of effective strategies, I looked for terms like 'strategies used for teaching challenging genetic concepts in Malawi' and 'teaching of genetics in general in Malawi' but all provided scanty information. Thus, I wondered as to what genetic concepts are difficult to teach; how such difficult concepts are approached by biology teachers in classroom situations; and why the teachers choose certain strategies to address the challenges. This study sought to find out the common strategies that Malawian biology teachers use to address teaching challenges in genetics.

1.1 The Research Problem

As discussed in the background, genetics is rated as one of the most difficult topics to teach at MSCE level in Malawi. However, it is not known how Malawian biology teachers address the teaching challenges in genetics. Thus, this study sought to find out the strategies that Malawian biology teachers use in addressing teaching challenges in genetics.

1.2 Aims of the Study

This study aimed at investigating the strategies that Malawian Biology teachers use in teaching difficult genetic concepts. It had the following objectives:

- To identify concepts in genetics that pose teaching challenges to Malawian secondary school biology teachers
- To describe strategies that Malawian biology teachers use in addressing the teaching challenges in genetics.
- To explain why Malawian biology teachers choose the described strategies.

1.3 Significance of the Study

As pointed out already, there seems to be no study that has investigated the strategies that Malawian biology teachers use in teaching difficult genetic concepts. Therefore, it is hoped that the findings of this study would be a significant filler of this existing gap. Additionally and more significantly, it is expected that the work will spur more in-depth studies in this research area. The information will be insightful to teachers, Secondary Education Methods Advisors (SEMA), Curriculum Developers and Teacher Educators on improving the teaching of genetics in biology education in Malawi in the following ways:

- Biology Teachers can use the findings of this study on concepts, strategies and reasons for using a strategy in teaching difficult concepts for planning and presentation of effective lessons.

- Secondary Education Methods Advisors (SEMAs) can use the findings of this study on difficult concepts and strategies for their advisory role by identifying areas in genetics that teachers need assistance for effective delivery of genetic lessons.

- Biology Curriculum developers can use the findings of this study on concepts and strategies for reviewing the biology curriculum to locate from the topic of genetics areas that are difficult to teach and suggest teaching strategies that addresses the teaching difficulties for student understanding of the topic content.

- Biology Teacher Educators can use the findings of this study on concepts, strategies and reasons for using a specific strategy for equipping prospective biology teachers with the necessary content and pedagogical knowledge in dealing with the teaching difficulties in genetics.

1.4 Definition of Operational Terms

Difficult genetic concepts : Genetic concepts that a teacher finds challenging to teach in such a way that learners can easily understand.

Teaching Challenges : Problems that a teacher encounters when teaching certain genetic concepts which make it difficult for students to understand the concepts.

Teaching Strategy : The overall procedure that a teacher employs in delivering the lesson content.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter begins by exploring the rationale for teaching genetics in secondary schools in Malawi. It also looks at the possible reasons for the existence of teaching difficulties in genetics and the effective teaching strategies for enhancing understanding of genetic concepts. It ends with discussion of the theoretical framework and research paradigm that I adopted in order to understand difficulties in teaching of genetics.

2.1 Rationale for the Teaching of Genetics

Haga (2006, p 108) states that "genetics is one of the fundamental parts of biology and is relevant to everyday life." According to MoEST (2001) biology syllabus, it is stipulated that genetics should be taught in Malawian secondary schools in order to help students develop broad understanding of themselves and the world around them. This understanding would help the students develop skills in solving personal and community problems that are related to health, population and environment. It would also sensitise students to the application and implications of genetics (Knippels, 2005; Haga, 2006).

Dawson and Schibeci (2003) argue that the application of gene technology has been received with mixed reactions by the society. It concurrently presents fears and hopes for the future. For example, Malachias et al. (2010) illustrate that in Brazil, the National Congress had mixed reactions on application of the gene technology and its ethical consequencies on the society. Despite the controvesial effects, Malachias et al. (2010) state that the advent of recombinant deoxy-ribonucleic acids (DNA) technology, genetic modified foods, DNA screening and cloning has led to improved technological development of many countries including Malawi in the field of agriculture, health and industry. In spite of its importance, the teaching and learning of genetics is associated with a lot of challenges (Dougherty, 2009).

2.2 Difficulties in Teaching and Learning of Genetics

Research done on teaching and learning of genetics has revealed that some of the difficult concepts that pose challenges to its teaching are crosses, mathematical calculations, genetic terms, mutations, mitosis, meiosis, sex determination, chromosomes, genes, variance and co-dominance (Haambokoma, 2007; Topcu & Perkmez 2009; Malachias et al., 2010; Cimer, 2012; Gericke & Wahlberg, 2013). These challenges emanate from their vocabulary and terminologies, abstract nature, complex nature, mathematical problems and misconceptions in textbooks, as well as teachers and learners (Mbajiorgu, 2006; Topcu & Perkmez, 2009; Thorne, 2012). Below are the possible reasons from empirical research findings regarding the difficulties in teaching of genetics:

2.2.1 Technical Terms

Genetics is difficult to teach because of extensive use of technical terms involved in the topic (Knippels, 2002; Thorne, 2012). Thornes (2012, p.9) defines technical terms as "words connected to a specific subject matter." Technical terms are a problem in genetics because of wrong use of terms, existence of synonyms, terms having different meanings depending on context used and disputed meaning of some technical terms (Knippels, 2002; Thorne, 2012). For instance, the terms *allele* and *gene* cause confusion in teaching and learning of genetics because textbooks and teachers use the two words interchangeably (Leech & Woodson, 2000). The term "gene" is a common synonym misused by teachers and textbooks (Knippels 2002). A gene is commonly misused in gene for red coloured flowers instead of *allele* for red coloured flowers. Another common mistake is the use of "*lethal gene*" for "*lethal alleles*." The gene cannot be lethal but the allele. Actually, it is the allele which expresses itself to produce phenotypes.

Some genetic terms bring confusion because they sound and look similar in their use (Knippels et al., 2005). Examples include *meiosis*, *mitosis homologous*, *homozygote, homologous chromosomes*, and *homologue* (Thornes, 2012).

Some technical terms in genetics convey a very different meaning depending on the context of use (Knippels, 2002). Terms like "*dominant*" are easily misunderstood to mean "frequent." Students misinterpret *dominant alleles* as being good over *recessive alleles* and attach *recessive alleles* as responsible for causing mutations (Knippels, 2002).

Definitions for some genetic terms are wrongly presented in most textbooks and teachers. Knippels (2002, p.28) illustrates "*mutation*" which is commonly referred to as "rare, harmful and recessive event." *Mutation* is the change in chemical structure of a single gene or physical make up of chromosomes (Fullick, 2000). Mutations bring variation in most organisms and can be harmful or advantageous. Most of them are rare and recessive depending on the environment in which the organism lives at a given period. Another common term which has a disputed meaning is *gene* (Thorne, 2012). This contributes to inconsistence in learning of genetics which makes it difficult for learners to comprehend.

2.2.2 Abstract Nature of Genetic Concepts

Abstract nature of the biological concepts increases the difficulties in teaching and learning of genetics. Abstractness in this context means lack of students' mental representation of concepts due to lack of connection between interrelated concepts for understanding genetic concepts (Knippels et al.,2005).

One factor for the abstract nature of genetic concepts is lack of connection between concepts (Chattopadhyay, 2005; Knippels, 2005; Cimer, 2012). Students relate better concepts that fall within the same cluster than in different clusters (Mbajiorgu, 2006; Gericke & Wahlberg 2013). According to Gericke and Wahlberg (2013) a cluster is "a representation of the students' knowledge structures" (p. 73). Teaching of biology requires teachers to focus on students' existing concepts from various clusters in order to make connections with the concepts and processes from different levels. For example; in teaching of genetics, students should form a physical link with reproduction, genes, chromosomes, DNA and fertilisation which all belong to different levels of organisation. Leach and Wood-Robinson (2000) argue that abstractness is formed in learners' mind when they fail to form a link between basic ideas and the relationship of these ideas in teaching separate concepts like variation, cell division and inheritance. This creates gaps in learners' mind as they try to understand and make connections between the terms. In the end, difficulties in learning of genetics are encountered.

Abstractness of genetic concepts in the curricula is created if related topics that provide basic knowledge to each other are not logically presented (Chattopadhyay, 2005; Haambokoma, 2007; Cimer, 2012; Gericke & Wahlberg, 2013). Students fail to form a link between concepts due to time and gap for teaching different concepts that provide foundational knowledge in learning of genetics. Chattopadhyay (2005) and Haambokoma (2007) admit that sequencing of topics that are related assists in students developing conceptual understanding of genetic concepts. For instance; structuring meiosis separately to heredity creates abstractness because genetics form a rich interaction with the topic of reproduction (Tsui & Treagust, 2004; Knippels, 2005). For example; the MSCE biology syllabus recommends teaching meiosis in reproduction at form three and heredity at form four. Although it is the teachers who make instructional decisions about the choice of instructional content or topic (Abimbola, 1998), the delay and separation of teaching reproduction and genetics for some months or a year makes learners fail to relate the concepts (Knippels, 2002). If the gap is long, students will have difficulties in relating meiosis to heredity. The sequencing of the two related topics by teachers in the MSCE biology syllabus can have serious consequences on learning of genetics if they are taught in disjunction.

In teaching and learning of genetics, lack of connection between genes, proteins and phenotypes presents abstractness in students' mind (Eklund, Rogat, Alozie, & Klajcik, 2007). Failure to show the importance of proteins in coming up with phenotypes creates inaccurate mental models in students when learning genetics (Eklund et al.,2007). For example, the MSCE Biology syllabus focuses much on genes and phenotypes without making explicit explanation on how phenotype comes about.This can be observed in teaching of sickle cell anaemia. Students fail to connect sickle cell anaemia to genes responsible for shape of blood cells and their functions in circulatory system. From the example given, abstractness is created because learners cannot see the importance of proteins in determining sickle cell anaemia. Learners think genes are directly responsible for different characteristics in organism without making the conceptual link of genes – proteins – phenotypes which ultimately creates abstractness in learning of genetics.

2.2.3 Complex Nature of Genetic Concepts

Genetic concepts and processes are complex because they involve different levels of organisation. Complexity in this context refers to conceptual problems created in learners' mind because of back and forth thinking between different levels of biological organisation of concepts. According to Knippels et al. (2005), genetics involves the following levels of organisation: molecular, cellular, organism, population and ecosystem. Knippels et al. (2005) argue that "when concepts and processes of a subject belong to different levels of organisation, students have difficulties in learning the subject" (p.35). The difficulties arise when students fail to explain and draw connections between numerous concepts. The complexity is attributed to the demand for learners to think at three levels of thought: macro, micro and symbolic level (Bahar, Johnstone & Hansel, 1999; Johnstone, 2006). Concepts at the macro level are tangible and therefore easily perceived by human senses without the aid of instruments. For example; the ability of an indivdual to roll ones tongue can be easily observed. Concepts at the micro level are difficult to understand and perceive by the senses (e.g recessive genes for controlling *tongue rolling*). At the symbolic level, the concepts are represented and manipulated by symbols and mathematical calculations. For example, the genes for tongue rolling can be presented symbolically as *rr* and use mathematical calculations to find the ratios and probabilities from the separation of gametes from the parents.

Students face problems in reasoning across these levels as they think backward or forward in trying to understand the concepts. They can see and experience events at the molecular level unlike the cellular level. At cellular level, they can use the instruments to see some of the abstract concepts like chromosomes, genes and DNA but the processes involved in them may still be invisible to the them. Failure to relate the processes at the molecular and cellular levels to relevant biological phenomena causes complexity in teaching and learning of genetics. Marbach- Ad and Stavy (2000) add that students may know the definition of these concepts but have no clear understanding about their mechanisms and the processes involved.

Knippels (2002) in her study on coping with abstract and complex nature of genetics in biology education found that in teaching of genetics, teachers do not realise the presence of these levels of thought and teach by moving across all levels simultaneously resulting into complex problems in understanding of genetic concepts. Thorne (2012) asserts that teachers may be able to graduate from one level of thought to the other but learners fail to think between these levels. Teachers' lack of understanding of different levels of biological organisation of concepts and thought contributes to learners finding the teaching and learning of genetics difficult.

2.2.4 Mathematical Problems

Genetics incorporates the use of mathematics in calculating probabilities for the phenotypic and genotypic ratios. Bahar et al. (1999) and Berlingeri & Burrowes (2011) report that studies done on integration of biology and mathematics indicate that students fail to apply mathematical knowledge in solving ratios and probability in genetics. Learners and some teachers find it difficult to apply the mathematical concept of probability to calculation of probability in segregation of gamates into phenotypes and genotypes.

Knippels (2002) argues that the use of symbols and mathematical calculations in genetics does not connect with real biological phenomena like heterozygotes, genes or homozygote. Robeva, Davies, Hodge & Enyedi (2010) opine that the root cause of mathematical problems in solving genetic problems is that most Biology curricula do not emphasize the role of mathematical knowledge. Berlingeri & Burrowes (2011) affirms that the literature on the effect of integrating or using mathematics in teaching and learning of biology is scanty as few research has been done on the topic area. Despite less research being done on the integration of mathematics and biology, Ŝorgo (2010) urges for the need of scientists to intergrate mathematics and biology and introduce suitable pedagogical models that can fuse mathematical and biological content knowledge to produce expert biology teachers who can teach mathematics integrated into biology. Berlingeti & Burrowes (2010) argue that mathematics integrated into biology can be useful in research for analyzing biological data that assists in predicting models and biological processes at various levels of organization.

2.2.5 Misconceptions in Text Books, Learners and Teachers

Teaching of genetics is associated with numerous misconceptions in textbooks, teachers and learners which contribute to difficulties in teaching and learning of the topic (Thorne, 2012). Misconceptions, according to Karagoz & Cakir (2011) are conceptual patterns that learners have and use for understadning of scientifc concepts which are contradictory to meanings widely accepted by the scientifc community.

Learners have inconsistent ideas acquired through experience when interacting with their environment through physical activities, conversations, media and formal education (Driver, Guesne, & Tiberglien.,1985a; Karagoz & Cakir, 2011). These inconsistent ideas require that instruction should strike a dissonance in learners’ mind and eliminate them (Smith, diSessa & Roschelle, 1993).

For instructional process to be effecive, teachers need to identify these misconceptions in learners and eliminate them because they interefere with understanding of genetic concepts. Andrews, Leornad, Colgrove & Kalinowski (2011) admit that science teaching can constantly maintanin misconceptions in learners if classroom instruction is not aimed at eliciting misconceptions and prior knowledge of the learners. Tanner & Allen (2005) warn that misconceptions can adhere in learners' mind and impede effective learning of genetics even after being presented with expert knowledge. It is these established misconceptions in learners which impede learning of genetics if teachers are not aware of their existence.

Textbooks are important educational source of knowledge in biology, although they present an obstacle to learning of genetics. Critical studies on genetics (Knippels, 2002; Dougherty, 2009) show that textbooks contain many misconceptions in definitions of technical terms. One of the genetic terms commonly misrepresented in different textbooks is the *gene* (Thorne, 2012). Gericke & Wahlberg (2013) express worry over lack of clarification or reaching a consensus over the meaning of *gene* by most textbooks. Varied meanings in genetic terms increase the confusion in understanding of genetic terms.

Misconceptions manifest in science teachers who then pass them to their learners. Tanner & Allen (2005) in their study about approaches to biology teaching and learning reported that misconceptions are widespread in most professionals in teaching of science. Similar findings were reported by Bowling et al. (2008) in their study on determining effects of introductory biology and genetic courses on students' genetic knowledge that high school students and undergraduate students possess a lot of misconceptions in genetics.The findings by Tanner & Allen (2005) and Bowling et al. (2008) reveal that some Biology teachers subscribe to misconceptions and pass them to students they teach. Liang & Gabel (2012) claim that teaching of science remains a critical concern to many education systems because science teachers feel incompetent to teach science as their content knowledge is full of misconceptions.

2.3 Strategies for Teaching Genetics

2.3.1 Demonstration

Demonstration method involves using few students to show to the whole class how certain phenomena work (Hackathorn et al., 2011). Crouch et al. (2004) contend that if students are actively engaged in a demonstration, it yields more positive results than making them watch the teacher doing the demonstration. Hackathorn et al. (2011) concede that demonstration is a good method that makes learners have first hand information on how certain phenomena work. It also arouses the interest or motivation of learners as they gain experience in working with certain concepts in genetics. Adekoya & Olatoye (2011) add that demonstration should cater for active participation of learners, sensory involvement and help learners to see, hear and experience the phenomena.

In teaching of genetics, demonstration method can be used in teaching challenging concepts by demonstrating how they work through use of charts or simulations (Hackathorn et al. 2011). For example, if learners have problems in understanding the separation of gametes in drawing of crosses, as a biology teacher, I can use demonstration to show how gametes separate using beans as teaching aids. In a demonstration activtiy like this one, one may give learners say twenty beans of two different colours and ask those learners to pair them by taking them from the bag without looking at them. Later, students can observe the pairs and categorise them as either homozygous or heterozygous. Basing on the colour outcome, concepts like phenotypes and genotypes can be defined using the outcome. Such type of demonstration can be useful in enhancing understanding of concepts like homozygous, heterozygous, phenotypes, segregation of gametes and the laws of independet assortment. Such involvement of learners will motivate students to learn, encourage group cooperation, increase retention of the knowledge and make learners discover concepts on their own.

This method guided this study by observing how learners were involved in demonstrations to develop understanding and higher order thinking skills on how certain phenomena works.

2.3.2 Group Work

In group work, the teacher engages students by giving them activities to discuss in their groups and report to the whole class (Adekoya & Olatoye, 2011). This method of teaching by focusing on social interaction has proved to yield meaningful learning (Liang& Gabel, 2012). The strategy depends on the social interaction between learner to learner through the teacher as the facilitator of learning. Lord (2001) agrees that dividing learners into small groups where they socially interact assists in comprehension of concepts for longer period of time. In these small groups, learners are free to ask questions and speak freely as they feel to be part of the group. Their active involvement makes them feel their in-puts are valued and respected.

In teaching of difficult genetic concepts, group work can help the learners to attain higher reasoning skills, motivation, develop positive attitude, increases self-esteem, collaborative skills and increased conceptual understanding which can lead to reduction of misconceptions (Liang & Gabel, 2012; Erdogan & Campbell, 2008). Attainment of higher reasoning skills and deeper understanding of concepts will equip the learners with skills for dealing with some difficult genetic concepts like application of mathematical skills in solving percentages and ratios in monohybrid crosses. The method also has the advantage of providing room for learners to explore issues of interest, ideas and opinions on their own (Hackthorn at al., 2011). In the end, learners are motivated and feel that their ideas and voices are valued in the learning of genetics.

Using group work in the Malawian setting would be important to the learners as it would increase their motivation towards learning of genetics, attainment of higher reasoning skills and collaborative skills which can be useful in solving genetic problems at community level. This is possible because the biology MSCE syllabus is based on constructivist approaches in its goals, content, strategies and assessment (MoEST, 2001). For example, if students have difficulties in understanding how certain traits such as haemophilia are passed from generation to generation, as a biology teacher, I can form smaller groups and give them a tree diagram illustrating the inheritance of haemophilia and ask them to discuss how it was passed from generation to generation. Such small group discussions for solving a challenging task, according to Lord (2001), make learners to develop deeper understanding of the concepts besides reducing misconceptions as learners test the fitness of their knowledge. It also helps learners to socially construct their own understanding which makes them feel valued and engaged in the teaching and learning process.

Such an approach and use of strategy guided this study in the understanding of how observed teachers used group work in solving difficult genetic concepts to help learners attain higher levels of thinking, elimination of misconceptions and construction of knowledge through social milieu.

2.3.3 Question and Answer

The question and answer method is a two way process. It involves the teacher asking questions to the learners for the purpose of checking their understanding on the concepts taught and the learners asking question to fill the knowledge gap (Chin & Osborne, 2008). Questions stimulate students' thinking and also help in arousing pupils' interest and curiosity. Good questions help learners develop the ability to speak very fluently. Cimer (2007) asks for teachers to ask open ended questions compared to closed questions because it caters for independent thinking and makes the learners to be actively involved in the lesson. Dickson (2005) adds that open ended questions encourage meaningful discussion and lead to real problem solving approach. Open ended questions give room for learners to explore various possible answers to a question in solving problems than encouraging them to memorise a single answer to a problem. Mudau (2013) urges teachers to refrain from using *test questions* that make the teacher to be dismissive of alternative answers to the question instilling in learners that there is only one answer to the question put.

In the teaching of genetics, question and answer method can be used to teach challenging concepts by stimulating learners' interest and curiosity through the asking of questions which directly relate to their life. This will help in addressing learners misconceptions which will lead to new knowledge if properly used. For example, the following question may be posed: *if a father belongs to blood group A and a mother belongs to blood AB. The offspring is blood group O. Using crosses; verify if the man is the real father of the offspring.* Learners will be expected to draw various crosses involving the expected genotype of A and AB. This type of question would capture learners' interest because it would additionally help them in trying to sort out issues of pregnancies which are prevalent among the youth. In solving the problem, they will develop interest in seeing how they can resolve such problems, eliminate misconceptions on drawing of crosses and develop their own thinking in drawing crosses to verify such cases happening in the community.

The question and answer model guided this study in assessing how the observed teachers used the question and answer technique in developing interest in learners and how learners applied the concepts in solving personal or community problems. It also guided on observing how teachers probed deeper after students' responses to enhance explanation of concepts, structuring of questions to provoke higher order thinking skills and how they summarize complicated or unclear answers to questions posed.

2.4 Theoretical Framework

This study was guided by pedagogical content knowledge (PCK) theory. The pioneer of PCK, Shulman (1986), defined it "as teachers' interpretation and transformation of subject matter knowledge in the context of facilitating student learning" (p.9). In Shulman's understanding, PCK includes the recognition of what makes specific topics difficult to learn, the potential student learning difficulties and student prior knowledge of specific concepts as well as the most effective strategies for facilitating student learning. For this study, the PCK model by Magnusson, Crajcik & Borko (1999), which has its foundation to earlier PCK models by Shulman (1986) and Grossman (1990) was chosen. It was chosen because it is useful in studying topic specific teaching difficulties and it is widely used in science research on teaching specific topics in education like genetics (Wongsopawiro, 2012; Mudau 2013). The Magnusson et al.(1999) PCK model has five components: knowledge and beliefs about orientations to science teaching, student understanding of specific science topics, representation, instructional strategies and assessment and curriculum.

Magnusson et al. (1999; p. 97) defines orientation to teaching science (OTS) "as teachers' knowledge and beliefs about purposes and goals for teaching the topic at a particular grade level." In this study, the orientation towards genetics teaching are general teachers' views towards teaching of genetics at MSCE level developed through background experience, teacher preparation programs and teaching experience (Lankford, 2010). It includes nine orientations: activity-driven, didactic, discovery, conceptual change, academic rigor, process, project-based, inquiry, and guided inquiry (Magnusson et al., 1999). OTS guides teachers' thinking in making instructional decisions and practice. In the study, it helped the researcher in assessing how the teachers made instructional decisions on selecting strategies and purposes for using it in teaching difficult genetic concepts.

The second component is knowledge of areas of student difficulties and requirements for learning. Magnusson et.al. (1999) state that teachers' knowledge of student difficulty encampasses teachers' understanding of the likely difficulties, preconceptions and misconceptions in learning specific content. Learning requirements are skills and prior knowledge necessary for learning genetics. This component contributed in the analysis of data by understanding how teachers prepare for difficulties likely to be faced by learners, identify learners' misconceptions and use of prior knowledge in teaching a challenging concepts.

The third component is teachers' knowledge of instructional strategies. Freidrich et.al. (2005) define instructional strategy "as approaches and activities teachers choose to support student learning; where activities are instructional events the teacher uses in the class to teach specific lessons"(p.25) The choice of instructional strategy depends on the teachers' experience on teaching the concept to determine its effetiveness on learners understanding (Magnusson et.al., 1999). This includes teachers' belief about the function of the strategy and its impact on learners' acquisition of concepts. This component was used in analysing how the four teachers used instructional strategies to teach difficult concepts that make it comprehensible to learners. In selection of participants for the study, the concept of experience was used as one of the judgemental factors in identifying participants for the study.

Knowledge of the content area to be assessed, ways and tools used is the fourth component of the model. In this study, it included attempts by the teacher to assess learners' progress to determine the effectiveness of the strategy. During data analysis, this component contributed in analysing how teachers evaluated the effectiveness of the strategies on teaching a challenging concept for learners' understanding.

The last component is the teachers' subject matter knowledge (SMK). SMK informs the selection of appropriate goals, teaching and learning materials, identification of difficult concepts, strategies for teaching difficult concepts and the scope of the content to be covered (Magnusson et al.,1999; Friedrichsen et al., 2007). The component was useful in analysing the PCK of the teacher in his or her selection of content area, teaching and learning materials, and strategy. It was also used in selecting participants for the study.

2.5 Research Paradigm

A paradigm consists of the basic set of beliefs or assumptions that guide the approach to an investigation (Guba & Lincoln 1994; Frankel & Norman 2000). My study was situated in an interpretive (constructivist) paradigm. Interpretive paradigm is based on the belief that multiple realities exist due to attachment of different meaning by individuals to one phenomenon under study or observation (Henning, 2004).

In this study, an assumption was made that biology teachers attach multiple understandings to strategies for teaching difficult genetic concepts based on their understanding of the teaching strategy or difficult genetic concepts. To understand those varied meanings to teaching difficult genetic concepts, I visited the teaching environment and interacted with the biology teachers.This was done to obtain data through observation and description of the subjects' belief, values, intentions and self understanding attached to the teaching of genetics.

Data was collected through naturalistic methods like observation and interviews. Methodology is the overall approach to research linked to the paradigm or theoretical framework (Punch, 2009). Methodology influence the whole research by revealing what constitutes the nature of reality under study, the knowledge of reality and eventually guiding the researcher on the methodology of synthesizing knowledge of that reality (Henning, 2004). In order to construct meaningful reality about the strategies for teaching challenging genetic concepts, obseravtion of the strategies for teaching difficult genetic concepts was done in their natural environment. This also helped the researcher to hear from the teachers about the genetic concepts that are difficult to teach and why they use certain strategies in teaching the difficult genetic concepts.

The Interpretive paradigm was chosen because it made it possible to have direct contact with the participants in their natural settings and hear from them about the strategies for teaching challenging genetic concepts. Cohen, Mario and Mourisson (2007) say that "the central endeavour in the interpretive paradigm is to understand the subjective world of human experience"(p.225). This study aimed at making an effort to get inside the biology teachers and understand from within the person and place of practice on strategies used for teaching challenging genetic concepts.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

The aim of the study was to investigate strategies that Malawian biology teachers use to teach difficult genetics concepts. In this chapter, I describe the methodology used, instruments for data collection, research geographical area, population sample, data analysis technique, trustworthiness of the study and ethical consideration.

3.1 Research design

The research used a case study approach in understanding the strategies for teaching difficult genetic concepts. Yin (2003) defines a case study as a program, an event or activity bounded in time and place. It employs multiple sources of data collection in the real environment of the study like interviews, document analysis and observation. Tayie (2005) asserts that a case study is useful in understanding a single phenomenon like strategies for teaching difficult genetic concepts. This was a case study of four teachers expressing their views on difficult genetic concepts, strategies for teaching difficult genetic concepts and rationale for using the described strategy in teaching difficult genetic concepts.

Case study was adopted because it provided rich information on strategies for teaching difficult genetic concepts through numerous sources of data collection. In addition, I heard and evaluated a variety of case teachers' perspectives in their natural setting. This helped me to gain deeper understanding on the difficulties biology teachers face in teaching difficult genetic concepts. Yin (2003) and Tayie (2005) assert that such approach makes the researcher gain a complete picture of the problem under study.

3.2 Research Geographical Area

This research was conducted in Mzimba district in the northern region of Malawi. The study was conducted in four secondary schools south of the district. I chose Mzimba South because of its proximity to the researcher and had secondary schools with qualified and experienced teachers.

3.3 Sample

This study used a sample of four teachers from government secondary schools in Mzimba South District as shown in Table 3.1. Government secondary school teachers were chosen because it was easy to access them and they possessed the required qualifications.

Table 3.1: Teachers' profile

Pseudonym	Qualification	Experience	Case Name
Mary	Degree in Ed.	3	Case A
John	Diploma in Ed	7	Case B
Angelina	Diploma in Ed.	10	Case C
Samuel	Degree in Ed.	8	Case D

To select the four teachers who participated in this study, I used convenience and purposive sampling. Cohen et al. (2007) states that convenience sampling involves choosing the nearest participants that are willing to provide the information. The schools chosen were easy to reach because of their proximity to the researcher's base and had teachers who were more than willing to take part in the study.

Purposive sampling, according to Cohen et al. (2007), involves selecting participants based on the researcher's judgement about certain characteristics being sought to meet the objectives of the study. In this study, purposive sampling was used in selecting teachers with experience and the required qualification within school settings. I chose those biology teachers who had more than three years of teaching experience and in possession of a diploma or degree in education at the time of data collection. The choice of both qualified and experienced teacher was because of the knowledge and experience of teaching accumulated within the teaching practice in classroom situations. Loughran, Mulhall & Berry (2008) assert that "so much of the knowledge of teaching is implicit in experienced teacher's teaching" (p.1302). The three years of teaching for the case teachers was deemed enough for one to develop experience and PCK for teaching a challenging topic like genetics.

The choice of diploma or degree in education or basic degree with a certificate in education was based on the assumption that the courses equipped the sampled teachers with the necessary subject matter knowledge (SMK) for teaching genetics at secondary school level. Also, the entry qualification for a government secondary school teacher in Malawi is diploma or degree in education (Government Teaching Service Commission, 2001).

3.4 Data Collection Methods and Instruments

3.4.1 Interviews

Structured interviews were used for collection of data on difficult concepts, reasons for using a described strategy and strategies for teaching a difficult concept. Structured interview involves the researcher asking a set of pre-arranged questions using the same wording and order as illustrated in the interview schedule (Kumar 1999). In this study, each case teacher was interviewed using an interview schedule (see Appendix 1) as an instrument for data collection. It contained open-ended questions which made the participants to open up on the challenges they face in teaching genetics

The interview process was divided into two: first, teachers were interviewed before observing them teaching two of the genetic concepts identified. The initial interview focused on identifying difficult genetic concepts and the strategies used in teaching those concepts identified as challenging to teach. The second interview was done after the last lesson observation to seek clarification for using a certain stratergy for teaching a challenging genetic concept. The order was pre-interview - lesson observation - post interview.

The interviews were recorded verbatim using a blackberry phone. The phone was first piloted on two teachers to learn the basic operation of the machine. The phone had the advantage of recording the whole interview and provided complete data for analysis. Furthermore, it was possible to concentrate on asking and listening without disturbing the interviewee through writing short notes.

The interview technique was chosen because provided rich information about difficult concepts, reasons why the identified concepts were difficult, strategies for teaching the identified concepts and rationale for using a described strategy. Structured interviews enabled the interviewee to reveal their opinions, values, motivations, recollections and experience about strategies for teaching genetics and interpreted it according to their own point of view. This was possible by asking them open ended questions and follow up questions to probe more explanation on the concepts discussed. For example, one of the open-ended questions was as follows, “Apart from using question- and- answer for involving learners, what was the other reason for using it?” Tayie (2005) and Cohen et al.(2007) add that structured interview makes interviewee to provide for their actions in words while Creswell (2003) argues that it helps in obtaining specific data in a very short space of time

Ethical considerations were followed in conducting the interview and audio taping. Permission was granted by the head teachers and the participating teachers to be interviewed and audio-taped. Each participating teacher signed a consent form to accept his/her participation in the study. All four teachers consulted agreed to take part in the study. The participating teachers were also given a chance at the end of the interview to listen to the taped interview so that they could make any changes that they thought were not supposed to have been said.

3.4.2 Observation of Lessons

Lesson observation was another method used for collecting data. Observation method according to Kumar (1999) is “a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place” (p.105). In the study, lesson observation was done by video-recording of genetics lessons and taking of field notes to supplement the video recording. Two lessons per teacher were observed to triangulate the strategies used to teach challenging genetic concepts. The researcher was a complete or passive observer in that he did not take part in the activities of the group being observed (Kumar,1999). By adopting complete observation, I was able to observe the classroom events as they unfolded, including the unusual practices in the teaching and learning of biology (Creswell, 2003).

Video recording was chosen because it enabled me to view the recordings several times before making a final conclusion on the analysed data. In addition, it gave room for fairness on the conclusion made as you can invite other professionals to view the tape before making the conclusion (Kumar, 1999). Creswell (2003) adds that it helps in observing the information as presented and gives the researcher access to first-hand information in their natural settings.

However, the observation method has its own shortfalls. One shortfall is that participants may opt to change their behaviour if they realise that they are being observed (Creswell, 2003).

This can lead to the data collected not to represent the true picture of the phenomena under study. The purpose of the research may also not be met if the researcher lacks observation skills. To improve on skills of observation, I piloted the video recording machine by practicing to focus on necessary information in the lesson.

Ethical procedures were followed in collecting video data by getting consent to conduct the study in the four schools from the Educational Divisional Manager (EDM) and the coordinator for Masters of Education in Teacher Education program. Permission was also sought from the head teachers and participating teachers to allow the lessons to be video recorded. Each participating teacher signed a consent form to be videotaped in two lessons that the teacher identified as challenging to teach. Learners were informed about the intent of the video recording by their biology teacher and were assured of their safety in the pictures taken at all stages of the research process.

3.5 Issues of Trustworthiness and Credibility

Credibility and trustworthiness of this study was attained through a pilot study, triangulation and confirmability.

3.5.1 Pilot Study

A pilot study was conducted to establish the effectiveness of the instruments in collection of data for the research. The pilot study was done in one of the secondary schools in Mzimba south district. The video tape recorder and blackberry phone were piloted to gain experience in operating them. Another reason for piloting the machines and the interview schedule guide was to check its effectiveness in achieving the objectives of the research. The pilot study revealed that the questions on post-observation interview were not directing the respondents to give reasons for using a strategy in their observed lesson. Modifications were made by recasting the questions to identify the strategies observed in the lesson for the interviewee to give reasons for using them.

3.5.2 Triangulation

Golafshani (2003) defines triangulation as evaluating the findings of the study from two or more sources of data. This study employed more than one source of data collection to attain the credibility of the study. Data from interview was triangulated with data from the classroom observation to check the credibility of the information provided by the teachers on the strategies used in teaching challenging genetic concepts.

3.5.3 Confirmability

Confirmability in qualitative research ensures that the data collected is not affected by the researchers' biasness and preferences but a true reflection of the experiences and ideas of the informants (Shenton, 2004). It involves the researcher justifying the selection of one approach to the other and explaining all cases of biasness. In this study, all cases of negative impact on the research outcome were explained. For instance, justification for choosing one approach over the other and weakness of the approach were thoroughly explained.

This research paper was constantly given to biology experts at Mzuzu University and Department for Teacher Education (DTED) in the Ministry of Education Science and Technology (MoEST) to check the content on genetics and the research process. This enabled the researcher to produce a research paper that is credible and trustworthy by improving the study with the input provided.

The debriefing sessions opened room for me to consider other people's experience and perceptions into the study which helped to gather credible data. To enhance trustworthiness of this study, peers and academics scrutinised the proposal for this report and made their own critiques. The critiques were capitalised as a tool for scrutiny of the work towards originality because my proximity to the study could have easily inhibited critical analysis of the study.

Procedures for the research methodology and analysis were all thoroughly explained and discussions on the findings of the study were supported with evidence. The researcher separated his own interpretation of the data from that of the four teachers. This was done by using direct quotes from the relevant section of the data so as to emphasize a point that was considered necessary.

3.6 Data Analysis

3.6.1 Interview Data

The data from interviews was transcribed verbatim following the order of the interview schedule. The transcription was done by replaying the audio interview several times in order to transcribe the right information and maintain accuracy of the information transcribed. Key points were identified from the transcribed data through repeated reading. The key points were coded by assigning an abbreviation to each and encircled using a red ballpoint pen. The abbreviations, meanings and their examples are shown in the Table 3.2 below;

Table 3.2 Abbreviations for coding interview data

Abbreviation	Meaning	Examples
DC	difficult concept	Homologous, meiosis
St	Strategy	Group work
RT	Rationale	Involvement, assessment
HCD	How is the concept difficult	Abstractness, terminology

The codes from interview data were grouped and categories were formed. The categories were later developed into themes for the research study.

3.6.2 Video Data

Video recordings were also transcribed verbatim by playing the video repeatedly in order to transcribe with accuracy. Key strategies were coded from the transcript by assigning an abbreviation to the strategy and encircling it using red ballpoint pen. The video recording was done to triangulate the results from the pre-interview on the strategies for teaching difficult genetic concepts. Excerpts from the transcribed data were presented in the research report. Table 3.3 shows the abbreviations that were used in coding video data.

Table 3.3 Abbreviations for coding video recording data

Abbreviations	Meaning	Category
GP	Group work	Strategy for teaching a difficult
Q&A	Question and answer	
PBS	Problem Solving	
LC	Lecture	
EX	Experiment	

The analysed data from both interview and video recording was presented as a case each following the order of the research objectives. The codes from both sources of data were grouped and categories were formed. The categories were later developed into themes for the research study. Three themes from the objectives of the study were pre –determined as follows: difficult genetic concepts, strategies for teaching difficult genetic concepts and reasons for using the described strategies in teaching difficult genetic concepts. This was done to save time on categorising of the data. In reporting the findings, all teachers' real names were replaced by pseudonyms for ethical purposes.

3.7 Ethical Considerations

All information provided by the four teachers in this study was treated with complete secrecy and restricted to the purpose of this study alone. Participants were also assured that they were free to stop participating in this study anytime they felt necessary. The right to privacy of the four teachers and their schools was upheld as all subjects of the study were kept anonymous throughout the study. Pseudonyms were used instead of real names for teachers and schools in the report. Lastly, consent and permission to conduct the study in the selected secondary schools was granted by Northern Education Division. Participating teachers were assured of their confidentiality by signing a consent form (see Appendix 5)

CHAPTER 4: RESULTS AND DISCUSSION

4.0 Introduction

This section presents the results and discussion of the findings. The results are presented and discussed on a case-by-case basis because it was assumed that each teacher understands the strategies for teaching difficult genetic concepts differently. The presentation is guided by the research objectives which were:

1. To identify concepts in genetics that pose teaching challenges to Malawian biology teachers
2. To describe strategies that Malawian biology teachers use in addressing teaching challenges in genetics
3. To explain why Malawian biology teachers choose the described strategy.

4.1 Case A

4.1.0 Introduction

Mary was interviewed before lesson observation to identify the concepts she finds challenging to teach in MSCE genetics and strategies that she uses for teaching the challenging concepts. Later, I observed Mary teaching two of the genetic concepts identified as difficult. The first lesson observed was on co-dominance and the second lesson was on incomplete dominance. After the two lesson observations, I met Mary for a post- interview observation to seek clarification on why she used the strategies observed in her lessons.

4.1.1 Difficult Genetic Concepts

In the pre-observation interview, Mary was asked about challenging concepts that pose teaching difficulties in genetics. The excerpt below shows how Mary responded to the question:

> **Researcher:** Are there any concepts in MSCE genetics that you find challenging to teach?
>
> **Mary:** Very much. Terms like homozygous, heterozygous, genotype, phenotype, gene, allele, dominance, co- dominance and incomplete dominance bring confusion in learners and teachers. It is very hard for learners to understand them from the first day

of the lesson as indicated from the syllabus. It is challenging for me as a teacher and students to clearly demarcate the meaning and apply them in real life situations because they sound and look alike. Even their meanings are confusing because they relate much to each other. Apart from the terminology part, it is also challenging to explain co-dominance and in-complete dominance where you have inheritance of anaemia, sickle cell anaemia which gives hard times for teachers to explain, therefore hard for learners to comprehend.

From the interview, Mary seems to face challenges in teaching concepts like homozygous, heterozygous, genotype, phenotype, gene, allele, co-dominance and incomplete dominance. The problem lay in explaining the terms apparently because learners were confusing the terms as they sounded and looked alike. These findings correlate with what Thornes (2012) and Knippels et al. (2005) reported that some genetics terms like meiosis, mitosis, homologous, homozygote, and homologue bring confusion because they sound and look similar in their use. The teacher also found it hard to thoroughly explain co-dominance and incomplete dominance because of the nature of the two concepts making it hard for the learners to understand and apply them in real life situations.

4.1.2 Strategies for Teaching Challenging Concepts in Genetics

After Mary identified the concepts that posed challenges for teaching genetics, I asked her about the strategies she uses to addresses those challenges. Below is an excerpt on the strategies Mary would use in teaching challenging concepts:

Researcher: Tell me about the strategies that you use to teach challenging concepts in MSCE genetics?

Mary: I try to relate what happens in everyday life to the concepts of genetics. Apart from that I make use of problem solving approach by giving learners much work on the concepts learnt to make them have an idea of what happens in real life situations.

From the excerpt above, Mary's strategies attempted to make learners transfer knowledge from the classroom to the outside world for solving problems. One method she said would use was problem solving. Mary's goal for teaching genetics was to assist learners to relate what is taught in class to the outside world. She emphasised that her lessons were student-centred and used problem solving approach in teaching genetic challenging concepts.

After the pre-observation interview, I asked Mary to observe her teaching two of the challenging concepts identified. Mary accepted to the request. The first lesson was on co-dominance and the second on in-complete dominance. Below is an excerpt on her first lesson on co-dominance:

Teacher: What did we learn in our last lesson?

Student M: Test cross

Teacher: What did I say is a test cross?

Student F: It is when the genotype of one organism is known while the genotype of the other organism is not known.

Teacher: I said when you have an organism with known genotype such as recessive organism, you cross it with an organism of unknown genotype. For example, you can do a *test cross* using horns in cattle. Presence of horns is represented as a dominant character in cattle. It can be represented in two forms: Hh and HH. The recessive character can be represented by hh. You can cross an organism of unknown genotype with a recessive genotype to identify its genotype using a test cross. After class, go to the library and read about test cross. Today, our lesson will be on co-dominance.

Teacher: What is co-dominance?

Student J: It is a condition when both genes have an effect on the phenotype of an organism.

Teacher: Yes. It is when both genes have an effect on the phenotype of an individual. What can be examples of co-dominance in plants?

Student M: Variegated leaf.

Teacher: Yes, in variegated leaf we have whitish and greenish patches. It meant both genes had equal effects on the phenotype of the leaf.

Teacher: In our lesson today, we are going to look at co-dominance by working with inheritance of blood groups in human beings as an example. Blood group is determined by presence of antigens on the surface of the red blood cells. A person with **A** antigen on the red blood cells belong to blood group **A**, while **B** antigens belong to blood group B. Absence of both antigens A and

B belongs to blood group **O**. We inherited blood groups from parents based on the gene combinations of **A, B** or **O**.

Teacher: Genotypes for blood groups can be written as follows:

Blood group A can be presented as **AA or AO or I^AI^A or I^Ai.**

Blood group B can be presented as **BB or BO or I^BI^B or I^Bi**

Blood group O can be written as **OO or ii**

Blood group AB can be written as **AB or I^AI^B**

Teacher: A woman with blood group A is married to a man with blood group AB. A child born from them is blood group O. Find out if the man is a legitimate father of the child?

Teacher: The person with blood group **A** can have the following genotypes; **AA** or **AO** while **AB** can have **AB** and a child with **O** blood group can have **OO**. Use these genotypes to solve the problem given by using the cross in Figure 4.1.

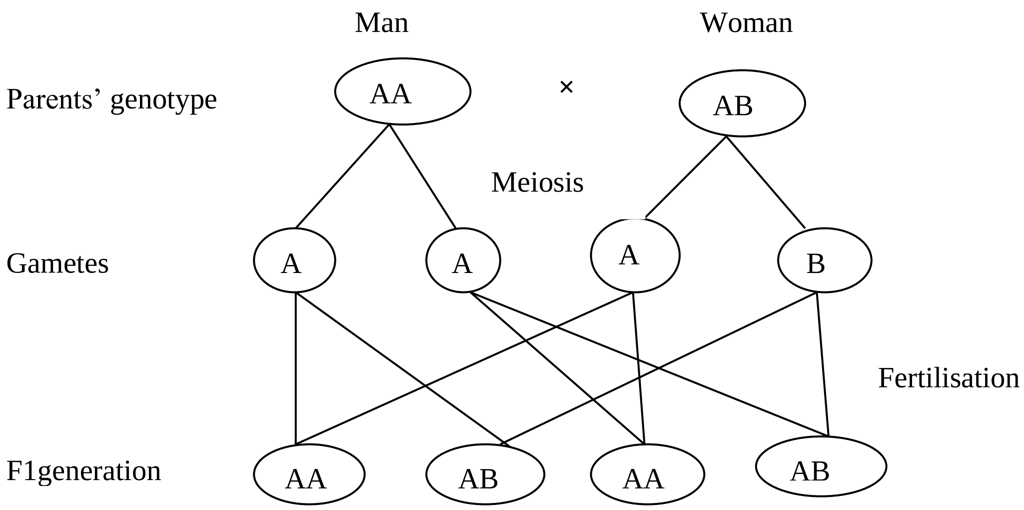

Figure 4.1: Mary's first example on drawing crosses for blood groups

Teacher: From the crossing, the woman's claim is not true that the man with **AB** blood group was the father of the child. Explain why the man is not the father of the child?

Learners: Because there is no child with blood group **O** born from the crossing.

Teacher: The other possibilities can be crossing the genotype of a man with blood group **B** married to the woman with blood group **AA** to have a child with blood group **O**. This time, let's cross genotypes of a father with blood group **B** as shown in Figure 4.2

Teacher: What is the genotypic combination of the father with blood group **B**?

Learners: BO or **BB**

Teacher: Drawing a cross for **AA** × **BB** as shown in Figure 4.2

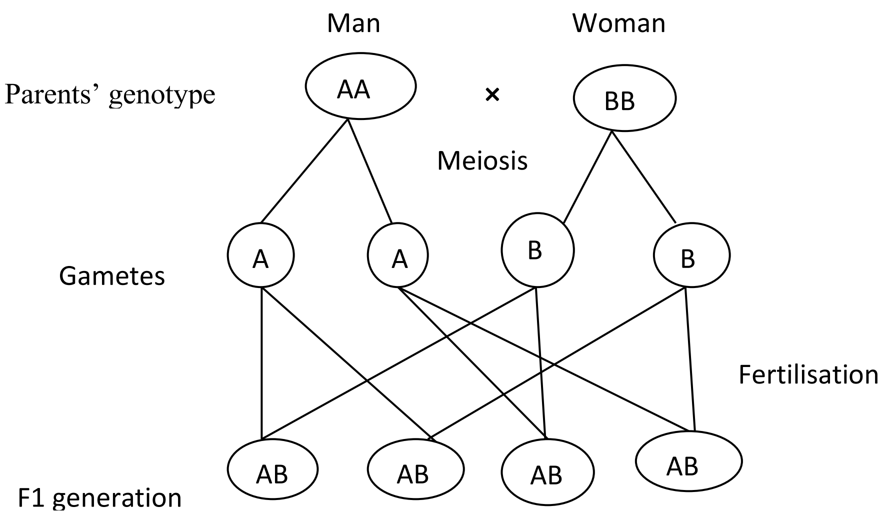

Figure 4.2: Mary's second example on drawing crosses for blood Groups

Teacher: What is the outcome of the off-springs?

Student K: it is not possible for the child to be born with blood group **O**.

Teacher: Let's try drawing the cross of **AA** × **BO** as shown in Figure 4.3

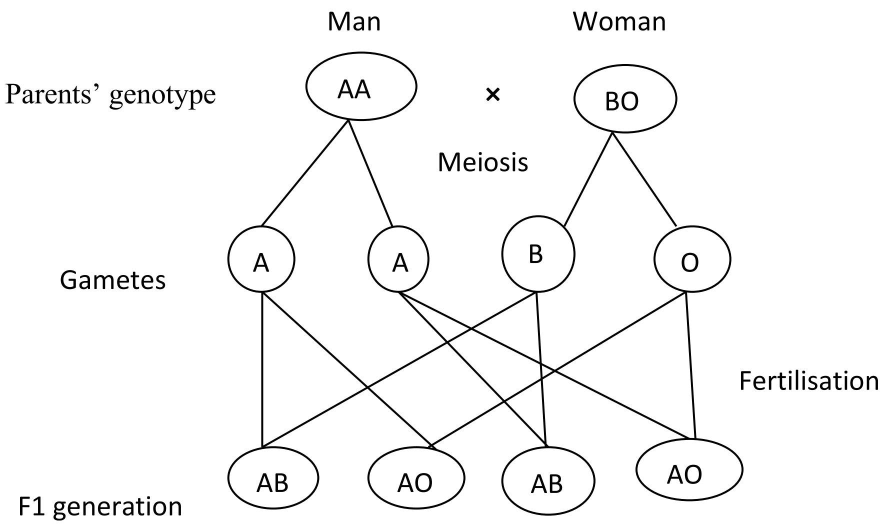

Figure 4.3: Mary's third example on drawing crosses for blood groups

Teacher: Can the combination produce a child with blood group **O**?

Student Y: The man with heterozygote genotype **BO** was supposed to be the father of the child.

The lesson ended by giving the students homework assignment as a form of problem solving approach.

Teacher: What are the possible blood groups likely to be inherited from parents of blood group **A** and **B** father? Explain your reasons.

From the excerpt above, the lesson observation shows that Mary used question and answer, demonstration, teacher explanation and problem solving approach to teach the concept of co-dominance. Demonstration method dominated the lesson. In demonstration, the teacher used three similar examples to show to learners how crosses involving blood groups are drawn. The demonstrations did not give some students a chance to draw the crosses to show to the whole class. She did most of the work in the classroom with students periodically involved. The implementation of the methods was not in line with how demonstration method should be implemented. Hackathorn et al. (2011) advices that demonstration should involve few students showing to the whole class how a phenomenon works. From the excerpts of the lesson above, Mary is doing most of the talking and demonstration on how to draw crosses. Cimer (2012) in his study on what makes biology difficult and effective reported similar findings that most biology teachers just talk and transfer theoretical knowledge that lacks proper application to daily lives of learners. The implementation of the strategy was incongruity with the goals she had of helping learners transfer the knowledge to other context. Cimer (2012) argues that traditional methods of teaching science where the teacher talks and transfers knowledge does not help learners to transfer knowledge to new context. Therefore, the method used by Mary did not assist the learners in transferring the knowledge to other context because she dominated in the lesson. Modell, Michael & Wendereth (2005) request teachers to create conducive learning environments where learners will be able to test and reshape their mental models without necessarily providing them with theoretical knowledge. In effective implementation of demonstration, the teacher was supposed to give students opportunities to work with the problems given by solving them on their own with the teacher as a facilitator.

Question and answer method accompanied the demonstration method in teaching the concepts of co-dominance and in-complete dominance. Mary used question and answer to assess if students were following what she was teaching. Students were also asking questions to seek further explanations from the teacher. Most of the questions asked by Mary were test questions that demanded obvious answers to her questions. Mudau (2013) asserts that test questions make the teacher to be dismissive of alternative answers to the question, instilling in learners that there is only one answer to the question put. Test questions encourage memorisation of concepts which does not activate cognitive and skills development in learners. Dickson (2005) advises that teachers should be encouraged to use open ended questions that encourage meaningful discussion and lead to real problem solving approach.

Mary also used problem solving approach in her lessons. Problem solving is a teaching technique where learners are left on their own solving a problem with minimum guidance from the teacher (Warnich & Meyer, 2013). The problem solving approach observed in Mary's lessons was full of practicing, making the learners to learn by experience which encouraged memorisation of concepts. Freitas, Jiménez, & Mellado (2004) call such type of problem solving as traditional problem solving approach. It does not encourage learners to apply the concepts because learners are denied the opportunity to discuss the concepts on their own. Eventually, it discourages cognitive development of learners. In her lessons, learners were denied the opportnuity to solve the given problem on their own in their groups. They were taught to emulate the problem solving approach which gives an impression that the teacher might have faced the problem many times in her profession and had answers to it.

The lesson presented shows that Mary did not include many activities for the learners in teaching the concepts of co-dominance and incomplete dominance to illustrate the concept in understandable forms to the learners. Mary failed to extract from the experience of teaching genetics to transform the content knowledge into understandable forms to the learners. In general, Mary had good command of content knowledge as observed from the two lessons, but the difficulties lay in transforming the content into forms that could make sense to the learners independently with the teacher as a facilitator.

4.1.3 Reasons for Using a Described Strategy

After observing the two lessons, a post-observation interview was arranged for Mary to explain why she used the observed strategies (question and answer, demonstration, teacher explanations and problem solving) in teaching the identified challenging genetic concepts. The excerpt below shows Mary's reasons for using one strategy over the other:

Researcher: From the lessons observed, you have used question and answer, demonstration and problem solving approach in teaching challenging concepts in MSCE genetics. Do you have any reasons for choosing the strategies?

Mary: Having realised that my students have problems right from the beginning of the topic, I thought it wise that they needed to be involved in the teaching and learning process than the teacher doing the work. This would make them understand the concepts more than the teacher doing the work for them. By involving them, it would make them easily remember and follow what is happening in the topic. Apart from that, the strategies also helped in identification of prior knowledge and assessment of the lessons to check learners' understanding.

Mary used question and answer, demonstration and problem solving approach to make learners attain independent learning through active involvement. Lord (2001) and Liang and Gabel (2012) assert that genetics teaching should encourage student participation through active teaching techniques (demonstration, question and answer and problem solving approach) which have positive learning outcomes in biology. From the exerpts presented from her first lesson, it show that she dominated the lessons and provided little room for learners to interact and share ideas on their own. Most of the times, learners were not given opportunities to solve the problems individually. Hence, failure by the teacher to involve all learners in the discussion made those who were shy and with special educational needs to be left out in the teaching process but could have benefited through social interactions within the class such as group work. Smith, Wood, Krauter, & Knight (2011) agree that peer interaction enhances conceptual understanding of concepts when sharing ideas through expression and discussion which effectively promotes understanding. The implementation of these strategies by Mary did not assist learners to be aware of their abilities and develop self confidence in learning genetics by reflecting on what they were doing and how their understanding was changing..

Mary used question and answer for formative assessment to check on the progress of the learners. She asked questions in all the three phases of the lesson: introduction, development and conclusion. In the introduction of the lesson, she asked questions to identify the entry levels of the learners. Questions were further asked in the development of the lesson to assess learners' understanding of the lesson. In the conclusion, she also asked questions to check the attainment of the objectives.

Similarly, question and answer was used in the identification of prior knowledge of the learners on the concept taught. This according to Magnusson et al. (1999) indicates that the teacher was aware of the potential learning difficulties, prior knowledge and conceptions learners bring to classroom situation in teaching co-dominance and incomplete dominance. The excerpt below shows how Mary elicited prior knowledge of the learners in her second lesson on incomplete dominance;

Teacher: What is in-complete dominance?

Student A: This is a condition where some genes do not express themselves completely on the effects of the individual.

Student U: A case where recessive genes is not completely masked by a dominant gene.

Teacher: In-complete dominance is a case that applies to homozygous recessive gene not being completely masked by the dominant gene in an individual. Examples of incomplete dominance are sickle cell anaemia and flower colour in Bassalm plants.

During the lesson, students too were so inquisitive about the concept of in-complete dominance. They asked so many questions on the two concepts of complete and in-complete dominance. The excerpt below shows some of the questions learners asked in the second lesson on sickle cell anaemia:

Student M: Is it true that a person suffering from anaemia has blood flowing in the same tube downwards and the other upwards in the arteries?

Teacher: The blood system is the same. Human beings have double circulatory system.

One reason for students' curiosity was that the examples used affected them directly from their real life situations. Chin & Osborne (2008) assert that students ask question to fill the knowledge gap existing in their mind. The questions raised by learners showed they were eager to know what happens with their life when someone suffers for example sickle cell anaemia.

The teacher discussed multiple instructional strategies in the interview with the goal of making learners attain independent learning which she believed would help them own the knowledge. Despite the teacher describing the knowledge and beliefs she had about the teaching of genetics, her lessons were teacher-centred. The excerpts show the teacher doing most of the work than learners. Mary dominated the lessons making it difficult for learners to attain independent learning as claimed in the pre-observation interview. According to Brown et al. (2013), teachers who use teacher centred approaches to teaching give less effort to difficulties learners meet in learning of science concepts. If Mary had used the problem solving approach effectively in teaching in-complete dominance and co-dominance, the purpose of helping learners to transfer knowledge to new situations could have been met. Students could have developed concrete knowledge and understanding on sickle cell anaemia and blood groups in co-dominance.

4.2 Case B

4.2.0 Introduction:

An interview with John was conducted before the lesson observation to identify the concepts he finds challenging to teach in MSCE genetics. Later, I observed John teaching two of the genetic concepts he identified as difficult. The first lesson was on calculation of percentages in variation and the second lesson on calculation of probabilities in crosses when teaching Mendelian genetics. After the observation of the lesson, I met John for post- interview observation to seek clarification on the use of the strategies observed in her lessons.

4.2.1 Difficult Genetic Concepts

John was asked during a pre-interview session about concepts in MSCE genetics that he finds challenging to teach. The excerpt below shows how John responded to the question;

Researcher: Are there any concepts in MSCE genetics that you find challenging to teach?

John: Very much. One is on calculations in variation using mathematical skills, but also on Mendelian genetics by calculating ratios in monohybrid crosses.

Researcher: In what ways are the concepts you have mentioned challenging to teach?

John: To begin with, calculations of ratios and percentages in variation demands application of mathematical skills. So learners with poor mathematical skills and negative attitude find the concept challenging to learn. For the teacher, it is all about the background and experience in teaching the concept. If the experience and background are poor and insufficient, you will have problems in teaching the concept.

In Mendelian Genetics, problems arise when trying to illustrate crosses to symbolise what happens inside the body. Crossing brings confusion to both learners and teachers to relate what really happens inside the human bodies. Students learn by memorisation because it is abstract to present to the learners' real life situations on how crossing takes place inside the human body.

From the excerpt above, the teacher said he had challenges in teaching calculations involving application of mathematical skills in solving percentages and ratios in variation and monohybrid crosses. The teacher also faced challenges in teaching crosses in Mendelian genetics. The problem lay in linking the concept of crossing with what happens in the human body. The drawing of crosses and use of symbols in calculating ratios and percentages made the concept of crossing abstract in learners' mind as it does not form any vivid connection with the real biological phenomena happening in the human bodies. This made it tough for learners to understand the concept evidently. Crosses were also reported to cause problems because learners were failling to utilise their mathematical skills in solving genetic ratios and percentages. This is the case mostly because a good number of learners have negative attitude towards mathematics or the syllabus does not emphasise the importance of mathematical knowledge in solving biological problems (Robeva et al., 2010).

In John's explanation on variation, he found it difficult to teach variation because it demanded application of both mathematical and biological skills. The difficulty is further driven if learners have negative attitude towards probabilities.

The findings are similar to those of Berlingeri & Burrowes (2011) which reveal that studies done on integration of biology and mathematics indicate that students fail to apply mathematical knowledge in solving ratios and probability in genetics. Learners and some teachers find it difficult to calculate probabilities in segregation of gametes into phenotypes and genotypes. Bahar et al. (1999) found similar results that solving ratios for phenotypes and genotypes in crosses does not show the real mechanism happening in the human body. The complexity comes because learners are supposed to think at three levels of thought: the macro, micro and symbolic levels. Consequently, learners are compelled to think forth and back to make connections between concepts (Bahar et al.1999).

4.2.2 Strategies for Teaching Challenging Concepts in Genetics

After John identified the concepts that posed challenges for teaching genetics, I asked him about the strategies he would use to addresses those challenges. Below is an excerpt from that interview:

Researcher: Tell me about the strategies that you use to teach challenging concepts in MSCE genetics?

John: I usually use participatory methods that engage learners mentally, physically and emotionally. For example; field trips by taking students to the field to appreciate variation…. Apart from field trips, experiments are also done but not fully utilised because genetics comes in November and the scheming and school calendar does not tally because at that time crops are not yet grown in the fields. I have to be honest; experiments in genetics are difficult to do.

From the excerpt above, John explained that he would use participatory methods in teaching concepts that were difficult to teach in genetics. Examples of such methods were field trips and experiments. John would use the participatory methods to allow greater participation of the learners to help them understand and know the basics of genetics to be applied in their real life situations. According to Magnusson et al. (1999) PCK model, his orientation was "activity driven." John's goal for teaching science was to help learners internalise the concepts and make use of the knowledge on their own through engagement in activities for verification or discovery.

After the pre-observation interview, I asked John if I could observe him teaching two of the challenging concepts identified. John agreed to the request. The first lesson was on calculation of percentages in variation and the second lesson on calculation of probabilities in crosses when teaching Mendelian genetics. Below is an excerpt on his second lesson on calculation of probabilities in crosses.

Teacher: The whole lesson will be based on principles of Mendelian Genetics. Mendelian genetics is based on an Australian monk called Gregor Mendel. He is regarded as the father of Genetics. In the lesson, I will give you an example of what Gregor Mendel did by crossing yellow peas with green peas as follows;

Teacher: Writing genotype **GG** × **YY** where allele **G** stands for green colour and **Y** for yellow colour. The outcome of off-springs was all green.

Teacher: Student K come and complete the crossing of GG × YY in diagram form.

Teacher: Student K has failed to draw an accurate diagram. Can someone come and help him finish drawing the diagram?

Teacher: He too has failed. Anyone to complete it?

Student L: Completing the diagram as shown in Figure 4.4.

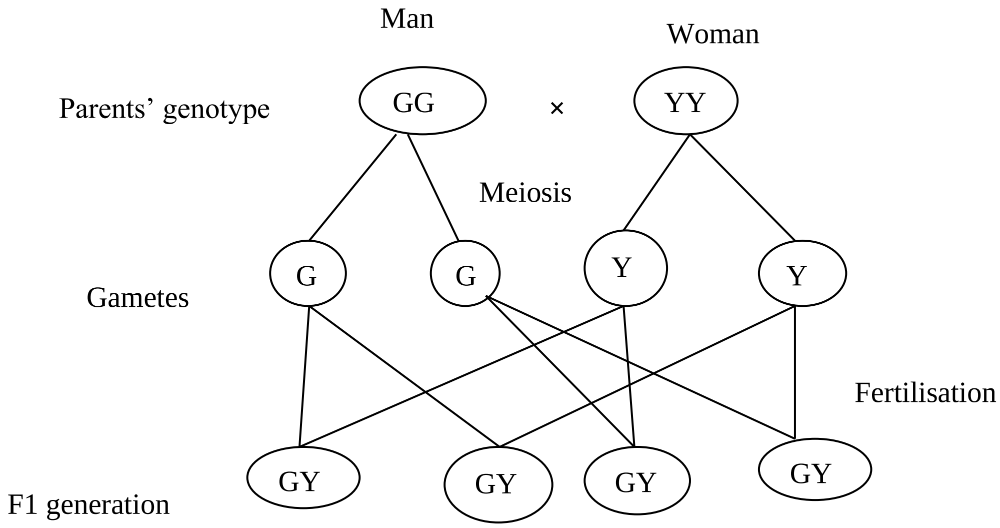

Figure 4.4 Student genetic cross for GG with YY

Teacher: What is the phenotype of F1 generation?

Student X: All the F1 generation were green.

Teacher: I will draw two diagrams of flowers to illustrate the transfer of pollen from anthers to stigma. Who can label the different parts of the flower that you see?

Students: Stigma, pollen grain, anthers, stamen, filament

Teacher: My focus is on anthers and stigma which are male and female sex organs in plants respectively. Mendel transferred pollen from anthers to stigma to come up with the first generation of off-springs from the parents.

Teacher: Can you self the first filial generation (F1) generation to illustrate how Mendel observed the appearance of a recessive gene in the second filial generation (F2)?

Learners: Selfing the F1 generation as seen in Figure 4.5 below;

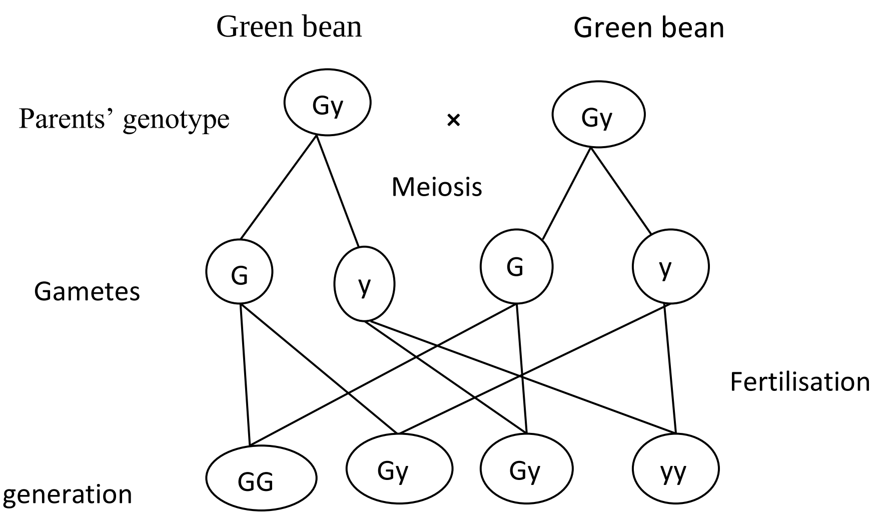

Figure 4.5: Student genetic cross for selfing F1 generation for GG with YY

Learners: The outcome of the crossing is:

a. **GG** for Green phenotype

b. **Gy** for Green phenotype and

c. **yy** for yellow phenotype.

Teacher: The outcome shows the yellow phenotype is appearing in the second generation. Explain why the yellow colour re-appears in the second generation?

Student Z: It was hidden by the dominant gene.

Teacher: Using the Figure 4.5, Calculate the number of green and yellow plants from the **pool** of 400 offspring?

Learners: Calculating the phenotypes as follows;

Yellow: The ratio is 1:3 for yellow to green.

¼ × 400 = 100 yellow plants.

Green plants: The ratio is 3:1 for green to yellow.

¾ × 400 = 300 green plants.

Teacher: Be in your usual groups. I will select three pair of girls and boys. I have selected three pairs with the phenotypes that either a boy is tall or a girl is tall. Can you draw crosses on the board based on the phenotypes of the pairs given that allele ***F*** stands for tall female and ***m*** stands for short male. ***F*** is dominant over ***m***

Learners: drawing the crosses as shown in Figure 4.6

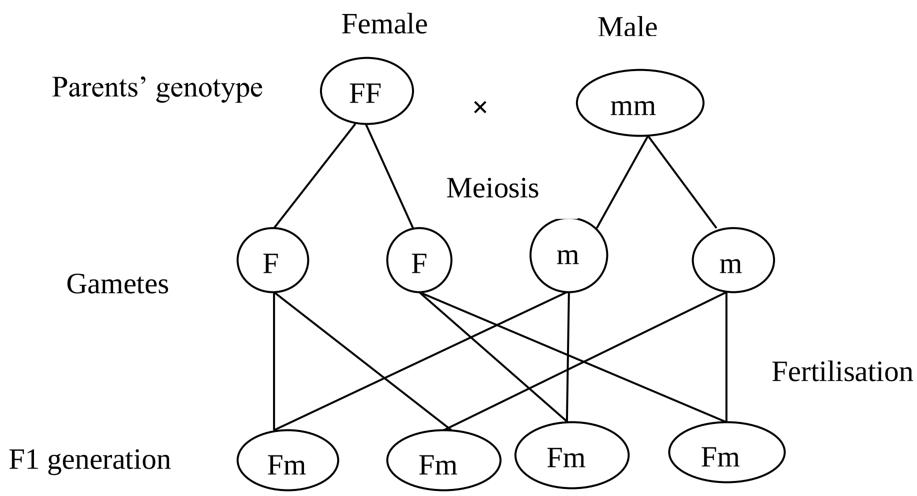

Figure 4.6: Student example on crossing phenotype height for FF with mm

Student B: All F1 generation are tall.

Students in groups: Crossing the F1 generation as shown in Figure 4.7

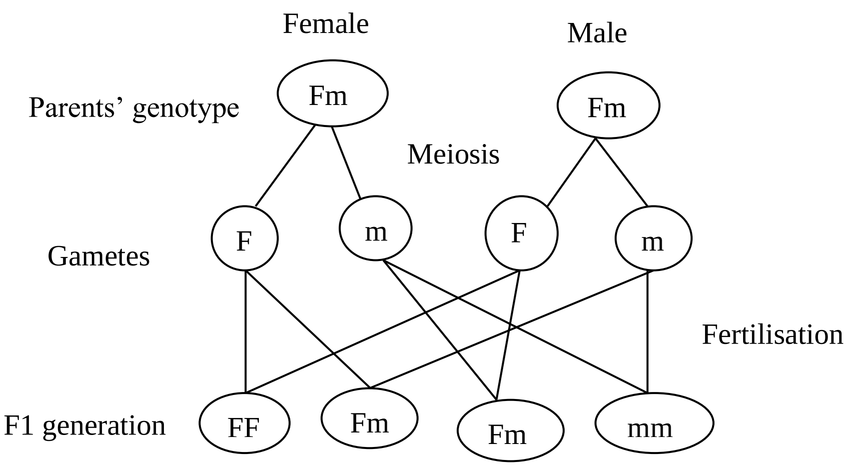

Figure 4.7: Selfing of F1 from *FF* crossing with *mm*

Learners discuss the outcome of the phenotypes from the crosses,

Group A representative: *mm* phenotype for shortness is appearing in the second generation.

Teacher: Do you have any questions on the lesson? Also, read in-advance on test cross and co-dominance.

Student D: What is the difference between *dominant* and *recessive* gene?

Teacher: Puts the question back to learners to explain on their own understanding.

Student J: Dominant is active while recessive is not.

Student L: Dominant is written in capital letters while recessive in small letters

Teacher: It seems the class has failed. This is a clear indication that you were not following what I was teaching. The dominant gene expresses itself more than the recessive gene in the phenotypes. Thank you for a good question.

The lesson observed was taught using three strategies: demonstration, group work and question and answer. Demonstration was used more frequently in illustrating drawing of crosses by both the teacher and the students. John drew crosses on the board and asked learners to observe how the crossings of gametes are done in Mendelian genetics. The use of demonstration method was well planned to achieve the objectives of the lesson. Learners were able to show to the whole class how crosses are drawn. Some demonstrated how percentages were solved from the outcome of the crosses. Although the teacher tried to involve students in his lessons, he partly dominated the lessons instead of guiding the learners where they failed to do on their own. Andrews et al. (2011) argue that teacher domination of a lesson has proved to be ineffective in the teaching of biology. Teacher-centred methods encourage learners to memorise the content without internalising. They consequently fail to apply the knowledge to the outside context

Group work was used for learners to discuss and share ideas on drawing of crosses and their outcomes. After the discussions, group representatives could draw the crosses for the rest of the class to see. Group work was used for learners to discuss or complete what the teacher initiated on the board. For example, the teacher divided students into small groups to discuss the phenotype of the pairs of girl and boys he randomly selected. Later he asked students in their groups to come up with crosses involving the phenotypes they observed. Using the genotypes *FF* and *mm*, he asked them to draw the crosses. Learners failed to identify some of the phenotypes from the crosses drawn because principles of Mendelian genetics were not followed.

The activity John gave students could not help them deduce concepts of principles of Mendelian genetics. The activities done were not clearly linking to the objectives of Mendelian genetics in transforming the content into understandable forms. For example, to enhance the concept of Mendelian inheritance, the teacher drew the diagram of two flowers to illustrate the transfer of pollen from anthers to stigma. Learners were given a task to label the different parts of the flower. After the labelling, John explained how pollen is transferred from the anthers to stigma using the two diagrams. Later, learners were given a task of selfing the F1 generation to illustrate how Mendel observed the appearance of a recessive gene in the F2 generation. The activity on pollen transfer and Mendelian genetics had no any link hence, it added to the abstractness of the concepts in Mendelian genetics.

Question and Answer was used in the progress of the lesson to check learners' understanding on the concepts. John asked questions throughout the lesson to involve his students in the teaching and learning process. Question and answer was also used in summarising the lesson to check if students had followed what was taught in the class. The teacher asked the students some questions to identify misunderstandings developed in the lessons. Likewise, learners asked questions for clarity. This is in line with what Chin & Osborne (2008) reported that teachers ask questions to assess learner's misunderstandings while learners ask questions to fill the knowledge gaps existing. Although John used question and answer in his lessons, most of the questions he asked were closed ended. For example; in his first lesson on calculating percentages, he asked a question like *"What are the two types of variation that you know?"* Cimer (2007) and Dickson (2005) contend that open ended questions are good because they cater for independent thinking and actively engages learners in the lesson. The content for discussion was obvious and close ended thus not igniting cognitive development of the learners. Little room was given for learners to think and come up with tangible suggestion for the task given. It was partly done by the teacher and learners' task was to finalise what the teacher already set off.

The lessons observed also give an impression that learners had no problems in solving probabilities in Mendelian genetics. Students managed to calculate the phenotypic ratio from a pool of 400 offsprings without any difficulties observed. as shown from the excerpt below:

Teacher: I will give you group work. I have drawn a cross showing the genotypes of parents and separation of gametes on the board as shown in Figure 4.8. Can you complete drawing the cross?

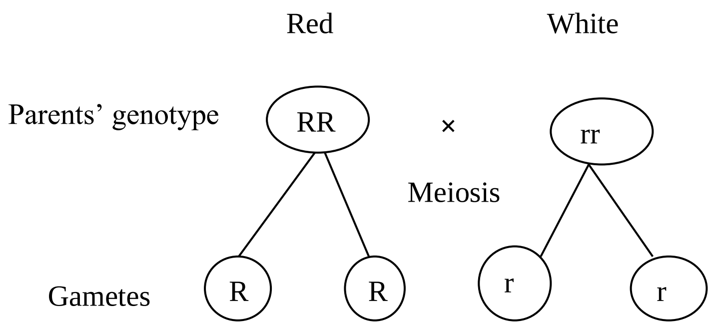

Figure 4.8: John's illustration of drawing crosses

Learners: discussing and completing the drawing of the crosses.

Group 1 representative: drawing the cross on the board as shown in Figure 4.9 and explaining to the whole class how they completed drawing of the crosses.

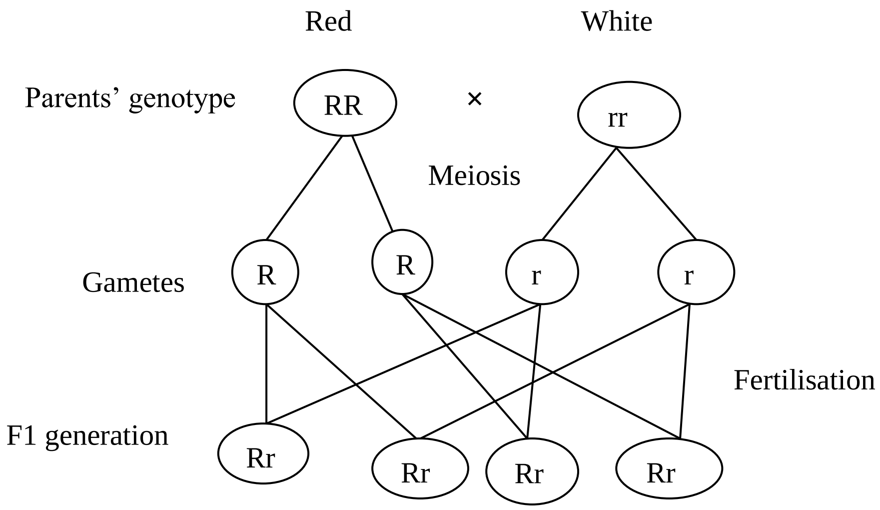

Figure 4.9: Group 1 presentation on drawing of crosses for RR with rr

Group 1 representative: All the F1 generation are red

Teacher: Phenotypic ratio: 100% red because all are red.

The total number of offspring produced is 4 and the red ones are 4. Therefore; It is written as 4/4 × 100% = 100%.

Teacher: Can you self the F1 generation and calculate the number of red and white off-springs from the outcome of the crossing, if in total there were 360 organisms.

Learners: Selfing the F1 generation in their groups.

Group 3: One group member presents the findings of their group as shown in Figure 4:10

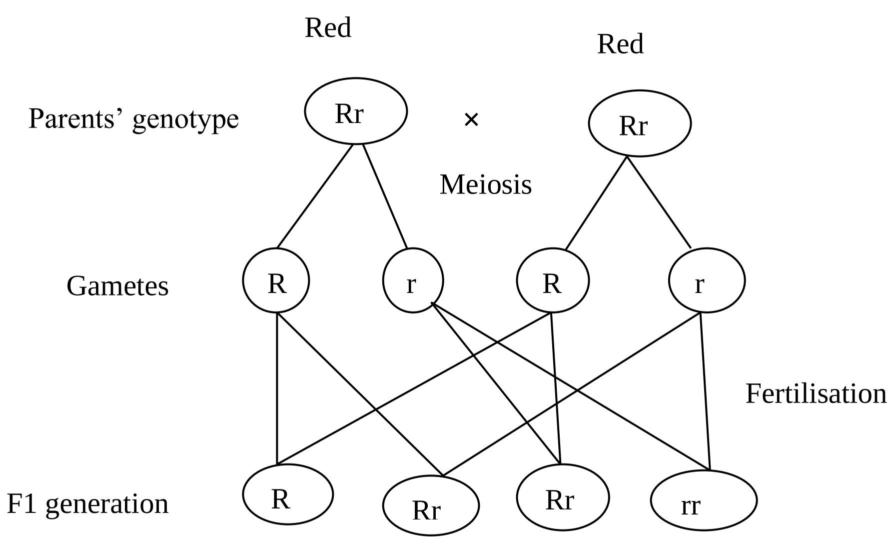

Figure 4.10: Group 3 presentation on drawing crosses for selfing F1 generation for RR with rr

The ratio from the cross is 3 reds and 1 white (3:1)

Teacher: Genotype ***RR*** stands for – Red

Genotype ***Rr*** stands for – Red (Heterozygote)

Genotype ***rr*** stands for – White

If there are 360 organisms, ¼ will be white and ¾ will be red.

Red organisms	White organisms
¾ × 360	¼ × 360
270 red flowers	**90 white flowers.**

The excerpt above shows John calculating the ratios and percentages on behalf learners. John's overindulging in solving the ratios and percentages could be one reason for the lack of difficulties in solving mathematical problems by learners because they were being drilled by copying what the teacher did from the first lesson in calculating percentages. Mudau (2013) contends that teachers are supposed to be facilitators of the teaching and learning process. As a facilitator, he was supposed to guide the learners where they failed to solve the problem on their own. John's use of demonstration method suggests that he wanted to actively involve learners in the teaching and learning process. Although students were actively involved, the implementation of the method could not cater for opportunities for learners to discover concepts on their own and enhance retention of the knowledge. One reason could be that he dominated the lessons by doing most of the work for them. This portrays what Magnusson et al. (1999) stated that the orientation towards science teaching can influence the choice of the strategy but the purposes for using it can be different.

The lesson observed also shows that John did not clearly state the principles of Mendelian genetics, yet the whole lesson was based on Principles of Mendelian genetics. The MSCE biology syllabus outlines the following principles of Mendelian Genetics for learners to know:

- ✓ Characters are controlled by a pair of genes (alleles) and that alleles of the same gene do not blend.
- ✓ Alleles of the same gene pass into separate cells during gamete formation (Law of segregation)

- ✓ Allele of the same gene are inherited independently (Law of independent assortment) (Source: MoEST, 2001, MSCE Syllabus)

John's lesson did not allude to any of the principles stated. Magnusson et al.(1999) PCK model contends that SMK should inform the selection of appropriate goals, teaching and learning materials, identification of difficult concepts, strategies for teaching difficult concepts and the scope of the content to be covered. John was supposed to draw from the experience and practice he had in teaching genetics at secondary level to articulately cover principles of Mendelian genetics. Mudau (2013) asserts that PCK as a skill and knowledge develop when the teacher is able to draw from his/her experience of classroom practice in terms of the understanding of the curriculum, student, subject matter and pedagogical principles. Eventually, learners were making mistakes in the task given on drawing crosses. Learners were drawing crosses using different letters that could not assist to the understanding of genetic crosses. For example; *FF* were used as alleles for a gene controlling tall height in females. So *F* was chosen because it is the first letter for females. While *mm* was used for alleles controlling short height in males because *m* is the first letter in males.

Lack of adequate SMK by the teacher resulted in learners being engaged in activities that did not promote understanding of genetic crosses. Also, learners subscribed to the same misconception from the teacher that they can use different letters (allele) for a gene controlling the same character. This agrees with what Bahar et al. (2003) reported in a research on misconceptions that teachers subscribe to the same misconceptions with learners.

4.2.3 Reasons for Using the Described Strategy

After observing John teaching two of the concepts identified as challenging, a post-observation interview was conducted to find out why he used strategies like group work, question and answer and demonstration. Below is the excerpt from the interview on why John used the described strategy:

Researcher: You have used group work, demonstration, question and answer in teaching challenging concepts in MSCE genetics. Do you have any reasons for choosing the three strategies?

Teacher: Yes I have used these methods to help learners grasp the concepts and make use of the knowledge on their own because they are future leaders. These methods allow greater participation of the learners to help them understand and know the basics of genetics to be applied in their real life situations because they own the knowledge. Participatory methods enable the content to stick into learners' minds for long period of time. Also, the question and answer method was frequently used to check the level of understanding in learners as part of formative assessment and identification of the misconceptions.

The excerpt points out that John had four main reasons for using the described strategies. These were: transfering of knowlede to new context, retention of knowledge for longer period of time, formative assessment and identification of prior knowledge to elicit misconceptions.

John explained that he used demonstration, question and answer and group work methods to actively involve the learners. By involving the learners, they could gain experience in working with concepts involved in genetics. In the end, they could own the knowledge and apply it to other context for solving personal or community problems.

John also used the described methods for retention of knowledge for longer period of time. By using methods like group works, demonstration, question and answer, John thought it could help the learners to explore issues of interest, ideas and opinions on their own. Active involvement of learners increases their motivation towards genetic learning as they gained higher reasoning skills. Strategies like question and answer would also help learners develop more interest in the lessons if the topic of discussion directly affected their lives. Such an approach would help the learners to challenge their naïve ideas and create room for owing new knoweldge through social interaction.

John used question and answer method to get feedback on learners' progress. The method dominated most of John's lessons. This agrees with what (Chin & Osborne, 2008) observed that three quarters of what teachers say in class are in form of questions. Although John used question and answer in his lesson, some of the questions asked lacked quality to stimlate students' thinking and arousing interest and curiosity. Most of the questions were recalling questions which Dickson (2005) states do not to help learners develop skills of reasoning and cognitive development. The excerpt below shows some of the close-ended questions from John's first lesson:

John: What are the two types of variation that you know?

Student 1: They are intra-specific and inter-specific variations.

Questions like the one in the excerpt above made learners to memorise the concepts. Learners might think there is only one answer to the question asked. In the end learners might conclude that biology involves learning by memorisation of concepts.

John also used the question and answer method for identifying learners' prior knowledge to point out misconceptions. In the lesson observed, John gave learners the opportunity to discuss things on their own through group works, questions and answers inform of brainstorming. For example, in the second lesson on selfing the F1 generation using the genotype GG and YY shows the dialogue aimed at eliciting learners' prior knowledge on Mendel's work:

Teacher: If you were Mendel, what could you have done to get a pure breed from crossing parents with genotype GG and yy?

Learners: Discussing in pairs

Student K: May be by crossing the breed

Teacher: Which breed?

Student K: Green and Yellow

Student M: Cross breeding green and yellow

Teacher: Just as the first one

Student B: By in-breeding

Teacher: Yes. In-breeding green with green from the F1 generation.

From the learners' responses, John used the prior knowledge of learners to point out the misconceptions learners had on Mendelian genetics. Cimer (2007) agrees to the approach by John that using group work and question and answer make learners to reveal their misconceptions. Although John identified the prior knowledge of learners, the excerpt shows that he did not use learners' responses in building his lesson on them. Cavallo (1996) argues that science teachers should use innovative techniques that help the teacher and the learners to use the prior knowledge and experience to make meaning out of what they are learning. The knowledge of potential learning difficulties and prior knowledge could have helped him in choosing instructional strategies that could promote effective understanding of genetic concepts.

4.3 Case C

4.3.0 Introduction

I interviewed Angelina before the lesson observation to identify the concepts she finds challenging to teach in MSCE genetics. Later, I observed Angelina teaching two of the genetic concepts identified as difficult. The first lesson was on use of mathematical skills in describing variation and the second lesson was on Mendelian genetics by applying mathematical skills in solving genetic ratios, percentages and its application to real life situations. After the observation of the lesson, a post-observational interview was conducted to seek a clarification on why she used the strategies observed in her lessons.

4.3.1 Difficult Genetic Concepts

In the pre-observation interview, Angelina was asked about challenging concepts that pose teaching difficulties in genetics. The excerpt below shows how Angelina responded to the question:

Researcher: Are there any concepts in MSCE genetics that you find challenging to teach?

Teacher: Generally, genetics is difficult to teach because the topic has abstract concepts which are very difficult to relate to real life situations.

Researcher: What about specific concepts from MSCE genetics that pose teaching challenges?

Teacher: As a teacher, I do face problems in teaching variations especially in applying mathematical skills in describing variations. Another concept is calculation of genetic ratios. The problem can be attributed to abstractness of genetic concepts hence; the topic is taught in a way that application of the concepts to other context is not encouraged. On the other hand, learners have mathematical problems which scare them in applying mathematical skills in solving variation and genetic ratios.

Researcher: How are the concepts mentioned challenging to teach?

Teacher: I find it challenging in practical ways e.g. transfer of genes from parents to off-springs. Learners would like to see it practically how genes are transferred from parents to off-springs. It is difficult for the teacher to illustrate that, hence we resort to theoretical teaching.

From the interview above, Angelina finds challenges in teaching variation and genetic ratios in monohybrid crosses. In variation, the problem lay on applying mathematical skills in describing variation. My analysis on the M.S.C.E biology syllabus on application of mathematical skills in variation indicates that learners are supposed to find mode, frequency, mean and standard deviation and plot graphs like histogram and bar chats to describe variation. The mathematical skills required in describing variation are the same with what they learn in mathematics. Therefore, it may not be necessarily the actual application of these skills which is difficult in describing variation, but the actual planning of an investigation, sampling, collecting and analysing data which is challenging for both teachers and learners. It is the interpretation of the data emanating from such investigations which demands the application of standard deviation, frequencies, mode and plotting of graphs. It suggests that learners are not comfortable in applying mathematical skills in the learning of biology when conducting investigation.

In Mendelian genetics, Angelina said that learners found the drawing of crosses, solving of genetic ratios and percentages challenging to understand. The reason was that crosses do not show a true picture of gene transfer. Learners and some teachers find it difficult to calculate probabilities in segregation of gamates into phenotypes and genotypes. Bahar et al. (1999) found similar results that in solving ratios for phenotypes and genotypes in crosses, it does not show the real mechanisms happening in the human body. The complexity comes because learners are supposed to think at three levels of thought: the macro, micro and symbolic levels.Learners get confused if the teacher teaches without being aware to this level of thoughts. Ultimately, learners have difficuties in understanding the concepts.

4.3.2 Strategies for Teaching Challenging Genetic concepts

After Angelina identified the concepts that posed challenges for teaching genetics, I asked her about the strategies she uses to addresses those challenges. Below is an excerpt on the strategies Angelina would use in teaching the challenging concepts:

> **Researcher:** Tell me about the strategies that you use to teach those concepts that are challenging to teach in genetics?
>
> **Teacher:** In general, teaching of genetics is teacher-centred. Rarely are students involved in experiments and classroom activities in teaching and learning of genetics. Genetics teaching is mostly characterised by teacher talking and learners grasping the concepts from the teacher. I do improve the

teacher-centred methods by using question and answer in trying to find out what learners think.

From the excerpt above, Angelina emphasised that genetics teaching is teacher-centred typified with explanatory and question and answer method to make the concepts understandable. Her responses to the questions on strategies used made me to find out more from her.

Researcher: Do you conduct experiments in genetics?

Teacher: Experiments are not conducted in genetics. Instead, activities like using beans are used in solving phenotypic ratios.

Researcher: Why do you opt for teacher-centred strategies in teaching genetics?

Teacher: I aim at finish the syllabus; therefore, teacher centred strategies help in teaching all the topics. I know it is bad, but I use it to accomplish the syllabus.

For Angelina, teaching of genetics was about teacher transferring knowledge to the learners. She used this approach to cover all the topics in the syllabus for learners to pass the M.S.C.E examinations. Angelina's understanding is that using active teaching techniques delays the covering of the syllabus. Angelina also holds that since experiments are not conducted in genetics, the only option was to simply transfer theoretical knowledge to the learners.

After the pre-observation interview, I asked Angelina to observe her teaching two of the challenging concepts identified. An agreement was reached to observe her teaching variation and monohybrid crosses. Lesson observation by video recording was done to triangulate the strategies she said would use.

Below is an excerpt from her second lesson. It was an 80 minute lesson discussing monohybrid crosses, modelling monohybrid crosses and working out the ratios of the monohybrid crosses. The main objective of the lesson was to work out the ratio of phenotypes and genotypes in monohybrid crosses up to F2 generation.

Introduction

Teacher: Would you remind me the meaning of gene from the previous lesson?

Student D: Traits

Teacher: Structures found in the deoxyribonucleic acids

Teacher: What do genes carry?

Student C: They carry genetic materials

Teacher: Genes are hereditary messages transferred from parents to off-springs.

Teacher: What structures are found in the chromosomes?

Student V: Chromatids

Teacher: Demonstrating the diagram of chromosomes from the chat paper as shown in Figure 4.11

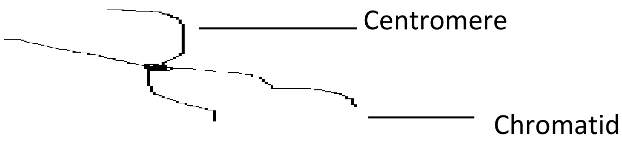

Figure 4.11: Structure of a chromosome

Teacher: Which process brings gametes from body cells?

Student N: Meiosis

Teacher: Correct

Teacher: Let's use colour of seed coat in beans as an example of phenotype controlled by genes. I have two beans with different seed coat colours. One is white the other is green. The green colour is controlled by gene *RR* while white colour is controlled by gene *rr*. A gene for green colour (R) is dominant over the gene for controlling white colour (r). Genotypes of both parents for green coloured beans and white coloured beans are expressed in Figure 4.12.

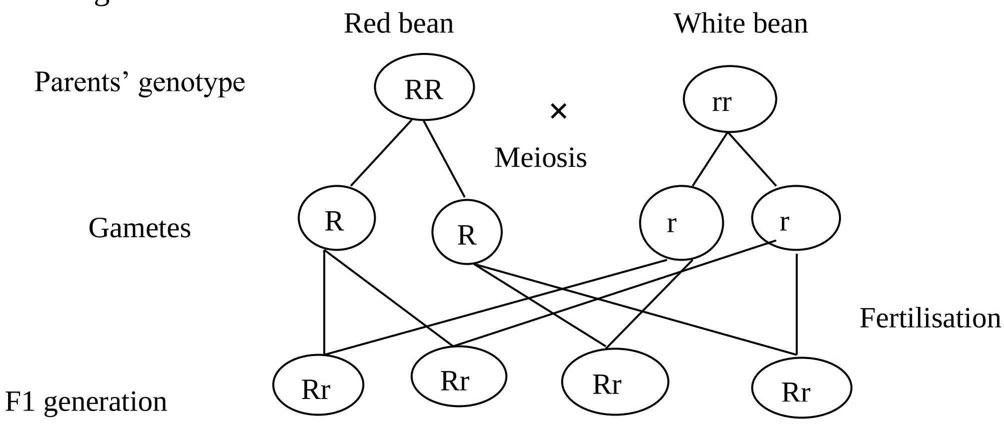

Figure 4.12: Angelina's example on drawing crosses for RR with rr

Teacher: What is the phenotype of the off-springs?

Student H: All are green.

Teacher: From the parents, the sperm cells undergo meiosis to produce the gametes

R, *R*, *r* and *r*. Relating to Mendel's Law of Segregation; alleles of the same gene pass into separates cells during gamete formation. This explains why the alleles of a gene for controlling green colour will pass out into *R* and *R* gametes while for white colour will pass into *r* and *r* gametes.

Teacher: After separating into separate cells, the gametes will be assorted independently into its own cells. This is the Mendel's Law of independent assortment which states that "alleles of the same gene are inherited independently." Gametes from the same parent cannot fertilise each other to form zygotes, but gametes from the father will fertilise the gametes from the mother to form the zygote.

Teacher: What is genotype?

Student J: The genetic makeup of the individual

Teacher: Rr is called heterozygote individuals

rr is called homozygote recessive individuals

RR homozygote dominant individuals

Teacher: What is phenotype?

Student L: Are outside appearance of an organism due to expression of the genes"

Teacher: Rr has green phenotypes

rr has white phenotypes

RR has green phenotypes

Teacher: I have two pairs of bags containing beans. The colours of the beans are mixed in these bags. One pair of bag represents females while the other pair represents the male organisms.

Teacher: Can I have two pairs of volunteers to work on the activity while others should be watching. I have four plastic bags of beans. Each pair should get two plastic bags of beans with mixed colours containing green and white.

Teacher: Can you listen to the procedure carefully;

i. Select 30 beans from each bag at random. The 30 beans from each bag represent gametes from each parent. You select randomly because during meiotic division of cells, parents do not chose which gamete to produce.

ii. Close your eyes and take one bean at a time from each of the 30 pile of beans selected randomly. Rationale: characteristics are controlled by a pair of genes.

iii. Pair the beans one from the pile of male parents with the other from the pile of female parents without looking at the beans.

iv. After pairing, observe and record the colour of the beans from the pairs you have made.

Learners: conducting the activity by following the procedures. The rest watches the demonstration.

Teacher: Moves around the two groups and guides them on how to conduct the activity.

After pairing the beans, learners presented the data as shown in the Table 4.4 for genotypic appearance and Table 4.5 for phenotypic appearance.

Table 4.4: Genotypic appearance of bean pairs

Genotypes	**Group A**	**Group B**	**Total**
RR	13	15	28
Rr	11	11	22
Rr	6	4	10
Total	30	30	60

Teacher: Explain why those beans with a combination of green and white are called green.

Student Y: Green is dominant over white; therefore, where there are two beans of different colours represent a dominant gene expressing its characters over a recessive gene.

Table 4.5: Phenotypic appearance of bean pairs

Groups	**Green**	**White**	**Total**
A	24	6	30
B	26	4	30

Teacher: Using the data collected, calculate the phenotypic ratio?

(a) Phenotypic ratio.

Student L: Writing on the board**.** From the two groups those beans which were green were 50 and those which were white were 10. Green 50: White 10. It represents a ratio of 50: 10 which if divided by 10 reduces to the ratio of 5:1. The ratio of green beans to white beans was 5:1.

(b) Genotypic ratio.

Student M: Purely green beans (RR) were 28, heterozygote (Rr) were 22 and purely white (rr) were 10. Therefore: RR: Rr: rr reduces to the ratio of 22: 28: 10. If divided by 2, the ratio reduces to 14:11:5. The genotypic ratio from the sample of beans collected was in the ratio of 14 pure green beans, 11 heterozygote beans and 5 pure white beans. The gene controlling green colour was dominant over the gene controlling white colour.

Teacher: Can two students come forward and draw the crosses with the following genotypes: (i) Selfing the F1 with genotype Rr (ii) Rr with rr?

Student N and C: Drawing the crosses as in Figure 4.13 and Figure 4.14 using the given parental genotypes.

Cross A: Selfing the F1 generation with genotype Rr.

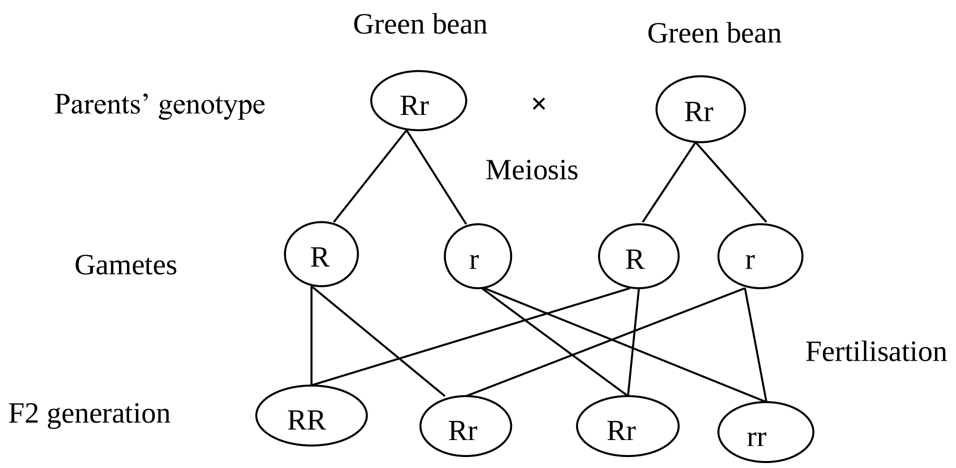

Figure 4.13: Student F cross for selfing the F1 with genotype Rr

Teacher: Find the genotypic ratio and phenotypic ratio of the organism from the cross drawn?

Student F: Genotypic ratio: RR: Rr: rr as 1:2:1 while phenotypic ratio as 3 green to 1 white (3:1).

Cross B: parent with genotypes Rr crossing with parent of genotypes rr

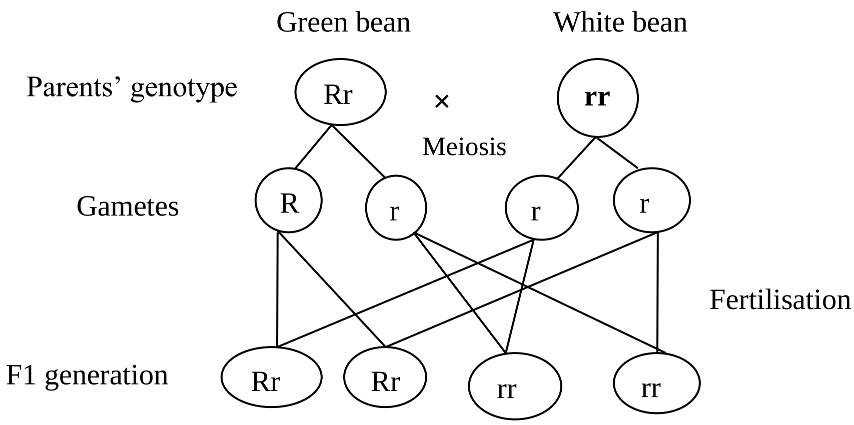

Figure 4.14: Student G cross for genotypes Rr and rr

Student G: Phenotypic ratio: 2 green and 2 white (2:2) which reduces to 1:1 and the genotypic ratio: 2 heterozygote (Rr) and 2 homozygote recessive white (2:2) which also reduces to 1:1.

Teacher: Demonstrating how percentages are calculated from the cross where F1 generation are selfed and there is a total population of 80 organisms. The teacher ask students to calculate how many organisms will be white and green from the sample of 80 individuals? From the sample given, how many will have the heterozygote genotypes?

Teacher: Drawing a cross for Rr × Rr as shown in Figure 4.15

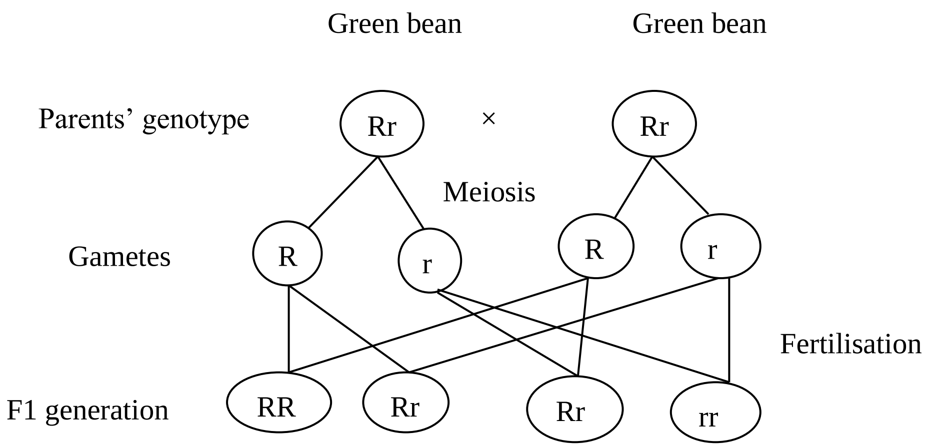

Figure 4.15: Angelina's cross for Rr with Rr

Teacher: Genotypic ratio: RR: Rr: rr is 1:2:1 while phenotypic ratio as 3 green to 1 white (3:1).

Teacher: From 80 organisms, how many will be Green and White?

Student S: Green: Total ratio is 4. Out of 4, 3 will be green and 1 will be white. Total number of organism is 80.Therefore; ¾ ×80 = 20×3 = 60. From 80 organisms, 60 will be green. To find those that will be white; 60 green organisms should be subtracted from 80 as total number of organism. The answer for white organism is 20.

Teacher: How many will have the heterozygote genotype?

Student U: The genotypic ration from the problem solved is 1:2:1 for RR, Rr and rr. Total ratio is 4. Out of 4 organisms, 2 will have the heterozygote genotype. Therefore; 2/4 should be multiplied by 80 to find those organisms which have heterozygote phenotype. Therefore; 2/4 ×80 = 40. It is 40 organisms with the heterozygote genotype from the pool of 80 organisms after selfing the F1 generation.

Teacher: Are there any questions on what we have just learnt?

Student M: At the end of calculations, are we supposed to put a percentage sign in genotypes or just a ratio sign?

Teacher: We can calculate percentages using the very same samples. We have four organisms of which 2 are green. Therefore, 2/4 *100= 50%

Teacher: Any further questions? If not, we will continue the calculations in our next lesson. Thank you

Angelina used demonstration, group work, question and answer to teach the challenging concepts. Demonstration method was used in showing how crosses are drawn, calculation of percentages, separation of gametes and fertilisation process. Students were actively engaged in the demonstration method making it learner centred. Throughout the demonstration process, it was learners demonstrating to their fellow students how certain phenomena work. The duty of the teacher was to guide the students where they failed to do it alone. Angelina's implementation of demonstration method complies with what Adekoya & Olatoye (2011) say that the method should include active participation of learners. Active participation will cater for learners to see, hear and experience the phenomena in ways that will enhance their understanding of the concept. Throughout her lessons, learners could be seen happy and motivated as they gained experience in explaining variations using mathematical skills and drawing of crosses involving calculations of percentages and ratios.

Group discussion was another method used by Angelina in teaching the challenging concepts. The teacher formed small groups and engaged learners in tasks relevant to the objectives to be achieved. The teacher supervised the groups by going through them to see how their work progressed. In their groups, learners were left to interact and share ideas and internalise the knowledge on their own. Where the students were stuck, the teacher could provide the required help to see the learners through the task given. For example, in the first lesson, learners had problems in plotting histogram as most of them were plotting a line or bar graphs. Angelina assisted the learners by reminding them the difference between histogram and bar charts. In the second lesson, the teacher assisted learners in making meaning out of the activity on beans to illustrate separation and independent assortment of gametes. Liang & Gabel (2011) contend that such approach to implementation of group work helps learners to develop higher reasoning skills, positive attitude, self-esteem and collaborative skills resulting into increased understanding of the concepts.

Question and Answer (Q&A) method was used throughout the lesson observed. The teacher planned for the questions to be asked well in advance. Most of the questions asked were of good standard by fusing open- ended and closed ended questions. Dickson (2005) states that the use open-ended questions gives room for learners to explore various solutions to a problem, unlike closed- ended questions which instil in learners that they is a single answer to the problem given. Such an approach makes learners to develop interest and curiosity in solving genetic problems. The questions were asked to elicit misconceptions in learners and assess learners' understanding of the concept taught. For example, from her first lesson, Angelina asked questions like:

Teacher: What do you understand by the term variation?

Male Student: Observable differences among organism

Teacher: Yes. Variation is observable differences among organisms of the same species. Anyone with a different definition?

Angelina probed deeper from students' responses in order to enhance their understanding of concepts. She also structured her questions to provoke higher reasoning skills and made some insertions to learners' explanations in summarising complicated answers from learners. The strategies Angelina used engaged learners in a social milieu where each learner had the opportunity to construct his/her own knowledge. For example, some of the learners were seen drawing crosses on the board and showing them to the whole class, while others were demonstrating how to select beans from the two bags representing gametes from parents. The strategies Angelina used contradicted what she said in the pre-observational interview that genetics is taught largely through teacher- centred methods. The actual lesson observation showed that her lessons were student-centred through the use of group work, question and answer and demonstration method.

The teacher showed an understanding of topic specific activities for teaching genetics drawing from her experience. This was seen from the activities done in the two lessons on variation and Principles of Mendelian Genetics involving monohybrid crosses. The activity on calculating ratios and percentages were meaningful in helping learners understanding the genetic terms as well as mathematical calculations. Loughran et al.(2008) concurs that experienced teachers have well developed PCK for promoting learners' understanding in a particular topic. Angelina was exceptional on extracting from her experience in teaching genetics.

4.3.3 Reasons for Using a Described Strategy

After observing Angelina teaching two of the concepts identified as challenging, I called for a post-observation interview to find out why she used strategies like group work, question and answer and demonstration method. Below is the excerpt for the post-observation interview:

Researcher: From the lesson observed, you have used group method, question and answer and demonstration in teaching challenging concepts in MSCE genetics. Do you have any reasons for choosing the three strategies?

Teacher: I wanted to involve the students more to make the lesson learner centred than teacher -centred. If students are actively involved, they may assist each other because some are fast learners while others are slow learners. The demonstration method was used to show to learners how some things happen in real life situation so that they can have a picture of what we are discussing. I used the question and answer method to probe learners if they are achieving the objectives of the lesson planned and identify the errors in reasoning on the topic of study.

Angelina used question and answer, demonstration and group work with the purpose of involving learners in the teaching process. Learner involvement helps them to own the knowledge and transfer it to new context with considerable ease.

The teacher specifically stated that question and answer was used to help in assessment of the lesson by checking attainment of the intended objectives. She used question and answer in the progress of the lesson to ascertain if learners were constructing knowledge on the activities done in the classroom. Partly, she used informal assessments where she could go through the groups and check what learners were doing in line with the objectives of the activities. Question and answer was also used for concluding the lesson as part of summative assessment. In concluding her first lesson, the teacher used a two way method of assessing learners' understanding. Below is an excerpt on how Angelina concluded her first lesson:

Teacher: Are there any questions on what we have just learnt?

Student F: At the end of calculations can we put a percentage sign or just a ratio?

Teacher: We can calculate percentage using the very same sample we have been working on. We had 4 organisms. Two are green. Therefore to calculate the percentage of green organisms from the sample: 2/4*100 = 50%. See how I have written the percentage sign at the end of our answer.

Teacher: Can you tell me anything that you have learnt from our today's lesson?

Student J: I have learnt how to calculate ratios and percentages in genetic crosses

Student Y: I have learnt how to draw crosses

Student R: I have recalled the difference between bar chart and histogram.

Teacher: We will continue with the calculations in the next lesson. Any questions?

She gave learners a chance to assess her lesson and ask questions where they did not understand. Secondly, she gave learners a chance to explain what they learnt from the lesson. Later, after listening to learners on what they have learnt from the lesson, the teacher asked questions which were planned to elicit if the objectives of the lesson were meant.

The teacher also alluded to using question and answer for identification of prior knowledge and misconceptions in learners. The excerpt below shows how Angelina responded when asked how question and answer was used for identification of prior knowledge and misconceptions.

Researcher: How do you identify prior knowledge and misconceptions in learners?

Angelina: By using question and answer which assists a lot in identifying misconceptions and revealing what learners think about the concepts.

Angelina's explanation in the excerpt above showed she knows the importance of learners' prior knowledge in teaching and learning science. With this, you would expect her to start her lessons with identification of prior knowledge and misconceptions learners have on the concept. Cimer (2007) asserts that an introduction is the proper time for eliciting learners' prior knowledge and misconceptions in a lesson. For Angelina, an introduction was used in bridging the gap from the previous lessons to the new lesson. The introduction was used for assessing learners' understanding of the previous lesson rather than using it for identifying and elucidating the misconceptions. Mdolo (2010) reported the same sentiments that some Malawian biology teachers use the introduction for bridging the content learnt in the previous lesson instead of using the introduction for eliciting learners' prior knowledge and misconceptions.

4.4 Case D

4.4.0 Introduction

Samuel was interviewed before the lesson observation to identify the concepts he finds challenging to teach in MSCE genetics. Later, I observed Samuel teaching two of the genetic concepts identified as difficult. The first lesson was on genetic terms and the second lesson was on monohybrid crosses. After lesson observation, a post-observation interview was conducted to seek clarification on why he used the strategies observed in his lessons.

4.4.1 Difficult Genetic Concepts

In the pre-observation interview, Samuel was asked about challenging concepts that pose teaching difficulties in genetics. The excerpt below shows how Samuel responded to the question:

> **Researcher:** Are there any concepts in MSCE genetics that you find challenging to teach?
>
> **Samuel:** Yes. Explaining certain genetic terms like homozygous, homologous, and heterozygous is challenging to students. It is very difficult to find teaching and learning aids apart from diagrams in books. I think if we can have models of genes, alleles and the like, students can easily understand. It becomes difficult to just be telling students about these terms. Mutation and crosses are other areas posing challenges for teaching because by its nature, the two concepts are difficult to explain.

Samuel indicated facing challenges in teaching genetic concepts such as gene, alleles, phenotypes, genotypes, homozygous and heterozygous. The difficulty lay in telling students their meanings without typical examples illustrating what they mean.

Other concepts Samuel identified as difficult were crosses and mutations. These concepts were difficult because of their complexity in nature.

4.4.2 Strategies for Teaching Challenging Genetic Concepts

After Samuel identified the concepts that posed challenges for teaching genetics, he was asked about the strategies he uses to addresses those challenges. Below is an excerpt on the strategies Samuel would use in teaching the challenging concepts:

> **Researcher:** Are there any strategies that you use in teaching challenging concepts in

MSCE Genetics?

Samuel: Generally, I use group works, question and answer and demonstration method. For example; to explain terms like genotype or phenotype you can use bean seeds with red colours or white to express phenotype through demonstration. It is difficult for students to understand genotypes because it is invisible to the learners. Therefore, using group works, students can discuss the concepts independently.

The teacher alluded to using group work, demonstration, question and answer in teaching concepts that were challenging in genetics. To verify the teacher's claims, the researcher went ahead to observe him teach two of the challenging concepts. Consensus was reached that I observe him teaching genetic terms and monohybrid crosses. Below is an excerpt on the first lesson on genetic terms. The lesson was for 80 minutes. The objectives of the lesson were to define genetic terms commonly used in genetics.

Introduction:

Teacher: What is reproduction?

Student M: The process in which new organism are formed from their existing parents.

Teacher: What is fertilisation?

Student C: The union of male and female gametes to form an organism

Teacher: Explain what happens in the prophase stage of mitosis and meiosis?

Student R: In prophase stages, the chromosomes become thick and short making them visible.

Teacher: Who can define genetics?

Student: The process where characteristics are passed from the parents to the off-springs.

Teacher: Fine. Can you be in groups of six and discuss the following terms from the hand-out. You have 15 minutes to discuss the terms. After discussing, choose someone to report the findings of the discussion to the class.

a. Gene and allele
b. Genotype and phenotype
c. Homozygous and heterozygous

Task presentation:

Group 1: *Gene:* are structures found in the DNA molecule while *allele* is a pair of genes controlling a single character e.g. *B* standing for a black colour or *b* standing for a gene controlling brown colour.

*Genotype***:** is the genetic combination in an organism while *phenotype* is the final appearance of an organism due to expression of genes.

Homozygous: is a condition in which a pair of similar genes controls a character while *heterozygote* is a condition in which dissimilar genes control a character.

Teacher: Do you have any questions to the group?

Student K: Clarify the definition of *DNA*.

Group 1: *DNA* stands for deoxyribonucleic acids.

Group 2*: Gene:* The basic unit of heredity because it controls all hereditary information while *allele* is a pair of genes controlling a single character.

Genotype: is a combination of genes to form a character while *phenotype* is a final appearance of an organism due to combination of genes.

Homozygous: is a condition in which a pair of similar genes controls a character while *heterozygous* is a condition in which a pair of dissimilar genes control a character.

Teacher: Any questions to the group?

Class: Silent

Teacher: Okay. Can the third group make a summary on what the two groups have presented?

Group 3: Heredity is the process in which parents pass their characteristics to the offsprings. Genes are hereditary structures found on the DNA in the chromosomes of nucleus while alleles are a pair of genes controlling a character.

Genotype e.g. *B* as a gene for controlling black colour in human and *b* as a gene for controlling brown colour in humans. The combination of the two genes is called genotype. ***Phenotype*** on the other hand is final appearance of the organism due to expression of genes.

Teacher: Any one from the group to help him explain homozygous and heterozygous?

Student S from group 3*:* *Homozygous:* as a condition where similar genes control a character while *heterozygous* is a condition where dissimilar genes control a characteristic.

The teacher makes a summary of the lesson using a chart paper as follows:

Teacher: Genes are structures found in the DNA in the chromosomes. It controls the characteristics of an organism. These genes are small sections of the DNA on the chromosomes as shown in Figure 4.16.

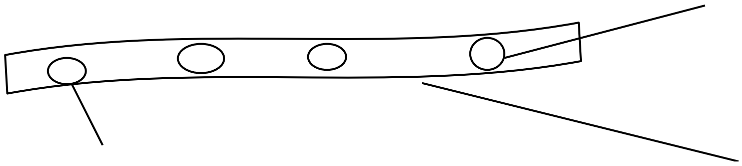

Figure 4.16: Illustration of genes on the chromosomes

On the other hand, an *allele* is a pair of genes controlling a single character.

Teacher: *Genotype* and *Phenotype*.

Genotype is the gene combination (genetic make-up of a character in an organism e.g. Bb, bb or BB). While phenotype is the final appearance of an organism due to expression of genes e.g. black skin, brown skin, red colour in bean or white colour in beans.

Teacher: I have two beans with different colours. Observe the colour of the beans and discuss the colour in terms of phenotype and genotype.

Teacher: *Homozygous* and *heterozygous*.

Homozygous is a condition in which a pair of similar genes controls a character e.g. BB, bb. An individual is called homozygote BB or bb. These are called pure breeds. Heterozygote on the other hand is a condition in which dissimilar genes control a characteristic. E.g. Bb an individual is called a heterozygote.

The teacher summarises the lesson by asking questions.

Teacher: Explain the difference between genotype and phenotype.

Student D: Final appearance of an organism due to expression of genes is *phenotype* while *genotype* is the gene combination or make of characteristics in the organism.

Teacher: Who can clarify the answer given by student D on genotype?

Student J: Genotype is gene combination inside the organism.

Teacher: Any questions on what you have learnt today?

Student L: In chromosomes, there are different kinds of genes e.g. gene for skin colour. There are some people with white hair and skins but they are Black Africans. Is it that there is absence of skin colour?

Teacher: That is due to mutations. Currently, we can mix up things but we are going to look at that when learning about mutations.

Student X: There is a gene e.g. B for controlling black hair colour. What happens to the gene when the person is growing old as the hair turns white?

Teacher: As the person is aging, the cells start to change in their function. We are going to understand this when we are through with the topic.

End of the lesson.

From the lessons observed, Samuel used group work, demonstration and question and answer method to teach difficult genetic concepts. Group work was used in discussing the genetic terms. Learners were put into small groups to discuss the genetic terms. The teacher supervised the groups to check learners' progress and clarified if there were misunderstandings. After the discussion in the groups, learners reported what they had discussed to the whole class. The group discussion method was beefed up with class discussion in order to reach a consensus. The task for discussion was relevant to the objectives he wanted learners to achieve. For example; he wanted learners to define genetic terms like homologous, gene, and heterozygote. In their groups, learners were given a task of reading a passage to come up with definitions of genes, heterozygote, and homologous.

Demonstration method was used by the learners and the teacher in expressing the genes, genotype and phenotype. Learners drew crosses on the board to illustrate genotype such as Bb or bb or BB. The teacher used a chart in the conclusion of the lesson to demonstrate the presence of genes on the DNA in the chromosome and drawing of crosses. Beans of different colours were also brought to the class to enhance the meaning of phenotype. Using demonstration method, challenges were encountered for both the teacher and learners in explaining of genetic terms that fall in cellular level of organization such as genes, genotypes and DNA. These terms were difficult to explain compared to terms like phenotypes, because they were not appealing to the senses of the learners. Bahar & Johnstone (1999) assert that concepts in the micro level are not tangible, hence difficult to understand and perceived by the senses (e.g recessive genes for controlling tongue rolling). Learners can easily undestand the phenotype like tongue rollling because they see someone rolling his/her tongue but have problems understanding the mechanism that causes tongue rolling.

Question and answer method was used throughout the lesson to check the progress of the learners in understanding of the concept and clarification of misunderstandings on the concepts. Samuel asked learners questions, gave them room to discuss the question and provided answers to the question posed where learners failed to understand. Students too asked the teacher some questions seeking further explanation on the concept. Although questions were asked in a two way process, the teacher did not give learners sufficient time to discuss the questions on their own before he provided them with answers to the questions posed. Failure by the teacher to give students room to discuss the questions on their own weakened the strategy. The teacher could have used learners' discussion on the question posed for identification of prior knowledge, misconceptions and assessment of their understanding on the concepts.

Samuel created a conducive learning environment for learners to interact, help each other and respecting ideas of others through the use of group work, question and answer and demonstration method. Amos (2002) argues that creation of positive learning environment encourages learners to feel important and valued by the group members which increase their interest in participation of classroom activities. Cimer (2007) contends that active teaching techniques make learners gain sense of ownership and personal involvement in the lesson. Ultimately, it yields motivation, good decision making, respect for the ideas of others and controls disciplinary problems among students. Students in Samuel's classroom could pay attention to what others were talking and could be seen enjoying the lesson as each one of them was ready to participate in the group work and classroom discussion. The strategies used were meaningful in helping learners internalise the concepts because the teacher liberated the lesson for learners to share the knowledge on their own. The teacher took the role of a facilitator to observing how learners were learning and providing scaffolds where necessary.

4.4.3 Reasons for Using the Described Strategy

After observing Samuel teaching the two lessons, I asked for a post-observation interview to find out why he used the observed strategies in teaching genetic terms and monohybrid crosses. Below is the excerpt from the post-observation interview:

Researcher: From the lessons observed, you have used question and answer, demonstration and group work to teach challenging concepts. Do you have any specific reasons for using the three strategies?

Samuel: I chose group work because I wanted each and every child to be involved in the teaching process. Demonstration method was used to help clarify concepts that words alone cannot explain hence, helps in breaking abstractness of concepts. Question and answer was constantly used to arouse reasoning abilities and identify misconceptions in learners. Also, questions provide feedback to the teacher on the effectiveness of the lesson. I do use the answers given by learners and exercise to assess if students understand the concepts taught.

Samuel used the described strategies for the purpose of involving learners in the activities taking place in the classroom. The purpose for using each strategy was for each learner to individually construct knowledge through the rich interactions taking place in the classroom.

Samuel used question and answer to make learners think and to identify the prior knowledge on the concepts. Question and answer also helped him in evaluating learners' understanding on the concept. In all stages of the lesson: introduction, development and conclusion, questions were asked and answered in a two way process. Students asked questions where they needed clarification and the teacher asked questions to check learners' attainment of the objectives.

Samuel used demonstration method to enhance learners' understanding of abstract concepts. For example, the term genotype is difficult for learners to see and make sense by explanation alone. 'Gene' is another term that is difficult for learners to comprehend because of its invisibility. Besides this, it cannot be felt by the learners as with the case of phenotypes. These findings corresponds to what Knippels (2002) reported that concepts in micro level such as genotypes and genes are not tangible, therefore, difficult for learners to understand because they are not appealing to the senses.

CHAPTER 5: FINDINGS AND RECOMMENDATIONS

5.1 Summary of Findings

This study aimed at investigating the strategies that Malawian biology teachers use in teaching challenging concepts in genetics. It had three objectives: identifying the difficult genetic concepts to teach, describing the strategies used to teach difficult genetic concepts and explaining the reasons for using the described strategies in teaching challenging concepts. The summary is presented following the themes of research developed from the objectives of the study.

5.2 Difficult Genetic Concepts

The first objective of the study was to identify the concepts that pose teaching challenges in genetics. The concepts identified as difficult by the four participating teachers are presented on a case-by-case basis because despite identifying similar concepts as difficult the participating teachers had varied reasons for regarding a concept as being difficult.

- **Case A**

Mary identified homologous, heterozygous, gene, allele, co-dominance, incomplete dominance as challenging concepts for teaching genetics. These concepts were difficult to teach and learn because they were not easy to explain to the learners, while some sounded and look alike which confused the learners. Other concepts identified by Mary were co-dominance and incomplete dominance. These concepts were challenging because they are abstract and complex in nature. She found these concepts difficult to explain and represent in classroom situation.

- **Case B**

John identified the use of mathematical skills to describe variations and drawing of crosses in Mendelian genetics involving monohybrid crosses as challenging concepts for teaching genetics. Variations were difficult because of the application of mathematical skills in drawing graphs when discussing the distribution of variation, calculating standard deviation, mode, mean and frequencies. Drawing of crosses presents challenges to learners when required to calculate ratios, and percentages using drawings which do not connect with real biological phenomena. Learners fail to develop real mental representations on the mechanisms of crossing in connection with separation of gametes.

- **Case C**

Angelina identified the use of mathematical skills to describe variations and drawing of monohybrid crosses to work out the ratio of genotypes and phenotypes of offsprings up to second filial generation (F2) as challenging concepts to teach. In variation, the problem lay in the application of mathematical skills to solve standard deviation, mode, and frequencies and describe variations using graphs like bar charts, histogram to give meaning to the data collected. In crosses, students fail to use mathematical skills to work out the percentages and ratios up to the second filial generation. The complexity is further attributed to abstractness of the genetic concepts for learners to make connections between the crossings of gametes in cross diagrams to the actual separation of gametes in the human body. This makes the concepts abstract for learners' understanding.

- **Case D**

Samuel identified genetic concepts like genes, alleles, phenotypes, genotypes, homologous and heterozygous, crosses and mutations as difficult to teach. Concepts like genes, alleles, genotypes, homologous were difficult to explain because they are abstract. Learners fail to explain them because they cannot easily be presented using forms that can enhance learners' understanding. They also sound and look alike which causes a lot of confusion when teaching them. Crosses and mutations are complex because they require higher order reasoning to explain them clearly. Most learners find it difficult to handle concepts that demand higher order reasoning skills (Cimer, 2007). Crosses lack real connection with what happens in the human bodies which makes it difficult for learners to understand because it demands higher order thinking skills.

5.3 Strategies for Teaching Challenging Genetic Concepts

The second objective was to describe the strategy that Malawian biology teachers use in addressing the teaching challenges in genetics. The strategies identified by the four cases were: group work, demonstration, question and answer, problem solving approach and teacher explanations. Although the four teachers used the five strategies in their teaching of the difficult concepts, their approach and implementation were not similar.

Group work was used by John, Angelina and Samuel. In these groups, learners were given activities to discuss on their own and later reported their findings to the whole class. Liang & Gabel (2012) asserts that teaching biology by focusing on social interaction has proved to yield meaningful learning. The implementation of the strategy by the three case teachers depended on the social interaction between learner to learner through the teacher as facilitators of learning. Lord (2001) contends that dividing learners into small groups where they socially interact assists in comprehension of concepts for longer period of time. In these small groups, learners were free to ask questions and spoke freely as they felt to be part of the group. Their active involvement made them feel their in-puts are valued and respected. Mary was exceptional because she did not use group work in any of her lessons in teaching the identified challenging concepts.

Demonstration method was used by all the four case teachers. It involved using few students to show to the whole class how crosses are drawn, calculations of ratios and percentages and gamete separation using beans. In this way, it made the demonstration method an active teaching technique. In Mary's lessons, demonstration method was dominated by the teacher. This made it teacher-centred because learners were left to observe how crosses were drawn without experiencing how they are drawn. Learners were periodically involved in showing how crosses are drawn either by completing the teacher's task or verifying if the learners were drawing the right cross.

Question and answer was used by all the four teachers. A good percentage of teacher talk time in class was in form of questions. Chin& Osborne (2008) agrees that most of what teachers talk in the classroom are in form of questions. Questions were asked in the introduction, development and conclusion of the lessons. Some of the questions used were open-ended while others were closed. Open-ended questions were effectively implemented by Mary, Samuel and Angelina. John used most of the closed-ended questions which according to (Dickson, 2005) does not stimulate cognitive development of learners. Open-ended questions gave room for learners to explore various possible answers to a question posed in solving problems than encouraging them to memorise a single answer to a problem.

Teacher explanation was used in all the four cases. John, Angelina and Samuel fused teacher explanation with questions to make it more learner-centred while Mary's dominated the talking in the classroom through teacher talking. Mary was transmitting knowledge to the learners instead of helping them constructing knowledge on their own. Learners were passive in the lessons by listening to the teacher and following what was being explained. Periodically learners were answering questions and asking questions. Cimer (2012) supports that most biology lessons involve teacher talking and transferring of theoretical knowledge that learners cannot properly apply to real life situations. Modell et al. (2005) argue that science teachers should not provide learners with theoretical knowledge instead they should create an environment where learners will be able to test and reshape their mental models.

Problem solving was mostly used by Mary. She used this strategy with the purpose of helping the learners to transfer the knowledge from classroom situation to other context. Mary dominated the problem solving approach by demonstrating how to solve the problems instead of leaving it for learners to do the problem. Eventually, it made learners passive by learning through reflection on what the teacher was doing. Her approach to implementation of problem based learning encouraged memorisation of concepts in teaching of co-dominance and incomplete dominance. Freitas et al. (2004) calls such type of problem solving as traditional problem solving approach which does not encourage learners to apply the concepts because learners are not given the opportunity to discuss concepts on their own. Such traditional problem solving discourages cognitive development of learners.

5.4 Reasons for Using the Described Strategies

The third objective was to explain why Malawian biology teachers use certain strategies in the teaching of challenging genetic concepts. Mary, John, Samuel and Angelina had varied reasons for using a particular strategy though their reasons seem to merge at some level. Below is a summary of each teacher's motivation for the choice of a particular strategy:

- **Case A**

Mary used demonstration and problem solving approach with the aim of making learners attain independent learning and transferring of knowledge to a different context from the one learnt. She used question and answer for assessing the achievement of the lesson objectives. Question and answer also was used to identify prior knowledge and misconceptions that learners bring with them to the classroom situation.

- **Case B**

John used demonstration, question and answer and group work to create a learning environment where learners could share knowledge on their own. This he believed would help learners retain the knowledge for longer period of time therefore, easily transferred to new context. Furthermore, question and answer was used to assess achievements of lesson objectives. Questions were asked by both learners and the teacher in all phases of the lesson. Question and answer was also used for identification of misconceptions that learners had on the concepts.

- **Case C**

Angelina used demonstration, question and answer, group work to involve all the learners in the teaching process. Involvement of learners would make them help each other because they had diverse backgrounds and understanding of the genetic concepts. Besides, demonstration was used to help learners feel how certain genetic concepts or problems are solved in real life situations in order to develop concrete understanding of the concept. Question and answer was used for probing learners' prior knowledge and identification of misconceptions on the concepts taught. This would arouse their interest to learn the concepts under discussion. Question and answer was also used for assessing the lesson to check attainment of the lesson objectives and clarifying misunderstandings developed during the lesson.

- **Case D**

Samuel used group work with the aim of involving all learners in his class to freely talk, share ideas and express themselves openly. Question and answer was used for arousing interest and reasoning abilities in learners. In addition, question and answer was used in assessing the achievement of the lesson objectives. This was done by asking questions in the development of the lesson as part of formative assessment and in the conclusion of the lesson as part of summative assessment. Demonstration was used for clarifying abstract concepts like alleles, genes, genotype which words alone cannot sufficiently explain. Demonstration method helped to show to learners how certain scientific principles work. Learners' involvement in the demonstration helped in retention of the knowledge for longer period of time and used to new context.

5.5 Research Limitations

The findings provided an insight on strategies for teaching difficult genetic concepts by the four biology teachers in secondary schools in Malawi. These findings are thus confined to the four case teachers.

This study was affected by the “Hawthorne Effect,” that is, the change in behaviour by the people being studied due to the presence of the researcher or realizing they are being observed (Neuman, 2007). From the pilot study, it was observed that the video-taping and audio-taping used in interviews and observation had high chances of altering the behaviour of the participants in order to impress or avoid the normal routine of the teaching and learning process.

To reduce the Hawthorne Effect, I introduced myself to the management using permission letters obtained from Mzuzu University and Northern Education Division. Secondly, I had to engage in open interaction with all biology teachers at each institution with the help of the Head of Department for Sciences (HOD) to explain to them the purpose of the study and the criterion for the selection of the participating teacher. After selection of a teacher to take part in the study, a tour to that teacher’s classroom was made to familiarise with the learners and the teacher himself. Later, I returned to the classroom with the teacher for data collection in two of the lessons that the teacher perceived as difficult to teach.

5.6 Recommendations

Basing on the discussed findings of the study, I would like to make the following recommendations:

- Biology teachers should give students opportunities to learn genetics through strategies that actively involve students in a social milieu.
- Biology teachers should reduce the extensive use of genetic terms which end up bringing misconceptions and confusion in learners.
- Curriculum developers should include a component in the syllabus that shows the importance of mathematics in biology education.
- Secondary Education Method Advisors (SEMAs) should enhance inspection of schools to check how biology is taught and encourage teachers to use active teaching techniques.
- Teacher Educators should equip prospective science teachers with PCK on teaching genetics terms, mathematical aspects and drawing of crosses involved in teaching of genetics at MSCE level to make them effective teachers in secondary schools.

5.7 Suggestions for Future Research

- Investigate why learners fail to apply mathematical skills in learning of variation and Mendelian genetics in biology.
- An investigation on the effect of learner centred strategies on content coverage compared to teacher centred strategies in completing the syllabus
- An investigation on biology teachers awareness of the micro, macro and symbolic level in teaching crosses
- Exploring the effect of large number of students in conducting an activity or experiment in biology lessons

5.8 Conclusion

The findings of the study reveal that most biology teachers find the teaching of genetics challenging for learners' understanding. Most biology teachers are aware of the importance of using learner centred strategies but lesson observation indicates that some biology teachers are failing to implement the strategies for meaningful learning gains. This is somehow surprising because the assumption was that experienced and qualified teachers have gained the necessary PCK for teaching genetics. Is it because of content coverage? Or effect of large number of students in our secondary schools? More research needs to be done to find answers to such questions because genetics teaching should be taught using learner centred strategies which foster cooperative learning, enhances peer interaction and yields higher learning gains.

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Appendices

Appendix 1: Interview Schedule

a. Pre-observation Interview

1. (a) Tell me about your experience in teaching genetics at secondary school

   (b) Are there any concepts in MSCE genetics that you find challenging to teach?"

   (c) In what ways are the concepts you have identified challenging to teach?

2. Tell me about the strategies that you use to teach challenging concepts in genetics?

b. Lesson Observation

Observing two of the lessons from the concepts identified as challenging to teach in MSCE genetics

c. Post-observation Interview

3. (a) From the lesson observed, you have used .... methods in teaching challenging concepts in MSCE genetics. Do you have any reasons for choosing the strategy?

   (b) How do you assess learners' performance using the strategy described?

   (c) In what ways does the strategy used helps in identifying misconceptions in learners when teaching genetics?

Appendix 2: Permission Letter by Education Division Manager (NED)

Thandeka Andreah Nkhonde
Mzuzu University
Private Bag 206
Luwinga, Mzuzu 2.
17th September, 2013.

The Educational Divisional Manager (North)
P.O. Box 133
Mzuzu.

Dear Sir/Madam,

REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SECONDARY SCHOOLS IN MZIMBA SOUTH DISTRICT.

I am Thandeka Andreah Nkhonde, a teacher in the Northern Education Division. Currently am studying towards a master's degree in Teacher Education program at Mzuzu University. As a partial requirement for the award of the master's degree, am conducting research titled "**investigating strategies that Malawian biology teachers use to address teaching challenges in genetics.**" I would like to request for permission to conduct the study in four secondary schools within Mzimba South district from 13th October 2013 to 13th December, 2013.

The aim of the study is to investigate strategies that Malawian biology teachers use to address teaching challenges in genetics. I intend to conduct interviews and observe two lessons per teacher from the four secondary schools. The choice will be based on those teachers who are qualified and experienced to teach biology at senior secondary school level.

The privacy of the participants will be upheld throughout the study by using pseudonyms instead of real names for specific teachers and schools for fear of jeopardizing their profession.

I believe their participation in the study will be of significance to them in improving the teaching of genetics by identifying strategies to address teaching difficulties in genetics but also filling the knowledge gap that exists in teaching of genetics in the country.

I will look forward to your favourable consideration on the request. Feel free to contact me on +265996678548/882965343 or e-mail: thankhondeka49@hotmail.com in case of further questions

Yours faithfully,

Thandeka A. Nkhonde

Appendix 3: Consent to Conduct the Study

Thandeka Andreah Nkhonde
Mzuzu University
Private Bag 206
Luwinga, Mzuzu 2.
17th September, 2013.

The Coordinator
Masters' in Teacher Education
Mzuzu University
Private Bag 206
Luwinga, Mzuzu 2.

Dear Sir/Madam,

APPLICATION FOR CONSENT TO CONDUCT RESEARCH IN SECONDARY SCHOOLS IN MZIMBA SOUTH DISTRICT

I am Thandeka Andreah Nkhonde, a student of Masters' in Teacher Education program; currently in the second year of study. As a requirement for the award of the master's degree, I am conducting a research titled **"investigating strategies that Malawian biology teachers use to address teaching challenges in genetics."** under academic supervision of Dr F.C. Lungu. I would like to ask for consent from the department to conduct the study in Mzimba South district.

The aim of the study is to investigate strategies that Malawian biology teachers use to address the teaching challenges in genetics. The study will involve conducting interviews with the four teachers on the topic and observing two lessons per teacher on agreed sub-topic which is perceived as difficult by the teacher to be observed.

Ethical issues on privacy of the participating teachers and schools will be upheld throughout the study by using pseudonyms. Consent to take part in the study will be sought from subject teachers. Further request to conduct the study in the district will be sought from the Education Divisional Manager (North) and head teachers of the participating schools.

Your assistance on the issue will be appreciated.

Yours sincerely,

Thandeka Andreah Nkhonde.

Appendix 4: Head Teacher's Consent Letter

Thandeka Andreah Nkhonde
Mzuzu University
Private Bag 206
Luwinga, Mzuzu 2.
17th September, 2013

TO: The Concerned Head Teacher

Dear Sir/ Madam,

REQUEST TO CONDUCT THE STUDY AT YOUR INSTITUTION

I am Thandeka Andreah Nkhonde, a teacher in the Northern Education Division. Currently am studying towards a Masters' degree in Teacher Education at Mzuzu University. As a requirement for the award of the master's degree, am conducting a research titled "investigating strategies that Malawian biology teachers use to address teaching challenges in genetics**."** I would like to request for your consent to conduct the study at the school from 13th October to 13th December, 2013.

The aims of the study is to identifying areas in genetics that are difficult to teach, strategies used in addressing the teaching challenges and reasons for using a certain strategy in teaching difficult concepts in genetics.

I intend to conduct interview and lesson observation with the teacher from your school. The choice will be based on those teachers who are qualified and experienced with three years of teaching experience in genetics.

The privacy of the participants and the school will be upheld throughout the study by using pseudonyms. I believe their participation in the study will be of significance to them in improving the teaching of genetics by identifying areas that are difficult to teaching in genetics but also filling the knowledge gap that exists in teaching of genetics in the country.

I will look forward for your favourable consideration on the request. Feel free to contact me on +265996678548/882965343 or e-mail: thankhondeka49@hotmail.com in case of further questions.

Yours faithfully,

Thandeka A. Nkhonde.

Appendix 5: Informed Consent Form for Teachers

Thandeka Andreah Nkhonde
Mzuzu University
Private bag 201
Luwinga
Mzuzu 2
E-mail:thankhondeka49@hotmail.com.
Cell No: +265996678548/882965343

Informed Consent Form for Teachers

I, ______________________________ consent to participate in this study conducted by Mr. Thandeka Andreah Nkhonde on investigating strategies that Malawian biology teachers use to address teaching challenges in genetics. I understand that the researcher will use this study for educational purposes only and that my participation will not in any way render my job in danger by bringing negative consequences. I give permission for the data to be collected in form of visual during lesson observation and audio during interviews to be used for research or teaching only. As agreed by the researcher on research ethical issues, I understand that my privacy will be uphold throughout the study by using synonyms for all real names to be used in the interviews or class observation. Also, I have the rights to withdraw my participation from the project at any time without giving explanations for the cause and that I can make changes to any of my remarks that I realise is not in line with the intent of the research.

My participation is voluntarily and expects no payment in return for providing the useful information for teacher development in the field of biology.

Name: ____

Signature: ____

Date: ____