AN INVESTIGATION OF THE DIFFICULTIES IN TEACHING AND LEARNING OF GENETICS AND RELATED TOPICS

by

LISETEELI SILUMESI

submitted in accordance with the requirements for the degree of

MASTER OF SCIENCE

Life Sciences Education

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: PROFESSOR HARRISON ATAGANA

~~June~~ 2022

CONTENT

ABSTRACT

The focus of this study is to investigate the teaching and learning difficulties and their causes in genetics and related topics at grade 12 in Port Elizabeth District, South Africa. Qualitative and quantitative methods of research were both used to find answers to which genetics topics do learners and educators experience difficulties, the causes, and the possible solution to this problem. The qualitative design addressed the enquiry on the causes and the solutions to learning and teaching difficulties in genetics and related topics. The educators and learners had to express themselves relating their experiences as to the causes of the difficulties and how they think would be the effective way in solving these difficulties. This was achieved by the open-ended questions in the questionnaire. The qualitative approach was used to provide opportunity for the learners and educators to express their unique experience by responding to open ended questions. The educators and learners expressed what they have experienced using their own words, understanding, expressions and emphasis and not what is suggested to them. The quantitative approach was used to identify the concepts in genetics and genetics related topics that the learners find more difficult and to ascertain which of the causes identified by other researchers in other countries are true to the South African context. The educators and learners responded to multiple choice and scaled questionnaire which is structured. In this study the sample was made of schools, educators and learners that were willing to participate. To study the population divisions as former model C and previously disadvantaged schools stratified sampling was used. Since both quantitative and qualitative data was obtained, data analysis was carried out both quantitatively and qualitatively. Frequency statistics and categories were developed from the data. Out of the four hundred and one (401) learners, twenty-five percent (25%) indicated that they found genetics topics difficult and very difficult. It was observed that the percentage was higher by six percent (6%) in previously disadvantaged schools. Twenty-two percent (22%) of the 198 learners from former Model C and twenty-eight (28%) of the 203 learners from previously disadvantaged schools found genetics topics difficult and very difficult.

Dihybrid crosses was rated by the educators as the most difficult topic to teach followed by Inheritance and variation, Monohybrid crosses and Importance of the cradle of humankind.

Intrinsic causes based on the nature of genetics that were listed by the learners include the abstractness of the topic, and unique terminology. Extrinsic causes named included poor study habits, inappropriate teaching methods and shortage of textbooks. The following are the solutions that were listed to address the causes of learning difficulties of genetics experienced by learners and educators: implementation of new teaching strategies, genetics to be allocated more time for teaching and learning and for revision and reducing the content of the genetics syllabus.

The findings of this study necessitates that there be adjustments in the way the Life Sciences textbooks are written, the teaching methods used in the classroom and the resources in terms of teaching aids. It further postulates that the grade 12 National School Certificate Life Sciences results will improve significantly when the causes to difficulties in teaching and learning genetics and genetics related topics are resolved

The key words and terms in this study are:

Genetics, Genetics related topic, Life Sciences, learning difficulties, high school, effective strategies, effective approaches, teaching and learning resources, learner, educator.

DEDICATION

This work is dedicated to my wife Mulako, our children Siseho, Sepiso and Sibeso.

ACKNOWLEDGEMENTS

I am grateful to Prof HI Atagana, my supervisor. I thank my wife Mulako and children Siseho, Sepiso and Sibeso for giving me the time, support, and encouragement. I also extend my gratitude to Dr Gerald du Preez and Mrs. Catherine Njekwa for the support, encouragement, and facilitation of financial assistance. I would not have completed this work without the financial assistance given by the Southern Africa Union Conference of which I am thankful. I am grateful and thankful to Dr Rejoice Mawela and Prof Marc Schafer for their valuable critic, comments, and suggestions and for agreeing to review my research proposal despite their busy schedule and tight programmes. I will forever be grateful and indebted to the Almighty God Jehovah who has been with me through the entire process blessing me with life, health, ability, skill, knowledge, understanding and wisdom to do this work.

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1. Background

In studies conducted in Zambia (Haambokoma et al., 2002), Kenya (Inset Curriculum Review Committee, 2002), United States of America (Banet and Ayuso, 2000), Australia, New Zealand and United Kingdom (Treagust & Tsui, 2002), Turkey (Topcu & Sahin-Pekmez, 2009), Netherlands (Knippels, Waarlo & Boersma, 2005), and Taiwan (Chu, 2008) genetics has been reported as a difficult topic to learn. In South Africa, genetics, and related topics such as evolution questions in the National School Certificate (NSC) examinations were difficult for learners as reported in the 2020 National Senior Certificate Diagnostic Report (Department of Basic Education, 2020). The NSC 2012 Chief Marker's report (Department of Education, 2013) states that the pedigree and genetically modified foods questions yielded an overall of 41% and 29% learner performance, respectively. According to the NSC 2017 Chief Marker's report meiosis question was poorly performed at 26% and followed by Mutation and Speciation at 35% and then the scientific investigation on Natural Selection at 43%.

Genetics and inheritance are one of the major topics in Life Sciences with a weight of 30% (45 marks out of a total of 150) of paper two NSC examinations (Department of Education, 2011). The entire NSC Life Sciences paper two examination consists of genetics and genetics related topics namely meiosis, Deoxyribonucleic acid (DNA): code of life, evolution through natural selection and human evolution. Consequently, it is not surprising that the average pass rate of learners in Life Sciences NSC examination with a percentage pass of 40-100 was 46.2% and 43.2% in 2011 and 2012 respectively (Department of Education, 2012). This indicates that learners are experiencing difficulties in answering genetics and genetics related questions in the end of year examinations (NSC examinations), hence the need to research the teaching and learning difficulties and their causes. In a study conducted by the Institute for Science and Technology Education genetics was identified as one of the difficult topics together with evolution and cell division (Atagana et al., 2009).

It is important then to investigate the difficulties experienced by students in learning genetics, and genetics related topics such as evolution. This is because genetics and genetics related topics form 100% of the content of the NSC Life Sciences Paper two examination and 7% of the paper one. This translates to 53.5% of paper one and two together. This means students

could pass the NSC Life Sciences examination by 53.5% if they studied genetics and related topics alone. One hundred and sixty-one (161) marks of the three hundred (300) marks of Life Sciences papers 1 and 2 are on genetics and related topics. Below are the details from the Curriculum and Assessment Policy Statement (Department of Education, 2011).

Paper 1

Topic	Time	Weighting	
		%	Marks
Meiosis	1 week	7	11
Reproduction in vertebrates	½ week	4	6
Human reproduction	3 weeks	21	31
Responding to environment (humans)	4 weeks	27	40
Human endocrine system	1½ weeks	10	15
Homeostasis in humans	1 week	7	11
Responding to the environment	1 week	7	11
Human impact (grade 11)	2½ weeks	17	25
Totals	14½ weeks	100%	150

Paper 2

Topic	Time	Weighting	
		%	Marks
DNA: Code of life	2½ weeks	19	27
Meiosis	1 week	7	12
Genetics and Inheritance	4 weeks	30	45
Evolution through natural selection	2 weeks	15	23
Human evolution	4 weeks	29	43
Totals	13½ weeks	100%	150

Table 1.1 National Science Certificate Life Sciences examination paper weighting and assessment of topics in paper 1 and paper 2

The 2022 Annual Teaching Plan (ATP) for Grade 12 Life Sciences shows that the entire NSC Paper 2 Life Sciences examination consists entirely of genetics and related topics.

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

Term 3 52 days	*Week 1 18 – 22 July (4 days*	*Week 2 25 – 29July (5 days)*	*Week 3 1 – 5 Aug (5 days)*	*Week 4 8 – 12 Aug (3 days) Week 5 15 – 19 Aug (5 days)*	*Week 6 22 – 26 Aug (5 days)*	*Week 7 29 Aug – 2 Sept (4 days) Week 8 5 – 9 Sept (5 days) Week 9 12 – 16 Sept (5 days) Week 10 19 – 23 Sept (5 days)*
	the parts involved in thermoregulation **Role of the following in negative feedback mechanism for controlling temperature /thermoregulation**: Sweating Vasodilation Vasoconstriction	Thorns	Crossing-over Random arrangement of chromosomes Mutations Random fertilisation Random mating Continuous and discontinuous variation		Interpretation of a phylogenetic tree to show the place of the family Hominidae in the animal kingdom. Characteristics that humans share with the African apes. Anatomical differences between the African apes and humans, with the aid of diagrams, as it applies to the following characteristics: Bipedalism (foramen magnum, spine, and pelvic girdle) Brain size Teeth (dentition) Prognathism Palate shape Cranial ridges Brow ridges **SBA task: Assignment**	existence of the three genera The fossil sites where they were found: emphasis on the fossil sites that form a part of the Cradle of Humankind The scientists who discovered them • Genetic evidence: Mitochondrial DNA • Cultural evidence: T toolmaking Evidence for the Out of Africa hypothesis: Fossil Evidence: Information on each of the following fossils that serve as evidence for the Out of Africa hypothesis: *Ardipithecus*	**Cognitive levels: Knowing Science – 40%; Understanding Science-25%; Applying scientific knowledge-20%; Evaluating, analysing, and synthesising – 15%** **Degrees of difficulty for examination and test questions:** **Easy - 30%; Moderate - 40%; Difficult - 25%; Very difficult - 5%**

						(fossils found in Africa only) *Australopithecus* (fossils found in Africa only) *Homo* (Fossils of *Homo habilis* found in Africa	

PAPER 2

Marks: 150
Time: 2½ hours
Learners must answer all 3 questions.

TOPIC	MARKS
DNA: Code of life	27
Meiosis	21
Genetics and inheritance	48
Evolution (Evolution through natural selection)	54

Table 1.2 Life Sciences Gr.12 ATP Term 3 starting 19 July 2022

The researcher proposes to identify and evaluate the causes of learning difficulties in genetics and genetics related topics at high school level in Port Elizabeth Education District, South Africa. The identification of the learning difficulties and their causes will lead to understanding some contributing factors to the poor Grade 12 Life Sciences examination results, and the solution to the causes. Cimer (2012) found that out of 207 participants 107 stated that cell division, and genes and chromosomes were among the most difficult topics to learn. Factors identified include nature of the topic, the teaching methods which are teacher centred, student learning and studying habits, and lack of proper biology laboratories. This study focused on the South African situation, using Port Elizabeth Education District as a reference point. The causes of learning difficulties in genetics and genetics related topics such as meiosis, mitosis, and evolution were identified using qualitative and quantitative research.

2. Problem Statement

Life Sciences as a subject is not taken only by Natural Sciences students but is also a combination subject for students intending to follow other fields of study such as business

commerce and management studies, arts and culture, and human and social sciences. The subject combination for a learner who wants to pursue a career as an accountant may include Life Sciences as follows: Home Language, First Additional Language, Mathematics, Life Orientation, Accounting, Business Studies and Life Sciences. The subject combination for a learner who wants to pursue a career in Business Studies may include Life Sciences as follows: Home Language, First Additional Language, Mathematics, Life Orientation, Business Economics and Life Sciences. The subject combination for a learner who wants to pursue a career in Human and Social Sciences may include Life Sciences as follows: Home Language, First Additional Language, Mathematics, Life Orientation, Geography, and Life Sciences. Below is an example of one school's subject choice.

One subject must be chosen from each column.

COMPULSORY				CHOICE		
				GROUP 1	GROUP 2	GROUP 3
ENGLISH	AFRIKAANS 1st ADDITIONAL	MATH	Life Orientation	Life Sciences	Physics	Life Sciences
	IsiXhosa Home Language	Maths Literacy		History	Business Studies	Geography
				CAT	CAT	Accounting
					Visual Arts: Th + Paint/Draw	Consumer Studies
	(Present Language)	(Based on current performance)				Music

Table 1.3 Grade 10-12 subject choices of a school in Port Elizabeth

All learners will take English HL, one First Additional Language and Life Orientation.

This implies that a large percentage of students in grade 12 are studying Life Sciences. The pass rate of Life Sciences as a subject therefore affects many learners and careers. The pass rate of Life Sciences has not gone beyond 77% for past ten years at the pass mark of 30% and above. The pass rate drops to below 50% at the pass mark of 50% and above. The pass rate in Life Sciences in Port Elizabeth District now named Nelson Mandela Metro was 69.3% in the 2019 National Senior Certificate examination results when the pass mark is at 30%

and above and drops to below 40% when the pass mark is pegged at 50% and above (National School Certificate School Subject Report, 2019). This means most of the learners pass Life Sciences at low pass mark of between 30% and 50%. Life Sciences Paper 2 which consists mainly of genetics has a low pass rate. This goes without saying that genetics contributes heavily to the low pass rate in Life Sciences hence the need to find out and understand what are the underlying factors that causes this?

What are the main causes of learning difficulties in genetics and genetics related topics at high school level in Port Elizabeth Education District, South Africa? In other words, what are the main problems in high school genetics education for South African educators and learners in Port Elizabeth Education District? Though the study is focusing on Port Elizabeth District, the results are applicable nationwide and to a great extent globally.

3. Rational of the study

Since genetics and related topics form the bulk of the Grade 12 Life Sciences National Senior Certificate examination it may be inferred that identifying the teaching and learning difficulties of these topics and solving these difficulties will improve the Life Sciences pass rate. Consequently, this will improve the national pass rate. In addition, the importance of understanding and knowledge of genetics and related topics is becoming inevitable because of the latest developments such as new technologies where it is used in criminal investigation, reproductive technology, archaeology and human history, medicine, prenatal diagnosis etc. Attempts are being made to produce vaccines using gene technology (Thörne, 2012).

4. Aim and Objectives of the study

The study aims to explore the difficulties in teaching and learning of genetics and related topics experienced by educators and learners, respectively. In addition, the study also seeks to provide explanations for poor performance in Life Sciences and possible solutions to address the problem.

The objectives of the study include:

a. To establish the concepts in genetics and related topics that learners and educators experience difficulties to learn and teach, respectively.

b. To establish the difficulties that educators and learners are encountering in teaching and learning of genetics and related topics, respectively.

c. To explore the solutions to the difficulties in teaching and learning genetics and related topics as expressed by educators and learners.

d. To provide recommendations that may contribute to addressing the difficulties in teaching and learning of genetics and related topics.

5. Research Questions

The study sought to find answers to the questions:

Primary Research Questions

1. What are the learning difficulties in genetics and genetics related topics at grade 12 in Port Elizabeth Education District, South Africa?
2. What are the teaching difficulties in genetics and related topics experienced by educators?

Secondary Research Questions

1. Which are the concepts in genetics and related topics that learners are experiencing difficulties to learn?
2. What are the causes of the learning difficulties in genetics and related topics at grade 12 in Port Elizabeth Education District, South Africa?
3. How can the learning difficulties in genetics and related topics be solved?
4. Which are the concepts in genetics and related topics educators find difficult to teach?
5. What are the causes of the teaching difficulties in genetics and related topics in grade 12?
6. How can the teaching difficulties in genetics and related topics be resolved?

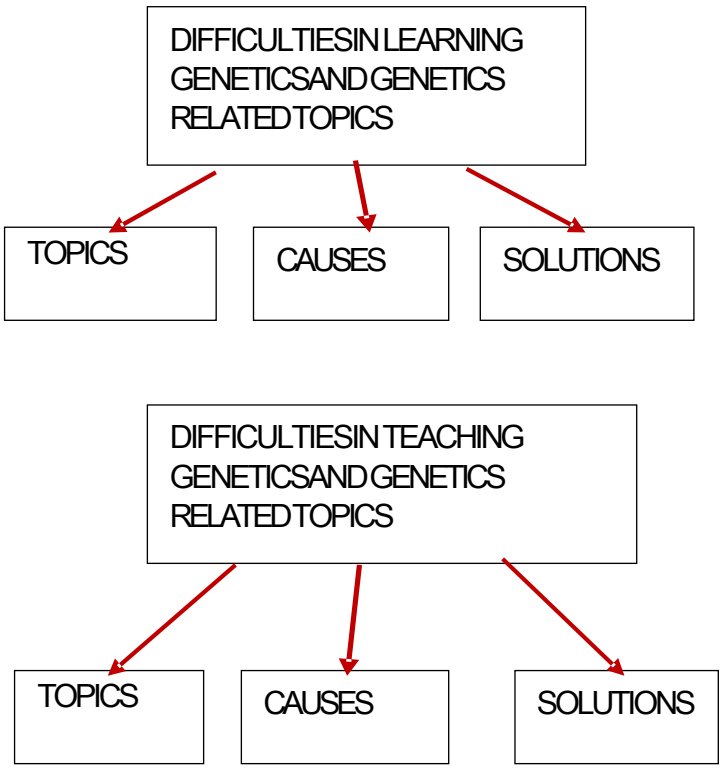
4. Significance of the study

The purpose of this study was to investigate the causes of learning difficulties in genetics and genetics related topics experienced by learners in high schools in Port Elizabeth Education District in South Africa. The results of this study though conducted at district level will pave a way to understanding the learning difficulties experienced by Life Sciences learners in the entire country of South Africa. It was hoped this study would contribute to improvement of teaching and learning of Life Sciences as subject and genetics and genetics related topics. Through the information that would be revealed by this study to curriculum developers, subject advisers, textbook writers, policy makers and educators, it was hoped the study would trigger development of effective strategies and approaches which would reduce learning difficulties in genetics and genetics related topics. It was further hoped that the study would lead to the production of teaching and learning resources that would improve the performance of learners in the NSC Life Sciences examination because of improved learning and declining or elimination of learning difficulties in genetics and genetics related topics.

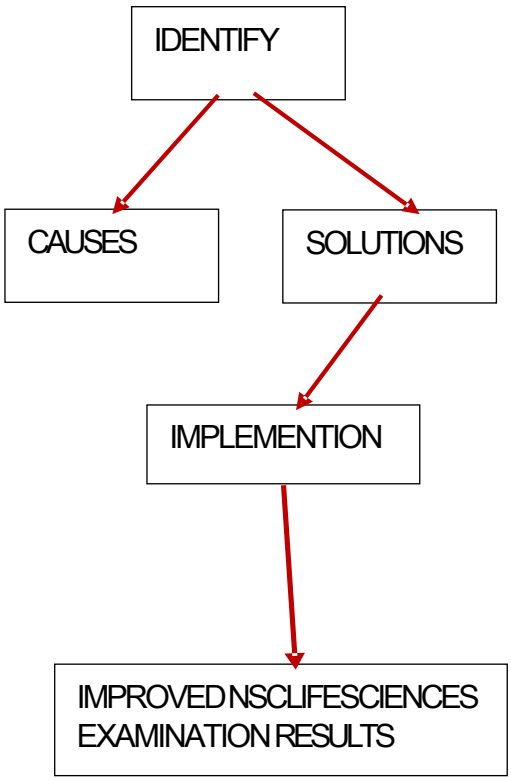
5. Conceptual and Theoretical Framework

Earlier researchers have established that learners and educators find learning and teaching genetics difficult respectively. Statistics from the Department of Basic Education reveal that the NSC Life Sciences pass rate is averaging at 40%. Since genetics and genetics related topics form up 53.5% of the NSC Life Sciences exam then the assumption is that solutions to the learning and teaching of genetics and genetics related topics should lead to improved pass rate of NSC Life Sciences examinations. The solution to improve NSC Life Science examination results lies in finding solutions to the difficulties of learning and teaching by learners and educators respectively.

CONCEPTUAL FRAMEWORK



THEORITICAL FRAMEWORK



6. Definition of terms

The key words and terms in this study are:

Genetics, Genetics related topic, Life Sciences, learning difficulties, high school, effective strategies, effective approaches, teaching and learning resources, learner, educator.

Genetics

Genetics is the branch of biology that studies heredity and variation in organisms (Klug et al., 2016). Genetics is one of the topics studied at high school level in grade 12. In the grade 12 curriculum the topic is referred to as “Genetics and Inheritance”. The content covered under this topic include genes, inheritance and variation, monohybrid crosses, dihybrid crosses, sex chromosomes and mutations (Department of Education, 2011).

Genetics related topics

Genetics related topics is used in this study to refer to topics that have a bearing to genetics namely Deoxyribonucleic acid (DNA), cell division (meiosis and mitosis), evolution by natural selection, and human evolution. According to the curriculum the content required to be covered under these topics include Deoxyribonucleic acid, ribonucleic acid, meiosis, mitosis, origin of ideas about origins, artificial selection, Darwin's theory of evolution by natural selection, formation/emergence of new species, mechanisms for reproductive isolation, evolution in present times, evidence of common ancestors for living hominids including humans, out of Africa hypothesis, importance of the cradle of humankind and alternatives to evolution (Department of Education, 2011).

Life Sciences

"'Life Sciences is the scientific study of living things from molecular level to their interactions with one another and their environments", quoted from Department of Education, 2011 p.8. Life Sciences is one of the learning areas or subjects studied at high school level. It is equivalent to Biology, the study of life.

Learning difficulties

Learning refers to the acquiring skills of knowledge, understanding, application of knowledge and synthesis of knowledge. The curriculum stipulates that learning has occurred when a Life Sciences learner develops:

i. Knowledge of key biological concepts, processes, systems, and theories

ii. Ability to critically evaluate and debate scientific issues and processes

iii. Greater awareness of the ways in which biotechnology and knowledge of Life Sciences have benefited humankind and what it means to be a responsible citizen and the contribution of South African Scientists

iv. An understanding of the ways in which humans have impacted negatively on the environment and organisms living in it

v. A deep appreciation of the unique diversity of past and present biomes in South Africa and the importance of conservation

vi. Scientific skills and ways of thinking scientifically

vii. A level of academic and scientific literacy that enables them to read, talk about, write, and think about biological processes, concepts, and investigations (Department of Education, 2011)

Learning difficulty is therefore a failure to attain or develop the above. It is important to also note that learning may be viewed from different perspectives namely Piagetian, cognitive and constructivist. From the Piagetian perspective focus is on levels of formal reasoning and problem solving, whereas cognitive perspective emphasises the concepts learners hold and how they process information and yet the constructive perspective focuses on differences in content and structure of personal and scientific knowledge and on bridging the knowledge gap (Kouicem, 2020). Learning difficulty will therefore include problems in developing formal reasoning and problem-solving skills, concepts, and information processing and, content and structure of personal and scientific knowledge.

CHAPTER 2

LITERATURE REVIEW

Context

In the research conducted by Cimer (2012) it was found that learning difficulties in biology include the nature of the topic, teachers' style of teaching, students' learning, and studying habits, students' feelings and attitudes towards the topic and lack of resources. Cell division, and genes and chromosomes, were among the topics that were listed that the students had the most difficulties learning. Reasons that have been reported as major causes to learning difficulties of genetics include vocabulary and terminology, mathematical content, the abstract and complex nature of the topic (Haskel-Ittah & Yarden, 2018).

In agreement with Cimer (2012) who listed students' learning and studying habits as one of the learning difficulties, Topcu & Sahin-Pekmez (2009) specified that memorisation of genetic concepts instead of conceptualising them was one of the difficulties experienced by Turkish Middle School students. In the same study lack of instructional resources, inadequacy of teaching time, and incorrect sequencing of subject matter were given as the other reasons.

Griffiths (2008) in his lecture on why students find genetics so difficult to learn lists the following reasons: the students being unskilled at numeracy, students having underdeveloped thinking skills, too much being cramped into course and textbook, the unfamiliar kind of assessment method of problem solving that genetics uses, and the ineffectiveness of traditional study methods towards learning genetics.

In a study conducted in Zambia (Haambokoma, 2007) inadequate explanation, the topic not being taught, the speed of lesson presentation, unfriendliness of the teachers, the scheduling of the topic, inadequate time for teaching, negative attitude, discouragement from teachers, poor mathematical knowledge, lack of learning resources, lack of practical activities, unfamiliar nature of the topic and too many terminologies were found to be the causes of learning difficulties in genetics. Has the South African education system taken these research findings into consideration? What are the causes of the learning difficulties in genetics that are experienced in South African schools, in Port Elizabeth high schools in particular? This was what this research focused on.

This study focused on the difficulties experienced by educators and learners in teaching and learning genetics and related topics, respectively. Are the difficulties pedagogical? Pedagogical difficulties relate to teaching involving such matters as have to do with lesson plans, from preparation to execution, approaches to teaching involving methods of teaching whether teacher centred or learner centred, teaching aids and even the classroom environment in general. Are the difficulties have to do with just genetics and related topics in themselves, that is, genetics being genetics, just because of what it is? Other studies have revealed the challenges experienced in other countries such as Zambia (Haambokoma et al., 2002), Kenya (Inset Curriculum Review Committee, 2002), United States of America (Banet & Ayuso, 2000), Australia, New Zealand and United Kingdom (Treagust & Tsui, 2002), Turkey (Topcu & Sahin-Pekmez, 2009), Netherlands (Knippels, Waarlo & Boersma, 2005), and Taiwan (Chu, 2008). The studies have confirmed that educators and learners find genetics difficult to teach and learn, respectively. This study focuses on the grade twelve learners of Port Elizabeth in South Africa. It is important to know what the difficulties educators and learners in this metropolitan city's experiences are in teaching and learning genetics, respectively. While other studies have restricted themselves to genetics only, this study goes further to include genetics related topics such as evolution, cell division, Deoxyribonucleic acid (DNA) and Ribonucleic acid (RNA).

Importance of Genetics and genetics related topics

Genetics and genetics related topics are very important in today's world which is faced and is experiencing critical issues such as "how safe are GMOs (genetically modified foods)?", "should human genome cloning be allowed?" Genetics knowledge has increased and is evident in new technologies where it is used such as criminal investigation, reproductive technology, archeology and human history, medicine, prenatal diagnosis etc. Attempts are being made to produce vaccines using gene technology (Thörne, 2012). To understand such issues and be able to discuss them intelligently one must have some knowledge of genetics. In addition, it may assist in dispelling wrong beliefs and myths about albinism and solve social issues such as women being divorced because they cannot give birth to male children. The understanding of how diseases such as cystic fibrosis and haemophilia come about requires knowledge of genetics and genetics related topics. Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) technology is a gene-editing tool consisting of a protein and RNA which can snip out sections of DNA and replace them with new, healthy genetic stretches. CRISPR technology is being tried on humans to remove and edit cells of people

with blood disorders such as sickle cell disease and beta-thalassemia and inherited form of blindness called Leber coigenital amaurosis 10. According to Live Science CRISPR's capabilities has made advances in the fight against cancer, HIV, Huntington's disease, Duchenne muscular dystrophy, malaria, and Lyme disease (Staedter, 2017). DNA is used in courts to solve complex cases. So, the understanding of genetics and genetics related topics has important political, social, medical, and legal impact. Secondly genetics is an important component of Life Sciences (Biology). It forms 30% of the grade 12 Life Sciences curriculum in South Africa (Department of Education, 2011). This makes the learning of genetics critical. Studies indicate that genetics is one of the most difficult topics (Gupta, 2019; Choden & Kijkuakul, 2020). Consequently, teaching of genetics becomes crucial.

Causes of learning difficulties of genetics

Studies indicate that the abstractness of genetics is one of the causes of learning difficulties (Cimer, 2012). Genetics deals with genes which are not visible and cannot be easily demonstrated or shown in high school laboratories if the school has any. This means the concept of genes must be abstractly conceptualised. The learners must create the reality of the genes using their imagination. How accurate these imaginations are depending on how the educator delivers the concept to the learners. The same applies for such concepts like meiosis, mitosis, DNA, RNA, monohybrid and dihybrid crosses, mutations and crossing over of genes. This is compounded by the reality that because of the abstractness of the concepts the educators tend to lecture them thereby rendering teacher-centered method as the main approach (Cimer, 2012). According to the concept of constructivism a teacher-centered approach is not effective because learning is not a passive process of simply receiving information but is an active construction and reconstruction of mental frameworks (Kouicem, 2020). Teaching for understanding is achieved by engaging learners in a series of processes namely elicitation, comparison, resolution and application in which the educator engages learners in some activity that requires them to reveal their initial knowledge, understanding and/or beliefs, the teacher using some form of demonstration that will contradict or challenge the learners' existing knowledge, the educator appropriately leading the learners to modify their previous understanding to accommodate new ideas, and finally the learners using their new understanding to further explore the concept under investigation respectively (Wieman, 2014)

In the study conducted by Cimer (2012), the educator's lack of mastery of genetics was identified as one of the causes to difficulties in learning genetics. To teach effectively an

educator must have a deep understanding of four types of knowledge namely knowledge of subject matter, knowledge about how learners learn, general pedagogical knowledge and pedagogical content knowledge. The educator should be able to interpret, discuss and explain genetics at molecular level dealing with DNA, RNA, ribosomal proteins, to micro level dealing with mitosis, meiosis, chromosomes, genes, crossing over, mutations, alleles, and genotypes. The molecular and microlevels should be linked to macrolevel explaining phenotypes. Effective learning would therefore occur proportionate to the understanding the educator has in teaching forms of content in ways that are consistent with general principles of teaching which are designed to enhance forms of learning.

Solutions to the causes of difficulties in learning genetics

Many studies have been conducted to find solutions to the causes of difficulties in learning genetics. Teacher centred teaching methods have been identified as one of the causes of difficulties to learning genetics (Cimer, 2012). Studies conducted by some researchers have come up with methods of how genetics should be taught as a possible solution to address the teaching and learning difficulties in genetics. Some researchers are advocating a migration from the traditional (teacher centered lecture method) to the modern methods of teaching genetics such as problem solving and project-based learning (Alozie et al., 2010; Rodriguez et al., 2018; John et al., 2019).

Problem solving is defined as the engaging of learners in a decision-making process leading to a goal, in which the course of thought needed to solve the problem is not certain (Jennifer & Jennifer, 2019). One of the modern methods of teaching genetics is scientific teaching (Gupta, 2019). Scientific teaching consists of three components namely active learning, assessment, and diversity. Active learning is characterized by students being actively engaged in learning process that includes enquiry-based learning, cooperative learning, or student-centered learning. The assessment component embodies a variety of tools used to measure progress towards the goals. Diversity entails making everything in the classroom unique. Another teaching method that is advocated is computer simulation instruction strategy (Akhigbe & Ogufere, 2019). Computer simulation instruction strategy is the use of a computer to represent the dynamic responses of one system by the behavior of another system modeled after it. A simulation uses a mathematical description or model of a real system in the form of a computer program. Another modern teaching method that is advocated is problem-based learning (PBL). Problem based learning is defined as an

authentic, experiential form of learning centered on the collaborative investigation and resolution of real-world problems (Fernandez, 2017). PBL involves engaging learners in real and meaningful problems and is characterized by a driving question, situated inquiry, collaborations, technology, and creation of artifacts (Alozie, 2010). Essentially PBL emphasizes learner inquiry-based learning in practical situations, encourages the creation of finished products based on learner experience, and motivates the cultivation of learner abilities in all aspects of the process (Liu et al., 2019). Choden & Kijkuakul (2020) in their research concluded that PBL's effectiveness is more enhanced when it is blended with scientific argumentation approach.

Other initiatives that have been developed as solutions addressing the difficulties of teaching and learning genetics include the development of programmes, establishment of organisations and Genetics Education Committees, holding special days, establishment of Genetics Resource Rooms and release of publications (Gupta, 2019). To assist in the teaching of genetics using e-learning in the United States the John Hopkins University has started the Online Genetic Assistant Training Programme which uses PowerPoint lessons with the lecturer's narration (Wang, 2020). Still in the United States they have established an organization that is responsible for developing resources for improvement of teaching genetics called the Genetics Society of America. The resources developed by the Genetics Society of America include Online web resources for teaching genetics such as 'GeneEd' and 'MendelWeb'. In a similar vein India has an organization called the India Society of Genetics and Plant breeding. In addition to societies and organisations, Genetics Education Committees used to address specific challenges in teaching of genetics are established. The societies and organisations hold events such as symposiums where best practices in teaching genetics are shared. The other initiative is the establishment of Genetics Education Resource Room where a collection of videos, animations, PowerPoint slides, games, problem sets, readings and simulations are available and can be accessed by educators and learners. Genetics journals containing articles on teaching of genetics in which some major problems are addressed, and solutions provided is one initiative that is used in United States and India (Gupta, 2019).

Teaching and learning genetics and genetics related topics in South Africa

South Africa is a developing nation and Port Elizabeth is a city. The grade twelve learners in Port Elizabeth are experiencing difficulties in learning genetics and related topics. What could be the causes of learning difficulties in genetics and genetics related topics experienced by the high school learners in this city of a developing nation? Are they pedagogical, curriculum induced, learner disposition propelled or inherent genetics and its related topics? This research seeks to find answers to these questions. According to the Department of Basic Education Diagnostic report (2019) performance in Life Sciences over the past five years is at an average performance of less than 50% at a pass mark of 40% and above as the table below shows. This drops to an average of 30% at a pass mark of 50% and above.

YEAR	PERFORMANCE % Achieved 40% and above
2016	45.2
2017	52.1
2018	51.7
2019	49.0
2020	47.9
2021	51.3

Table 2.1 Performance in Life Sciences

Candidates' performance indicates that they are still having trouble in some aspects of meiosis, genetics, and evolution. Some candidates could not differentiate between different terms such as centromere and centriole/centrosome, chromosome and chromatid, nuclear membrane and cell membrane, gene and allele, sex determination and sex-linked disorders, DNA replication and transcription. This report shows how necessary and important is a study such as this one that is looking into the causes to learning and teaching difficulties in genetics. The percentage of learners that have achieved fifty percent and above in the Grade 12 NSC Life Sciences examinations from 2015 to 2019 has not gone beyond fifty percent. In the same

period the learners that have achieved 40% and above has not gone beyond fifty three percent.

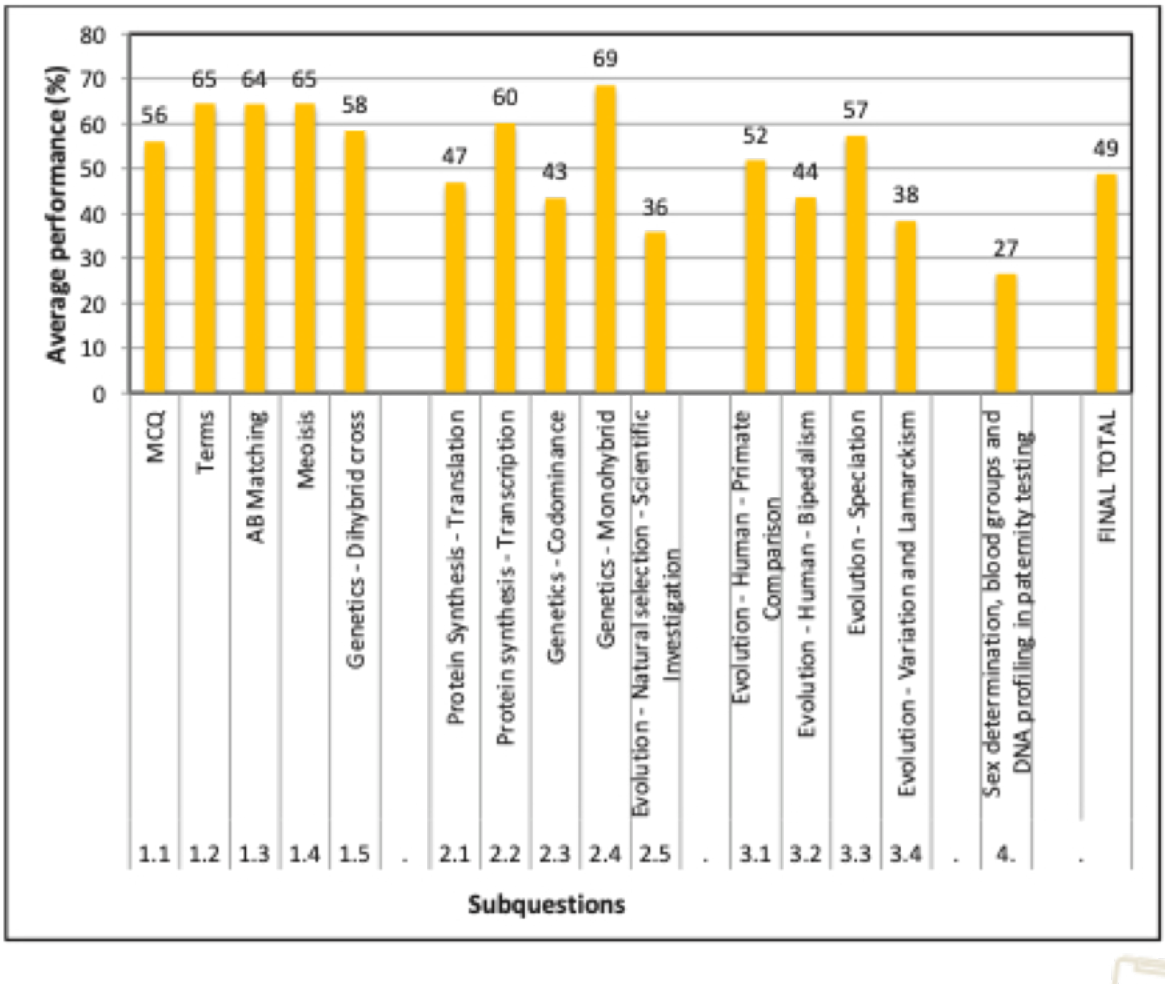
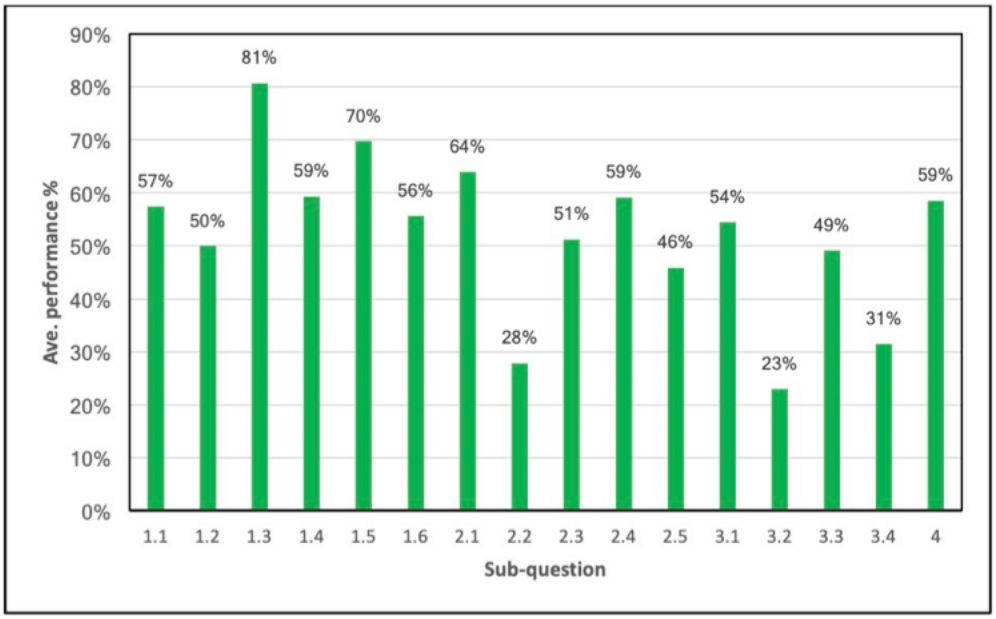


Table 2.2 Diagnostic report of 2019 National Senior Certificate average performance per sub- question in Life Sciences Paper 2

The table above is the diagnostic report for the 2019 National Senior Certificate performance per question in Life Sciences Paper 2. This further appeals to the need to find out what are the causes to the difficulties in teaching and learning genetics and genetics related topics the objective of this study. The average performance percentage should be read with the understanding that it is based on the number of learners that got a pass mark of 30% and above. As indicated earlier the average performance percentage drops to 30% and below when the pass mark of 50% and above is used. This is cause for concern hence the significance of this study. The diagnostic report for the 2020 National Science Certificate

performance per question in Life Sciences Paper 2 still portrays a similar picture as shown below.

Graph 8.6.2 Average performance per sub-question in Paper 2



Sub-question	Topic/s
1.1	Multiple-Choice Questions
1.2	Terminology
1.3	AB matching
1.4	Meiosis
1.5	Genetics - Dihybrid cross
1.6	Evolution - Evidence for evolution
2.1	DNA profiling
2.2	Genetics - Cloning
2.3	Genetics - Blood groups and genetic cross
2.4	Genetics - Mutations
2.5	Genetics - Pedigree diagram
3.1	Evolution - Natural selection
3.2	Evolution - Human evolution
3.3	Evolution - Scientific investigation (reproductive isolating mechanisms)
3.4	Evolution - Biogeography and Speciation
4	DNA - Location, structure, replication and significance of replication

Table 2.3 Diagnostic report of 2019 national Senior Certificate performance per sub-question in Life Sciences Paper 2

The 2021 matric results also show a similar trend. Below is the diagnostic report.

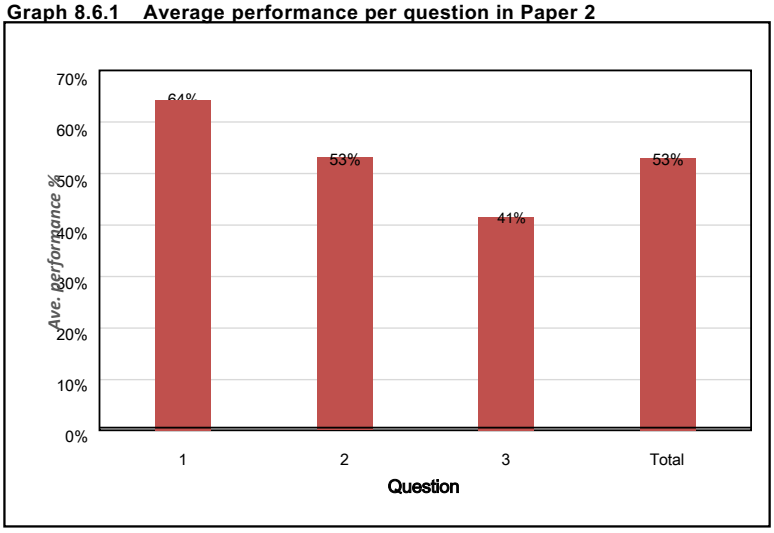
Overall achievement rates in Life Sciences

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2017	318 474	236 809	74,4	166 071	52,1
2018	310 041	236 584	76,3	160 208	51,7
2019	301 037	217 729	72,3	147 436	49,0
2020	319 228	226 700	71,0	153 028	47,9
2021	384 216	274 584	71,5	197 017	51,3

TABLE 2.4 Overall achievement rates in Life Sciences

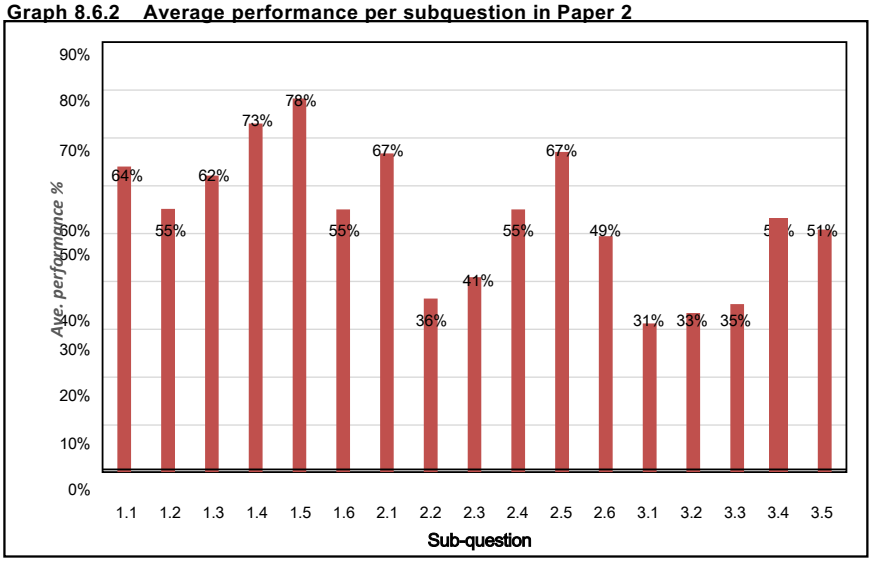
Life Sciences

Graph 8.6.1 Average performance per question in Paper 2



Q	Topic
1	Multiple choice, terminology, matching items, DNA, Meiosis, Dihybrid cross
2	Protein synthesis, Meiosis, Genetics
3	Genetics, Evolution

Graph 8.6.2 Average performance per subquestion in Paper 2



Sub-Q	Topics	Sub-Q	Topics
1.1	Multiple-choice Questions	2.4	Genetics - Pedigree diagram
1.2	Terminology	2.5	Genetics - Genetic cross
1.3	AB matching	2.6	Genetics - Mutations
1.4	DNA	3.1	Genetics - Cloning
1.5	Meiosis	3.2	Evolution - Speciation
1.6	Genetics - Dihybrid cross	3.3	Evolution - Natural selection
2.1	DNA - Protein synthesis	3.4	Evolution - Scientific investigation
2.2	Meiosis - Non-disjunction	3.5	Evolution - Human evolution
2.3	Genetics - Karyotype		

8.7 ANALYSIS OF CANDIDATE PERFORMANCE IN EACH QUESTION IN PAPER 2

Table 2.5 Diagnostic report of 2021 national Senior Certificate performance per sub-question

QUESTION 1: question NUMBER 1 Life Sciences PAPER 2 **MATCHING 2 ITEMS, DNA, MEIOSIS, AND A DIHYBRID CROSS**

According to the 2021 examination report, "Candidates' misconceptions performance indicates that they are still having trouble with certain aspects of meiosis, genetics and evolution." In Q1.1.5 and Q1.1.7 A *profile* to be analysed for many candidates, as they may be familiar with DNA profiling for forensics, but not sounding terms such as *homologous* and *homozygous*, the stem of the question in Q1.1.7 and resulted in many candidates responding incorrectly. Candidates were supposed to select the dominance. Candidates lost marks because they still confused similar sounding terms such as chromatid, chromatin, centriole, centromere, etc. This meant that the phases and not to be included in the response.

(a) The two multiple-choice questions in which candidates performed poorly were Q1.1.5 and Q1.1.7. They proved confused by problematic similar terms such as *co-dominance* and *complete dominance*. Candidates lost marks because they still confused similar sounding terms such as chromatid, chromatin, centriole, centromere, etc. This meant that the phases and not to be included in the response.

(b) Providing the correct biological terms in Q1.2 was problematic for many candidates. In this regard candidates:

Educators in Port Elizabeth are experiencing difficulties in teaching, instead of genetics and related topics. What difficulties in teaching genetics and related topics are experienced by the educators in Port Elizabeth? According to the 2020 report, difficulties could be due to misconceptions educators well have various such as *co-dominance* and *complete dominance* in genetics. This study focused on identifying the difficulties educators in Port Elizabeth were facing in teaching fossils and genetics related topics and solicited from the *Examination Guidelines* (2021) resolution to the problem.

- Provided responses, difficulties in *phylogenetic* trees and related in Q1.2.1; *punctuated* rather than *punctuated equilibrium* in Q1.2.3 and *artificial* rather than *artificial selection* in Q1.2.5.
- Lost marks due to poor spelling. Although credit was given in general for phonetic spelling. According to the 2020 report, the nature of difficulties could be due to
- Confused similar sounding terms, e.g. *homologous* and *homozygous* in Q1.2.4 as well as *co-dominance* and *complete dominance* in Q1.2.6.

(c) Candidates poorly in Q1.3.2 where they were asked to identify the fossils found in South Africa. This performance was unexpected, since these fossil names are usually solicited in the *Examination Guidelines* (2021) resolution to the problem.

(d) Performance in Q1.4 was encouraging, with infrequent misconceptions being presented. Some candidates confused *hydrogen* bonds and *peptide* bonds in Q1.2.2 and Q1.4.1 (c). Candidates used colloquial language to describe the shape of the DNA molecule in Q1.4.3 instead of using the scientific terminology.

(e) Many candidates lost marks due to misinterpretation of the question. This occurred in the following questions:

- Q1.2.4 where candidates responded to the *type of evidence presented* rather than the *structures* that serve as evidence
- Q1.4.5 where the response was *type of DNA* rather than the *location of DNA*

CHAPTER 3

RESEARCH METHODOLOGY

Research design

A mixture of quantitative and qualitative research approaches was used. This method is also called mixed method research (Doyle et al., 2016). Quantitative research approach focuses on figurative data and has the advantage of allowing the researcher to validate and test already constructed theories about how and why some occurrences happen. It also enables simplification of research findings when the data on arbitrary samples of sufficient mass. Other benefits include the fact that with the quantitative approach data is more precise and concise and the analysis of the data is less time consuming. On the other hand, qualitative research approach focuses on descriptive data from interviews, collected from participants' groups of explaining the meaning. It has the advantage of adequately describing complex phenomena and provides better focal point in as far as providing an understanding and description of people's personal experiences of such phenomena. Another benefit is that it enables the researcher to study dynamic processes (Almalki, 2016). It is based on harnessing the advantages from both approaches that in this study the mixed method research approach has been used. This method was chosen in order that a broader and more complete range of research questions would be tackled and provide stronger evidence in the conclusion through convergence and collaboration of findings of qualitative and quantitative data and results. Studies have been conducted on the teaching and learning difficulties and their causes in genetics in other countries such as Zambia (Haambokoma et al., 2002), Kenya (Inset Curriculum Review Committee, 2002), United States of America (Banet & Ayuso, 2000), Australia, New Zealand and United Kingdom (Treagust & Tsui, 2005), Turkey (Topcu & Sahin-Pekmez, 2009), Netherlands (Knippels, Warlo & Boersma, 2005) and Taiwan (Chu, 2008), and by using this method the already constructed theories are validated and tested.
The mixed method research approach may be done through the following research designs namely triangulation, embedded, explanatory and exploratory. In this study the triangulation research design was used. The qualitative and quantitative data were collected concurrently but remained separate. A sample survey design was used to collect qualitative and quantitative data, and this was in form of structured questionnaires administered to learners and educators. Quantitative data and results, and qualitative data and results were collected and integrated for analysis and interpretation.

The qualitative design addressed the enquiry on the causes and the solutions to learning and teaching difficulties in genetics and related topics. The educators and learners had to express themselves relating their experiences as to the causes of the difficulties and how they think would be the effective way in solving these difficulties. This was achieved by the open-ended questions in the questionnaire. The qualitative approach was used to provide opportunity for the learners and educators to express their unique experience by responding to open ended questions. The educators and learners expressed what they have experienced using their own words, understanding, expressions and emphasis and not what is suggested to them. The qualitative approach was used to find answers to the questions, “what are the learning difficulties in genetics and genetics related topics at grade 12 in Port Elizabeth Education District, South Africa?”, “what are the teaching difficulties in genetics and related topics experienced by educators?”, “what are the causes of the learning difficulties in genetics and related topics at grade 12 in Port Elizabeth Education District, South Africa?”, “what are the causes of the teaching difficulties in genetics and related topics in grade 12?”, “what are the solutions to the learning difficulties in genetics in genetics and related topics?”, and “what are the solutions to the teaching difficulties in genetics and related topics?” Since the study is dealing with what learners and educators are experiencing during teaching and learning of genetics the qualitative data and results were beneficial in providing a natural flow of events and processes. It also provided more insights in the concerns of the learners and educators. Though it was the intention of the researcher to conduct face to face interviews with all the sampled educators only two were available for the interview (one face to face and the other over the telephone).

The quantitative approach was used to identify the concepts in genetics and genetics related topics that the learners find more difficult and to ascertain which of the causes identified by other researchers in other countries are true to the South African context. The educators and learners responded to multiple choice and scaled questionnaire which is structured. Scaled multiple choice questions were used which is an effective tool for collecting quantitative data. The concepts that the grade 12 learners must cover are already outlined by the curriculum and the questionnaire had just to ask the respondents which of these concepts were the educators and learners experiencing difficulties and at what level of difficult (difficult or very difficult). A scale of 1 to 5 was used as follows:

1: very easy; 2: easy; 3: average; 4: difficult; 5: very difficult.

To find answers to the questions, “which are the concepts in genetics and related topics that learners are experiencing difficulties to understand?”, “which are the concepts in genetics and related topics educators find difficult to teach?”, the quantitative approach was used.

Research Paradigm

A research paradigm is a basic belief system and theoretical framework with assumptions about ontology, epistemology, methodology and methods (Rehman & Alharthi, 2016). Ontology answers what is reality. Epistemology is the study of knowledge. Methodology and methods deal with process of data collection and analysis. In this study positivism and interpretivism approaches are used. Positivism refers to a branch of philosophy that assumes that reality exists independently of humans and therefore researchers are objective observers studying phenomena that exists independently of them. It is because of this approach that influences the method of data collection. Numerical data (quantitative data) was generated in this study. The study also included an interpretive approach by investigating reality through the eyes of the participants and qualitative data was obtained from the participants.

Study Population

The study focused on grade 12 learners studying Life Sciences in High Schools in Port Elizabeth.

Pilot testing

The raw structured questionnaire was piloted at one school in Uitenhage, a town belonging to the same municipal demarcation as Port Elizabeth called Nelson Mandela Metro. The school had two grade 12 classes with a total of eighty (80) learners. The purpose of the pilot study was to refine the questionnaire. An appointment was secured with the Life Sciences educator through the Principal. The Life Sciences educator in consultation with the learners set the date. On the appointed date I delivered the questionnaires. The questionnaires were administered to the learners during their Life Sciences class period by the researcher. The Life Sciences educator also answered her questionnaire. From this pilot testing the questionnaire was refined and it became clear that interviews were not necessary with the learners. This is because the learners expressed themselves clearly and exhaustively in answering the open-ended questions of the questionnaire. Interviews were therefore dropped from the research methods for learners and reserved for educators. It also became clear that

there was no need to ask the learners to list or name the topics of genetics and related topics that they found difficult to learn.

Sampling

The population for this study was the grade 12 learners in the Port Elizabeth Education District. From this population the sampling was done using both non-probability and probability sampling methods. Non-probability sampling methods are convenience, voluntary, purposive and snowball and are used in qualitative research approach. Probability sampling methods are simple random, systematic, stratified, and cluster and are used in quantitative research approach (Taherdoost, 2016). In this study the schools were chosen using convenience sampling. The schools that responded positively to the request to carry out the research at their school automatically became part of the sample. Convenience sampling is where members of the target population that meet certain practical criteria, such as easy accessibility, geographical proximity, willingness to participate, or availability at a given time are included for the purpose of the study (Etikan et al., 2016). In this study the sample was made of schools, educators and learners that were willing to participate. To study the population divisions as former model C and previously disadvantaged schools stratified sampling was used. Stratified sampling involves division of population into smaller groups called strata which are formed based on members shared attributes or characteristics (Sharma, 2017).

There are 75 high schools in Port Elizabeth. Stratified sampling was used since the schools in Port Elizabeth have a history of apartheid and may therefore be divided into two main groups namely previously disadvantaged schools and former model C schools. There are 49 previously disadvantaged and 26 former model C high schools in Port Elizabeth. The ratio of previously disadvantaged schools to former model C schools is approximately 2:1, respectively. It was therefore determined that 4 schools will be from the previously disadvantaged schools and 2 from the former model C schools. The number and type of school was therefore determined using systematic sampling. Convenience sampling technique was used to choose the schools based on the systematic sample. Unfortunately, the fourth school was uncooperative such that the sample consisted of 3 and 2 previously disadvantaged and former model C schools respectively each with three grade 12 classes. Nevertheless, this does not create a bias because the study is not about schools but the learners and educators and their experience with genetics learning and teaching,

respectively. 401 learners and 5 Life Sciences educators from former model C schools and 7 from previously disadvantaged schools were surveyed. The table below summarises the profile of the educators. Letters are used to represent the individual Life Sciences educators and numbers to represent the schools where they were teaching.

EDUCATOR	SCHOOL	TYPE OF SCHOOL	PROFESSIONAL QUALIFICATION	TEACHING EXPERIENCE
A	1	Former Model C	Masters	>20 years
B	1	Former Model C	Bachelor's Degree	10-20 years
C	1	Former Model C	Bachelor's Degree	10-20 years
D	2	Former Model C	Bachelor's Degree	5-10 years
E	2	Former Model C	Bachelor's Degree	5-10 years
F	3	Previously Disadvantaged	Bachelor's Degree	10-20 years
G	3	Previously Disadvantaged	Bachelor's Degree	10-20 years
H	3	Previously Disadvantaged	Bachelor's Degree	5-10 years
I	4	Previously Disadvantaged	Bachelor's Degree	10-20 years
J	5	Previously Disadvantaged	Bachelor's Degree	10-20 years
K	5	Previously Disadvantaged	Bachelor's Degree	5-10 years
L	5	Previously Disadvantaged	Bachelor's Degree	5-10 years

Table 3.1 Profile of educators

The sample of this study was 7% of the Port Elizabeth high schools and 100% of the Life Sciences learners and teachers in the 7% sample were surveyed with a questionnaire. Each

of the schools had three Life Sciences classes. This interprets to 6 classes and 9 classes from former Model C and previously disadvantaged schools, respectively.

Instrumentation

Structured questionnaire and semi-structured interviews were prepared and administered to educators and learners. Consent to administer the questionnaires was sought from the educators and learners through the principal by email. Each school emailed back to confirm that the educators and learners had given their consent. No consent was sought from the parents of the learners because the grade 12 learners were 18 years and above with identity documents and have the right to make such a decision. The structured questionnaire consisted of the categories, multiple choice, scale, and open questions. There was a questionnaire for educators and a questionnaire for learners (students).

There are different types of survey instruments namely personal interviewing (face to face, telephone), self-enumeration (postal, hand-delivered) and computer assisted interviewing. The choice to use structured questionnaire and semi structured interviews was influenced by several factors such as the aim and objective of the survey, the data to be obtained and the accuracy required. To satisfy the cognitive and communicative processes the concepts in the questionnaire were tabulated exactly as they appear in the grade 12 curriculum and textbooks. This means the language, terms and expressions were familiar to the respondents.

On the structured section a scale of 1 to 5 was used. Studies have revealed that when respondents are given a choice of a rating scale from 1 to 5 where 1 is very low and 5 is very high, it is a very effective in capturing the informative, truthful, relevant and clear responses of the respondents.

Validity and Reliability

Validity is the extent to which a concept is measured accurately in a quantitative study. Reliability is the extent to which a research instrument consistently has the same results if it is repeated in the same situation (Heale & Twycross, 2015). The validity of the structured questionnaire was established by being proofread by two researchers whose opinions was sought as to the relevancy, clarity, and understandability of the questions. These researchers were randomly chosen from Rhodes University. The questionnaire was then administered on

a sample from a neighbouring district. In this way content validity (the extent to which a research instrument accurately measures all aspects of a construct), construct validity (extent to which a research instrument measures the intended construct) and criterion validity (extent to which research is related to other instruments that measure the same variables) were assured. The pilot study showed homogeneity (measuring one construct), convergence (measuring concepts like that of other instruments) and theory evidence (behaviour is like the theoretical propositions) of the questionnaire. According to Lincoln and Guba (1985) reliability is sufficiently established once validity is demonstrated.

Data collection

In this study a self-enumerated hand delivered survey questionnaire was used. A self-enumerated survey is one where the respondents complete the survey questionnaire. Although self-enumerated survey questionnaire may be posted, hand delivery was used because of the advantage of the response rate of this method. The Life Sciences educators were used as the executors and collectors of the questionnaire to the learners. This was deliberate to ensure that the learners were at ease and the questionnaire was answered in an environment that was natural and used to (familiar) the learners so that they would freely express themselves. The researcher visited the schools and the questionnaires were administered to the learners by their subject educators in the classrooms. The learners were informed of the purpose of the study and that they should not write their names on the questionnaire. In the same visits the questionnaire was also applied to the Life Sciences educators. In other words, as the learners were completing the questionnaire the educators also completed theirs. The researcher managed to interview two educators (one face to face and the other telephonically). The rest of the educators could not be interviewed because of not being available but completed the questionnaire.

Data analysis

Since both quantitative and qualitative data was obtained, data analysis was carried out both quantitatively and qualitatively. Frequency statistics and categories were developed from the data. The structured multiple choice and scaled responses were analysed quantitatively summarised in form of a frequency percentage. This was populated on a grid. The number

of learners who indicated each level in each school were counted and expressed as a percentage.

		NUMBER OF LEARNERS CHOSING LEVEL OF DIFFICULTY				
TOPIC	TOTAL NUMBER OF LEARNERS	1	2	3	4	5

The open-ended questions responses were analysed qualitatively. The qualitative analysis tools used were qualitative content analysis and qualitative thematic analysis. These were chosen among a variety of qualitative analysis tools namely content, thematic, narrative, discourse, grounded theory, and interpretive phenomenological (Li & Zhang, 2022). The responses were grouped based on similarity. Then the frequency of each group of responses was determined by the number of participants who gave that particular response. This was done by first giving each category of response a code after having gone through all the responses and listing them. Then the frequency of each response was determined by counting the number of times a particular response code appeared or was given. This was populated on a grid. This was then expressed as a percentage. Essentially the thematic analysis method as outlined by Braun and Clarke (2006) was followed by familarising with the data, generating initial codes, searching for themes, reviewing themes, defining, and naming themes and finally producing the report, (Kiger & Varpio, 2020).

RESPONSE					
FREQUENCY					

The narrative data obtained from the two educators that were interviewed, one face to face and the other telephonically was analysed qualitatively using content, narrative, and thematic analysis tools. The interviews were examined using content analysis based on the transcribed record where the guided interviews were documented. The frequency of an idea was thereby identified. The patterns from the educators' responses were identified using

qualitative thematic analysis. The data from the educators was grouped according to similarities. I used narrative analysis to gain insight in the way the responses were given.

There is some computer software that may be used to assist with qualitative analysis such as MAXQDA, NVivo, QDA Miner, and Atlas.ti (Gibbs, 2013). In this study Computer Assisted Qualitative Data Analyis was not used. The data was analysed using the qualitative analysis tools manually.

Ethical Issues

Permission was sought and granted from the Port Elizabeth Education District office to execute the questionnaire and conduct the interviews in the participating schools (Annexure 3).To ensure the rights of privacy of individuals the questionnaire did not solicit for identity of the learner and the school. Participation in the survey was voluntary. This was clearly explained to the participants before the questionnaires were administered. The raw data collected has not been published, only the findings form part of this research document.

Scope and Delimitation of the Study

The research provides insights into what genetics and genetics related topics the learners in some Port Elizabeth schools find difficulty in learning, their causes, and the suggested solutions. 401 learners were surveyed. Former Model C and previously disadvantaged schools were covered. Port Elizabeth is a Metropolitan city. The study also provides insights into the experiences of educators as to what genetics and genetics related topics they find difficulty to teach, the causes and suggested solutions. These are the educators that were teaching the learners in this study. 12 educators were surveyed (5 from former Model C schools and 7 from previously disadvantaged schools) of which 2 were interviewed (1 from a former Model C school and 1 from a previously disadvantaged school). No learners were interviewed.

Limitation of the Study

The study is confined to the schools in Port Elizabeth Education District. The study is not representative of schools in all the nine provinces of South Africa. Port Elizabeth is a Metropolitan city. No learners and educators in rural or independent schools were surveyed or interviewed. Findings in this study therefore cannot be generalised to all schools.

CHAPTER 4

RESEARCH FINDINGS

The following are the findings of the research:

1. The learning difficulties in genetics and genetics related topics at grade 12 in Port Elizabeth Education District, South Africa.

The findings below address the research question “Which are the concepts in genetics and related topics that learners are experiencing difficulties to learn?”. The qualitative approach was used to obtain these results. A questionnaire was used. The educators and learners responded to an open-ended question. The responses the learners and educators gave were coded, counted, and expressed as a percentage.

The following are the learning difficulties listed by both learners and educators:

a) inadequacy of textbooks

b) limited and non-availability of audio-visual teaching and learning material

c) the large volume of content required to be covered in limited time

d) the unique terminology

e) the abstractness of the topics

2. The teaching difficulties in genetics and related topics experienced by educators.

To address the research question, “What are the teaching difficulties in genetics and related topics experienced by educators?” educators were interviewed and asked to respond to an open-ended question in the questionnaire. The findings were coded, counted, and arranged in order from the most frequently occurring to the least mentioned.

The following are the teaching difficulties listed by educators:

a) shortage of textbooks

b) lack extra learner support material

c) 21st Century skill teaching versus old school teaching

d) absence of electronic learning

3.The concepts in genetics and related topics that learners are experiencing difficulties to understand.

The findings below were obtained from learners responding to a questionnaire question, and are addressing the research question, “Which are the concepts in genetics and related topics that learners are experiencing difficulties to learn?”. The quantitative approach was used to obtain these results. Educators and learners were provided with a list of genetics and related topics and asked to indicate on a scale of 1 to 5 the topics learners found difficult to understand where 1 is very easy, 2 easy, 3 average, 4 difficult and 5 is very difficult. The number of learners that recorded 4 or 5 were counted per topic and expressed as a percentage.

Learners had trouble in the following topics. The number of learners who had trouble per topic is expressed as a percentage and some of the highest percentages are the following:

Importance of the cradle of humankind	47%
Alternatives to evolution	43%
Out of Africa hypothesis	35%

The above are all genetics related topics. The genetics topics that have the highest percentage of being difficult are:

Dihybrid crosses	26%
Inheritance and variation	23%
Mutations	23%

These are the same topics the educators have indicated they find difficult to teach as per answers to question 2 below.

Table 4.1 Concepts in genetics and related topics that learners are experiencing difficulties

TOPIC	DIFFICULT %	VERY DIFFICULT %
Meiosis	6	3
Deoxyribonucleic Acid	8	4
Ribonucleic Acid	12	2
Genes	17	3
Inheritance and Variation	20	3
Monohybrid Crosses	14	5
Dihybrid Crosses	20	6
Sex Chromosomes	15	3
Mutations	18	5
Origin of ideas about origins	27	7
Artificial Selection	12	2
Darwin's Theory of Evolution by Natural Selection	11	3
Formation/emergence of new species	21	4
Mechanisms for reproductive isolation	24	7
Evolution in present times	25	5
Evidence of common ancestors for living hominids	23	10
Out of Africa hypothesis	24	11

Importance of the Cradle of Humankind	33	14
Alternatives to Evolution	29	14

The results that were obtained were in form of how many learners found the concept very easy (level 1), easy (level 2), average (level 3), difficult (level 4) and very difficult (level 5). Only level 4 and level 5 have been tabulated in the table above as that is the focus of this study. The number of learners that responded with level 4 or level 5 were expressed as a percentage by dividing the number of learners by the total number of learners (401) and then multiplying by 100. In other words, the following formula was used:

Level % = $^{n}/_{TOTAL}$ X 100 where n is the number of learners.

3. The concepts in genetics and related topics educators find difficult to teach.

The findings below were obtained from educators responding to a questionnaire question, and are addressing the research question, "Which are the concepts in genetics and related topics educators find difficult to teach?". The quantitative approach was used to obtain these results. Educators were provided with a list of genetics and related topics and asked to indicate on a scale of 1 to 5 the topics that they found difficult to teach where 1 is very easy, 2 easy, 3 average, 4 difficult and 5 is very difficult. The number of educators that recorded 4 or 5 were counted per topic and expressed as a percentage. The questionnaire question read, "Please look at the genetics and genetics related topics listed below and based on your teaching experience indicate by circling the number 1 to 5 how you as an educator find the topics difficult to teach."

Dihybrid crosses was rated by the educators as the most difficult topic to teach followed by Inheritance and variation, Monohybrid crosses and Importance of the cradle of humankind.

The genetics topics that have the highest percentage of being difficult or very difficult to teach as rated by educators are:

Dihybrid crosses	60%
Inheritance and variation	40%
Monohybrid crosses	40%

These are the same topics the learners have indicated they find difficult to learn as per answers to question 1 above. A quantitative approach was used to obtain these results. The educators responded to questions where they were to choose an answer according to the provided rating scale of 1 to 5 with 1 being very easy and 5 very difficult.

4. The causes of the learning difficulties in genetics and related topics at grade 12 in Port Elizabeth Education District, South Africa.

These findings are addressing the research question, “What are the causes of the learning difficulties in genetics and related topics at grade 12 in Port Elizabeth Education District, South Africa?”. The qualitative approach was used to obtain these findings. A questionnaire was used. The educators and learners responded to an open-ended question. The responses the learners and educators gave were coded, counted, and expressed as a percentage.

The following are the four main causes of the learning difficulties that were listed:

Terminology	44%
Abstractness of topic	15%
Insufficient time for study	13%
Tricky exam questions	10%

Table 4.2 shows the number of learners expressed as a percentage who listed the causes tabulated.

Table 4.2 Causes of the learning difficulties in genetics and related topics

REASON	FREQUENCY	%
Requires a lot of study	2	2
Tricky exam questions	11	10
Explanations not clear	5	4
Explanations done over short periods	6	5

Lessons taught fast	4	4
Terminology	49	44
How lesson is taught	2	2
Poor study habits	3	3
Abstractness of topic	17	15
Textbook shortage	7	6
Curriculum not completed	6	5
Insufficient time for study	14	13
TOTAL	112	100

The reasons listed above were all listed by the learners. The qualitative approach was used to obtain these results. The learners had to respond to open-ended questions.

5. The causes of the teaching difficulties in genetics and related topics in grade 12.

The research question that the findings below are addressing is, “What are the causes of the teaching difficulties in genetics and related topics in grade 12?”. The qualitative approach was used to obtain these findings. A questionnaire was used. The educators responded to an open-ended question, “What are the causes as to why some genetics and genetics related topics have been rated 4 or 5?”, that is difficult or very difficult respectively. Some educators were also interviewed. The responses the educators gave were coded, counted, and arranged in order from the most frequently occurring to the least mentioned.

The educators listed the following as the causes of the teaching difficulties:

i. the large content required to be completed in a short period

ii. the abstractness of the concepts

These results were obtained using the qualitative approach by asking the educators to respond to open-ended questions in the questionnaire. The educators indicated that genetics and genetics related topics were too bulky, there was too much content to be covered in a short time. They become overwhelmed by how to effectively teach so much content in so short a time. The educators also listed the abstractness of the concepts in genetics such as genes, alleles, crossing over, mutations and the list goes on, which must be mentally visualised.

6. The solutions to the learning difficulties in genetics and related topics.

To the research question, “How can the learning difficulties in genetics and related topics be solved?” below were the findings obtained using a qualitative approach by means of a questionnaire administered to learners and educators. Some educators were also interviewed.

The four most suggested as solution to the learning difficulties in genetics and related topics are as follows:

Increasing time for teaching and learning	21%
Teaching using living examples	20%
Giving enough time for revision	14%
Using videos	11%
Providing textbooks	11%

Table 4.3 tabulates the number of learners expressed as a percentage that listed each solution.

Table 4.3 Solutions to learning difficulties in genetics and related topics

SOLUTION	FREQUENCY	%
Learners to understand terms and practice	7	4
Implement new teachings strategies	6	4
Increase time for teaching and learning	35	21
Given enough time for revision	23	14
Change teachers	10	6
Teach using living examples	33	20
Provide study guides	11	7
Use videos	18	11
Provide textbooks	18	11
Reduction of syllabus content	3	2
TOTAL	164	100

7. The solutions to the teaching difficulties in genetics and related topics.

The findings below address the research question, “How can the teaching difficulties in genetics and related topics be resolved?”. A qualitative approach using a questionnaire and interview was used to obtain the results.

The educators listed the following solutions:

i. reducing the content of genetics and genetics related topics.

ii. addressing the causes to teaching difficulties by providing textbooks and audio-visual teaching aids.

The qualitative approach was used to obtain these results. The educators responded to an open-ended question “What can be done to overcome the difficulties educators experience in teaching genetics?”. The educators indicated that one solution was to drop the genetics and genetics related topics content from the grade 12 curriculum and push it to college and university curriculum. They felt that providing each learner with a textbook, study material and videos on genetics and genetics related topics would provide a lasting solution.The table below summarises the responses of the interviews conducted on two educators.

Table 4.4 Summary of responses of the interviews

INTERVIEW QUESTION	EDUCATOR’S RESPONSE
According to your experience which are the topics learners find difficult or very difficult in Life Sciences?	Genetics, DNA, and evolution
Are there specific topics in genetics or is it the entire genetics topic?	It is most of genetics although the dihybrid crosses, monohybrid crosses and inheritance and variation stand out
What about evolution, are there specific topics?	The cradle of mankind. Most learners do not believe in evolution. Maybe they get it from their parents or pastors I am not sure.
What about you as an educator, are there topics you find difficult to teach?	Evolution stands out followed by genetics
Why is it so?	Evolution is not scientific, it is kind of history, assumptions etc and learners get confused especially for those that believe in the Bible narrative of how life began. Secondly making learners understand the microlevels of genetics is quite a challenge because they must use their imagination. These learners are lazy to think.
What is the solution to all this?	The Department should reduce the genetics and evolution curriculum. It is too bulky. And besides these children are too young to be taught evolution. This should be moved to colleges and universities.

The interviews revealed that genetics and two genetics related topics namely DNA and evolution are pinpointed by educators as topics that are difficult to teach. It further revealed that learners find learning monohybrid and dihybrid crosses and inheritance and variation difficult to learn.

The in-depth analysis and discussion of the findings of this study is dealt in the next chapter.

CHAPTER 5

DISCUSSION OF FINDINGS

Genetics and genetics related topics learners experience difficulties

The research results show that the topics in genetics that learners had trouble are as follows in order of difficulty starting with the most difficult, dihybrid crosses 26%, inheritance and variation 23%, mutations 23% and genes 20%. Under dihybrid crosses the learners are expected to know Mendel's principle of independent assortment, dihybrid genetics problems, determination of the proportion/ratio of genotypes and phenotypes. Learners are to learn about harmless and harmful mutations with examples of diseases, disorders, genetic engineering (stem cell research, genetically modified organisms, biotechnology, and cloning). Under the genes topic, dominant and recessive genes and alleles are to be studied. Understanding of these topics requires conceptual understanding of fundamental genetics concepts of allele, phenotype, genotype, crossing over, heterozygous and homozygous. Some studies found that learners struggle with understanding the genetics related words such as homologue, homologous, homozygous and homozygote, mitosis and meiosis, chromosomes, and chromatids (Kilic *et al.*, 2016). The problem is compounded by that even the educators and textbook writers use genetics basic concepts incorrectly (Nusantari, 2014).

Understanding the concept gene is very central to understanding genetics. As has been found out in other studies (Boujemaa *et al.*, 2010) learners find understanding the gene concept difficult. Some scholars (Thörne, 2012) suggest that the reason why learners find understanding the gene concept difficult is because the gene concept is complex and that its complexity is brought about by the term gene having a lot of different meanings. This contributes in turn to the gene concept being portrayed differently in different textbooks contributing to confusion among learners thereby leading to learners finding problems in learning genetics (dos Santos, Joaquin & El-Hani, 2012; Gericke & Hagberg, 2010).

The results of this research show that learners found dihybrid crosses as the most difficult to understand. Studies suggest that the mathematical content of Mendelian genetics tasks contributes to learners having difficulties in understanding genetics. Dihybrid crosses use probability and symbols for phenotypes and genotypes, and this contributes to the problems that learners experience. This is compounded by the macro-micro problem (Kilic *et al.,* 2016).

When dealing with phenotypes in dihybrid crosses one is at the macro level of genetics involving visible characteristics such as colour, height, size and so on. When it comes to genotype the level changes to micro and even molecular involving genes, alleles which are invisible, not even visible to the light microscope. No direct experience is possible through touching at this level. Since this level is not directly accessible to the senses what is happening at microscopic and molecular level is represented and manipulated by mathematics (ratios and probabilities) which are symbolic which is challenging to learners. In addition, the micro and molecular level are dealt with in detail in Chemistry leaving the learners that are not doing Chemistry but doing Life Sciences at a loss. Some Life Sciences learners are not doing Mathematics and Chemistry and because of this the molecular level of genetics becomes difficult to understand (Osman *et al.,* 2017).

Genetics related topics that learners experience difficulties

The results obtained indicate that learners experience difficulties in understanding the following genetics related topics listed in descending order of difficulty: importance of the cradle of humankind 47%, alternatives to evolution 43%, out of Africa hypothesis 35%, Origin of ideas about origins 34%, evidence of common ancestors for living hominids 33%, and mechanisms for reproductive isolation 31%. Importance of the cradle of humankind deals with the main fossil sites in South Africa, looking at the evolutionary trends of the sites such as Sterkfontein, Kromdraai, Swartkrans, Malapa, Piovers Lake, Gladysvale, Makapansgat, Florisbad, Border Cave and also mention of scientists such as Dart, Broome, Tobias, Brain, Ron Clark, Berger, Keyser and others. Out of Africa hypothesis covers evidence of African origins for all modern humans focusing on Rift valley fossil sites and the fossils discovered at these sites such as *Ardipithecus, Australopithecus and Homo.* Under alternatives to evolution the focus is on different cultural and religious explanations for the origin and development of life on earth, creationism, intelligent design, literalism, and theistic evolution. Cultural, genetic, and fossil evidence is considered under evidence of common ancestors for living hominids. Mechanisms for reproductive isolation on the examples such as infertile offspring in cross-species hybrids, prevention of fertilization, adaptation to different pollinators (plants), species-specific courtship behaviour and breeding at different times of the year (Department of Basic Education, 2011).

The genetics related topics that learners find difficult are those that are about evolution. These topics are at the end of the curriculum. With educators and learners stating that

genetics and related topics is bulky and time to cover it is short it is likely that the evolution topics are covered in a hurry leaving most of the learners not understanding it. However, this needs to be tested by another research. The nature of Evolution topics is that they cannot be demonstrated and consists of theories and hypothesis which are contradictory to the beliefs of most of the learners resulting in the topic not being taken seriously.

Strong entrenched religious beliefs in educators and learners is a major cause of the problems affecting evolution education (Mpeta *et al.,* 2014). In their study, Mpeta *et al.,* reported that the influence of learners' beliefs manifested itself in learners refusing to accept the notion of evolution. Studies suggest that evolution may be taught more effectively by moving away from traditional teaching to extensively using structured active learning, focusing on scientific and critical thinking, and directly addressing misconceptions and student resistance. Active learning is defined as any instructional method that engages students in the learning process. In their study, they concluded that teaching of evolution could be more effective if teachers were in procession of the most up-to-date information and having access to richer lesson planning (Pobiner, 2016).

Genetics topics educators find difficult to teach

The results indicate that educators find the following genetics topics listed in their order of difficulty difficult to teach; Dihybrid Crosses 60%, Inheritance and Variation 40%, and Monohybrid crosses 40%.

As discussed earlier the Life Sciences learners may not be studying mathematics and chemistry, and are the majority, making it hard for these learners to grasp the mathematical and gene concepts which form the core of monohybrid and dihybrid and crosses. Understanding of the mathematical operation of probability and ratios is necessary to understanding genotypic and phenotypic ratios. The same applies to educators in that some completed their high school without doing mathematics and chemistry and completed their diploma in education without mathematics and chemistry. It is more effective to teach a topic where one has deeper information than the learners being taught. Some scholars (Satterthwait, 2018; Šorgo, 2010; Hoffman *et al.,* 2016; Karsai & Kampis, 2010) have suggested that mathematics should be linked to Biology (Life Sciences) and integrated as early as possible in schools as a solution to the ineffective teaching of genetics. Several

studies (Satterthwait, 2018) have also suggested changing the way the topics are taught (moving from traditional to active and inductive learning) including the order in which the topics are taught (teaching the inheritance process first, then using the data generated to seek explanations and associated vocabulary).

There are different methods of teaching. In this study we will restrict teaching to a process of assisting learners acquire new knowledge and skills, Mohan (2010). Teaching is therefore effective when learners are guided successfully to perform tasks with above average measurable results. Each topic is taught effectively using a particular teaching method which has been chosen based on fitness for a particular purpose taking into consideration the age, academic level of the learners, time available, physical environment, availability of teaching and learning resources (Chifwa, 2015). Examples of teaching methods include demonstration, question and answer, lecture, problem solving, discussion, and practical. An investigation into what type of methods the educators used to teach genetics was not part of this research.

Demonstration method of teaching refers to the teaching where learners are showed how. Chifwa (2015) states a good demonstration has clearly defined aims and objectives, can clearly be observed by each learner, involves the class at every stage, uses simple apparatus, has logical order of presentations, stimulates inquiry and curiosity in learners and is easily performed by learners (Mohan, 2010; Davar, 2012).

The Question-and-Answer method of teaching refers to where the lesson progresses in form of questions and answers. The questions are prepared beforehand by the teacher. They questions are asked in such a way that they progressively lead the learner from the known to the unknown concepts.

The lecture method of teaching refers to when the teacher presents to the class the facts about the concepts in a logical systematic manner. It is teacher-centred. The educator is active whereas the learners are passive. This method of teaching is at times referred to as the traditional method of teaching.

Problem Solving as a teaching method is one where learners set on an inquiry path by presenting to them a problem for which they should seek a solution. It therefore consists of activities requiring both subject matter knowledge and selection of appropriate cognitive strategies to find ways to reach the desired outcomes. The following have been suggested as phases of problem-solving interactive model (i) understanding the problem, (ii) gathering the necessary information, (iii) searching for the root of the problem, (iv) developing solutions (v) deciding on the best pathway, and (vi) solving the problem (Yew & Goh, 2016).

The discussion teaching method is one in which a two-way communication between participants is used to reach instructional objectives. Generally, it stimulates thinking, develops imaginative solutions to problems, prepares learners for application of theory and emphasises main teaching points. During discussion exchange of content, ideas and opinions takes place and learners practice how to express themselves clearly, explain content, justify opinions, and even tolerate different views (Chifwa, 2015). The learners therefore collaboratively construct their knowledge (Mohan, 2010; Davar, 2012).

The practical work teaching method is one where learners get the instructional objectives by hands on experiments. It enables learners to develop skills of investigation, observation, experiencing phenomena, data interpretation, prediction, hypothesis testing and critical thinking (Chifwa, 2015).

Educators may find genetics difficult to teach because of the teaching methods they are using. Cakir, (2011) concluded that there is evidence that inquiry-based instruction, enriched with computer simulation and collaboration promoted conceptual understanding of Mendelian genetics.

Genetics related topics that educators find difficult to teach

The topics that were listed by educators as difficult to teach in order of descending difficulty are: Importance of the cradle of humankind (40%), Out of Africa hypothesis (20%), Evidence of common ancestors for living hominids (20%) and Dawin's theory of evolution by natural selection (20%). Why the educators found these topics difficult to teach is a subject of another research. These are the same topics learners also found difficult to learn.

The topics on evolution are controversial as they touch on learners and educators' beliefs. Research has shown that educator beliefs influence how they value certain aspects of knowledge and consequently how much emphasis the educator will put on the topic (Cheng & Wong 2010). De Beer (2013) found in his research that educators in South Africa found it difficult to teach evolution based on lack of pedagogical content knowledge and their religious views. Some teachers feel teaching evolution is teaching "evilution" or "devilution" (De Beer, 2013) meaning it is evil and devilish respectively. Since many educators believe that acceptance of evolution is contradictory to the belief of a religious person, they therefore experience difficulties in teaching evolution to learners. In Christian and Moslem schools for example, the teaching of evolution causes negative reaction among learners, parents, and community members (Pillay, 2011).

Evolution through natural selection makes up 15% and human evolution 29% of the Life Sciences Paper 2 examination. This is a substantial 44% of the Life Sciences Paper 2 examination. The rest of the Paper 2 examination, 56%, consists of DNA 19%, meiosis 7%, and Genetics and inheritance 30%.

Causes of learning difficulties

The research shows that the main causes of learning difficulties are terminology (44%), abstractness of the genetics and genetics related topics (15%), insufficient time for study (13%) and tricky exam questions (10%).

Learners and educators listed the terminology used in genetics as the major cause of learning difficulty. They say genetics has many terminologies that are unique and confusing. In this research terminologies should be understood to mean vocabulary, words, and terms. The three sources that introduce genetics terminology to learners, namely the educator, the textbook, and the requirement of examination, do not use the words, terms, and vocabulary of genetics consistently. Educators are sources of vocabulary to the learners consequently the terminology difficulties experienced by educators are transmitted to learners. Learning of science involves learning a specific language, a way of talking about phenomena (Nusantari, 2014). Thörne (2012) suggests that the teacher's ambiguous use of words, different ways of relating gene to trait and unclarity about the role played by proteins could be source of the confusion learners experience. According to Thörne (2012) the words gene and trait were used interchangeably by educators such that learners took them to mean the same thing.

The existence of synonyms, misuse of terms and occurrence of redundant and obsolete terms were named as the different ways that genetics terminology causes difficulties. The terms such as gene and allele are confused. The misunderstanding of what is a gene leads to several misconceptions such that the gene concept is not related to other genetics concepts such as phenotype and genotype and let alone with DNA. The concept of gene is at micro level and in teaching it is introduced together with phenotype which is at the macro level resulting in learners finding it difficult to comprehend. The gene concept may not be explained without relating it to DNA which is at molecular level. The Life Sciences curriculum is such that DNA and genetics are taught at different separate times such that some educators/schools cover DNA in grade 11 and genetics in grade 12. This makes the learners not to relate genes to DNA. There are therefore words in genetics whose

explanation requires covering the molecular, micro, and macro levels thereby causing difficulties for it to be understood.

As mentioned earlier the existence of synonyms and similar words such as homozygous, homozygote, homologous, heterozygous etc. has been identified as causes of difficulties as far as genetics terminology is concerned (Chu *et al.,* 2012).

In a research conducted by Karagöz & Çakir (2011) it was found that the concept of “allele” was the most problematic concept among prospective biology educators. The study showed that biology educators had inconsistent, incomplete understanding and misconceptions of several basic Mendelian genetic concepts. This study’s research results that educators found monohybrid and dihybrid crosses, inheritance and variation are in line with these findings.

The second cause of difficulties listed by both learners and educators is the abstractness of the genetics and related topics. Genetics is intrinsically abstract and complex with content mostly at micro and molecular levels, which require imagination and mental visualisation to internalise the concepts. There is therefore movement in thinking across all the different levels (molecular, cellular, organismic, and population) in one lesson. Learning difficulties are caused by failure to interrelate the molecular, cellular, organism and population aspects (Berry, 2014). This is compounded by the fact that some genetics concepts may easily be appreciated if one has prior chemistry knowledge. A good number of learners doing Life Sciences are not in the science stream and therefore are not doing chemistry. There are learners in the commerce stream that are doing Life Sciences and there are learners in the humanities stream that are doing Life Sciences. These learners doing Life Sciences who are in the commercial and humanities streams are not doing Chemistry at all. By interpretation most learners doing Life Sciences are not Chemistry learners. The non-science stream learners have not done the progression of organization from atom to molecule to cell to tissue to organ, to organ system, to organism to species to population to ecosystem. Such learners are likely to experience difficulties in visualising the molecular level concepts of genetics. Visualising that the colour of a pea is because of a gene can be challenging for a non-science student. Genes cannot be seen and therefore their understanding depend on imagination and mental visualization.

Genes cannot be seen in a school laboratory. Mutations and inheritance cannot be experimented in the school laboratory. A lot of imagination and visualization must be used

to grasp the concepts. Audio visual teaching aids help in facilitating the imagination and visualization thereby speeding up the understanding of the concepts.

Insufficient time for study is the third cause of difficulty that was listed by both educators and learners. Educators indicated that the content for genetics was bulky and there was not sufficient time to complete it, whereas learners put it as there was not sufficient time to study. The study conducted by Chifwa (2015) concluded that educators taught genetics at the end of the grade 12 academic year consequently it was taught in a hurry and usually never completed. This contributed to the learners finding the topic difficult because it was taught in a hurry and because the learners were panicking.

The fourth reason listed by learners is tricky examination questions. This study did not investigate the type of examination questions and how they are asked. The listing of examination questions as a difficulty experienced suggests that learners are failing to transfer knowledge from one scenario to another. In other words, learners are experiencing problems in applying knowledge. This necessitates a close examination of how the learners learn, whether it is meaningful learning or rote learning. Meaningful learning happens when a learner has relevant prior knowledge, cognitive structures, and the intent to relate the relevant ideas to the new material substantively and non-arbitrarily. Put in another way meaningful learning occurs when a learner consciously and explicitly ties new knowledge to relevant concepts in the mind schema. This is the type of learning that can transfer knowledge to new situations and therefore the examination questions will not be tricky because they will be displaying similar situations encountered by learners in the classroom. However, the learners taught by rote learning will not be able to transfer the knowledge and will therefore find the questions difficult and tricky. Rote learning happens when learning is verbatim, sequential, and unrelated to learner's prior knowledge (Gupta, 2019). The difficulty of trick examination questions may be addressed by learning for understanding by educators paying attention to learners' learning processes.

Solution to learning difficulties

The following are the main solutions to difficulties of learning genetics that were listed by learners:

1. more time be given for teaching and learning 21%
2. teaching be done using living examples 20%

3. enough time be given for revision 14%.

These suggested solutions are not divorced from the ones earlier research have given (Chu *et al.,* 2012). The statement that “teaching should be done using living examples” is quite loaded. It suggests the following:

a) the planning and development of teaching strategies should consider learners’ previous knowledge,

b) that lessons should include activities that use many relevant examples and construct new knowledge,

c) the textbooks should sequence content from organism level descending through cellular to molecular levels and include activities that link content to current situations and realities.

Two solutions have to do with time, more time for teaching and learning and more time for revision. Each day has only twenty-four hours and no one can change that. However, we seemingly increase our time by accomplishing more work than before but in the same time. Let me use an illustration to explain this. A 200m X 200m garden field would take an individual one week to cultivate using a hand hoe. The same plot would take a day when ploughed by an individual using oxen. But the same plot would take an hour to plough by an individual using a tractor. By using the tractor, the time has been increased by six days and twenty-three hours when compared to the time required for the field to be ploughed by a hand hoe. A lot of the teaching and learning in genetics and related topics is still being done by the traditional method (“the hand hoe”) and more time would be made available if computer generated simulation lessons and games (“the tractor”) were incorporated in the classroom. Most of the learners if not all in grades eleven and twelve have access to smart cellphones which may be loaded with genetics PowerPoint presentations, genetics games and exercises and computer simulations about heredity, monohybrid, and dihybrid crosses. The DNA sequencing game played on a genetics app on a smart phone may enable the learner to grasp the concept faster than the traditional method.

Solution to teaching difficulties

Educators gave the following suggestions as solutions to teaching difficulties:

1. reducing the content for genetics and genetics related topics

2. addressing the causes to teaching difficulties which include bulky content required to be covered in a short time, and the abstractness and complexity of genetics.

A comprehensive solution may be arrived at by a holistic overview of both the solution to teaching and learning difficulties. Learners' viewpoint is that more time be given whereas educators suggest reducing the content so that the available time becomes sufficient. A Life Sciences Educator from a former Model C School responded in the questionnaire as follows: "The genetics and related topics has a lot of content which in my opinion is not necessary at high school. Some of the content needs to be moved to university. I feel all the Evolution topics should be removed from the high school curriculum and moved to university".

These solutions need to be interrogated further by another research to find out why is time allocated for teaching genetics and genetics related topics not sufficient as voiced by the learners. Is it because there is too much content to cover as stated by the educators or are there other factors? Are the educators teaching according to the time allocated by the Department of Education or do they spend more time on the topics they enjoy and then rush through the genetics and related topics? Is genetics and related topics taught towards the end of the year when already the panic about examinations is in the minds of the learners? Are the methods of teaching being used relevant and effective? Could it be old traditional methods are being used in the 21st century digital and electronic age? These are some of the questions such a research could address. The solution should also include addressing curriculum deficiencies as well as lesson plan inadequacies which are both indicated as causes of poor teaching and learning. Studies (Olanrewaju & Atangana, 2012) suggest that traditional teaching methods, cannot promote genetics understanding since the learners learn by rote resulting in them recalling facts but failing to apply knowledge to new experiences.

Out of the four hundred and one (401) learners, twenty-five percent (25%) indicated that they found genetics topics difficult and very difficult. It was observed that the percentage was higher by six percent (6%) in previously disadvantaged schools. Twenty-two percent (22%) of the 198 learners from former Model C and twenty-eight (28%) of the 203 learners from previously disadvantaged schools found genetics topics difficult and very difficult.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Conclusion

To the research question, “Which are the concepts in genetics and related topics that learners are experiencing difficulties to learn?” the study established that the genetics topics that Grade 12 learners find difficult to learn are dihybrid crosses, inheritance and variation, mutations, and genes. The genetics related topics that the learners found difficult are importance of the cradle of humankind, alternatives to evolution, out of Africa hypothesis, origin of ideas about origins, evidence of common ancestors for living hominids and mechanisms for reproductive isolation.

The research results show that terminology and abstractness of genetics, insufficient time for study and tricky exam questions are the main causes of learning difficulties for genetics and genetics related topics according to the responses from the learners, addressing the research question, “What are the causes of the learning difficulties in genetics and related topics at grade 12 in Port Elizabeth Education District, South Africa?”. From the research it has been found that learners believe the causes to learning difficulties may be alleviated by more time being given to teaching and learning of genetics and genetics related topics and for revision and that teaching be done using living examples, addressing the research question, "How can the learning difficulties in genetics and related topics be solved.

As pertains to the research question, “Which are the concepts in genetics and related topics educators find difficult to teach?” the results of this research revealed dihybrid and monohybrid crosses and inheritance and variation are the genetics topics educators find difficult to teach. When it comes to genetics related topics the educators struggle teaching importance of the cradle of humankind, out of Africa hypothesis, evidence of common ancestors for living hominids and Darwin’s theory of evolution by natural selection. The findings of the current study showed that educators identify the bulky content that is required to be covered in a short period of time, abstractness, and complexity of genetics as the main causes of the teaching difficulties. From the educators’ standpoint the causes to learning difficulties may be resolved by reducing the content of genetics and genetics related topics and addressing the causes of teaching difficulties, addressing the research question, “How can the teaching difficulties in genetics and related topics be resolved?”.

The findings of this study add to the conclusions other research studies have come up with on the same. The uniqueness of this one is that it portrays the current setting and for the Port Elizabeth Education District with an addition of the comparison between the former Model C Schools and previously disadvantaged schools. The current findings that are like previous studies suggest that the findings of the previous studies have not been taken seriously. It means that there has been little, or no attempt made to address the challenges that the studies unearthed.

Recommendations

There is no doubt that genetics is an important topic in high school curriculum as it equips the learners to be able to understand and take part meaningfully in society issues that are directly or indirectly involving genetics. Issues such as genetically modified foods, and gene technology have huge impact on the society. The importance of genetics is increasing. This is observed on its impact on health and society (Redfield, 2012). This research and the research before it have concluded that learners find genetics and related topics difficult, and the causes have been identified.

Based on the findings of this study it is recommended that:

1. The Department of Education and textbook writers consider the sequencing of the Life Sciences topics.

Genetics is abstract and complex as it consists of multilevel concepts of macro, micro, and molecular. Its subject matter requires that the learner must migrate across the three levels to understand. This means that there are some concepts and subject matters that should not be separated by space and time. Separating mitosis, meiosis, DNA, genes, monohybrid, and dihybrid crosses by having some taught in grade 11 and others in grade 12 with unrelated different topics in between causes confusion among learners.

2. The Department of Education streamlines the genetics and related topics

This study found that one of the causes for difficulties experienced in learning and teaching genetics and related topics is that it is bulky, and the available time is not enough for the content to be covered. Learners indicate that they do not have time for revision. Some of the evolution topics could be moved to tertiary level.

3. The Department of Education equip educators with non-traditional methods of teaching genetics and related topics

This study found out that one way the causes of difficulties could be addressed is to teach using living examples. Genetics knowledge has been increasing and society in general including learners have been impacted by technology. The traditional method of teaching is no longer as effective as it used to be in the past. Workshops in the emerging active learning instructional strategies should be conducted for educators and be introduced as part of the curriculum for those in tertiary institutions training to be educators (Gupta, 2019).

4. The Department of Education and the schools invest in audio visual aids for teaching genetics

This study revealed that learners indicated that they would grasp the genetics concepts easier if they were shown living examples or videos. DNA and genes are at molecular level and these cannot be seen or touched, and it would therefore be easier to grasp the concepts if computer generated simulations are shown to learners.

5. The Department of Education and the schools consider establishment of genetics associations at school, district, provincial and national level.

The association will serve to continuously upgrade the genetics materials and resources such as textbooks and teaching aids. It will assist in organising in-service training of educators in genetics and development of resources to augment the available textbooks. The association may organise workshops for educators to equip them with latest effective teaching methods and strategies. This way it will be ensured that all the educators nationwide will have the latest knowledge and understanding in genetics. There are many new methods and strategies that are being developed for genetics and genetics related topics. Currently these methods and strategies are only exposed to the inquisitive and enquiring educators who read journals and research papers, and these are very few. It will be more beneficial in the classroom when the new knowledge, methods and strategies are shared in seminars, workshops, and trainings organised by the genetics associations.

The associations would also continuously be exploring, researching, and looking for new, effective ways of teaching genetics. In this way the association would continuously be

ensuring new cutting-edge research proven methods and strategies are used in the classroom.

The association would ensure that the textbooks, workbooks, and other resources produced for learners would have the topics correctly sequenced such that learners are able to grasp the concepts and knowledge with ease.

REFERENCES

1. Achebe, j. N., and Ogufere, J. A. (2020). Effect of Computer Simulation Instructional Strategy on Students' Attitude and Academic Achievement in Genetics. *KIU Journal of Social Sciences 5*(4) 305 –315

2. Almalki S. (2016) Integrating Quantitative and Qualitative Data in Mixed Methods Research – Challenges and Benefits. *Journal of Education and Learning* 5(3) 288-296

3. Alozie, N., Eklund, J. Rogat, A., & Krajcik, J. (2010). Genetics in the 21st Century: The Benefits & Challenges of Incorporating a Project-Based Genetics Unit in Biology Classrooms. *The American Biology Teacher, 72*(4) 225-230

4. Atagana, H. I., Mogari, L. D., Kriek, J., Ochonogor, E. C., Ogbonnaya, U. I., & Makwakwa, E. G. (2009). An analysis of Educators' and Learners' Perceived Difficult Topics in Mathematics, Physical Science and Life Science at the Further Education and Training (FET) Band in Gauteng Province: A Report of the ISTE 2009 Winter School. Pretoria. Institute for Science and Technology, UNISA.

5. Banet, E., and Ayuso, E. (2000). Teaching genetics at secondary school: Strategy for teaching about the location of inheritance information. *Science Education, 84,* 313-351

6. Berry, K. (2014). Middle School Science: Using Conceptual Models to Develop Molecular Genetics Concepts

7. Boujemaa, A., Pierre, C., Sabah, S., Salaheddine, K., Jamal, C., & Abdellatif, C. (2010). University students' conceptions about the concept of gene: Interest of historical approach. *US-China Education Review,7*(2), 9-15.

8. Braun, V., Clarke V. (2006) Using thematic analysis in psychology. *Qual Res Psychol*. 3(2), 77-101

9. Cakir, M. (2011) Enhancing Mendelian genetics concepts using a guided Computer-mediated inquiry. *Journal of Baltic Science Education, 10*(3), 156-167.

10. Cheung, D., & Wong, H. W. (2010). Measuring teacher beliefs about alternative curriculum designs. *Curriculum Journal, 13*(2), 225-248.

11. Chifwa, J., (2015). The teaching of genetics in selected secondary schools in Kitwe district, Zambia. d*space. unza, zm:8080/xml*

12. Choden, T & Kijkuakul, S. (2020). Blending Problem Based Learning with Scientific Argumentation to Enhance Students' Understanding of Basic Genetics. *International Journal of Instruction, 13*(1) 445 - 462

13. Chu, Y., and Reid, N. (2012). Genetics at School Level: Addressing the Difficulties. *Research in Science and Technological Education,* 30(3) 285-309.

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

15. Davar, M., (2012). Teaching of Science. New Delhi. PHI Learning Private Ltd.

16. De Beer, J. (2013). Challenges in the teaching of evolution in the life sciences classroom. Retrieved January 25, 2021, from

https://uir.unisa.ac.za/bitsream/handle/10500/22517/*Josef%20De%20Beer.pdf?sequence=1&isAllowed=y.*

17. Department of Education Republic of South Africa (2011). Life Sciences National Curriculum Statement (NCS) Curriculum and Assessment Policy Statement. Cape Town: Government Printing Works.

18. Department of Education Republic of South Africa (2019). Report on the 2019 National Senior Certificate Diagnostic Report Part 1. Retrieved January 25, 2021, from

https://www.education.gov.za/Portals/0/Documents/Reports/DBE%20Diagnostic%20Report%202019%20-%20Book%201.pdf?ver=2020-02-06-140204-000

19. Department of Education Republic of South Africa (2021). National Senior Certificate 2020 Diagnostic Report Part 1: Content Subjects. Retrieved September 16, 2021 from

https://www.education.gov.za/Portals/0/Documents/Reports/2021%20NSC%20Reports/Diagnostic%20Report%202020%20-%20Part%201.pdf?ver=2021-03-25-105406-000

20. dos Santos, V. C., Joaquim, L. M., & El-Hani, C. N. (2012) Hybrid deterministic views about genes in biology textbooks: A key problem in genetics teaching. *Science & Education, 21*(4), 543-578.

21. Doyle *et al.* (2016) An overview of mixed method research – revisited. *Journal of Research in Nursing.* 21(8): 623-635

22. Etikan, I., Musa, S. A., & Alkassim, R. S. (2016) Comparison of convenience sampling and purposive sampling. *American Journal of Theoritical and Applied Statistics 5*(1) 1-4

23. Fernandez, F. B. (2017). Action research in the physics classroom the Impact of authentic, inquiry-based learning or instruction on the Learning or instruction on the learning of thermal physics. *Asia – Pacific Science Education, 3*(3). Doi: 10.1186/s41029-017-0014-z.

24. Gericke, N. M., & Hagberg, M. (2010). Conceptual incoherence as a result of use of multiple historical models in school textbooks. *Research in Science Education, 40*(4), 605-623.

25. Gericke, N. M., & Hagberg, M. (2010). Conceptual variation in the depiction of gene function in upper secondary school textbooks. *Science & Education, 19*(10), 963-994.

26. Gibbs, G. R. (2013). Using software in qualitative analysis. In: SAGE Handbook of Qualitative Data Analysis. Sage, London, UK, pp. 277-295. ISBN 9781446208984

27. Griffiths, T (2008). Why do students find genetics so difficult to learn? *The XX International Congress of Genetics,* Berlin, Germany.

28. Gupta, P. K. (2019). Teaching Genetics in India: Problems and Possible Solutions. *Indian Journal of Genetics 79*(1) 326-339

29. Haambokoma et al. (2002). Strengthening of Mathematics and Science in Zambian Secondary Schools: Baseline Study Report. Lusaka: JICA-Zambia.

30. Haambokoma, C. (2007). Nature and Causes of Learning Difficulties in Genetics at High School level in Zambia. *Journal of International Development and Cooperation,13*(1) 1-9

31. Haskel-Ittah, M. and Yarden, A. (2018) Students' Concept of Genetic Phenomena and its Effect on Their Ability to Understand the Underlying Mechanism. *CBE Life Sciences Education* 17(3).

32. Heale, R., and Twycross, A. (2015). Validity and reliability in quantitative studies. *Evid Based Nurs 18*(3) 66-67

33. Hoffman, K., Leupen, S., et al. (2016). Development and assessment of modules to integrate quantitative skills in introductory biology courses. *CBE-Life Sciences Education, 15*(2) 1-12.

34. INSET Curriculum Review Committee (2002). Report on SMASSE Inset Curriculum Review, 31st January 2002. Nairobi: SMASSE.

35. Jennifer S. A. and Jennifer K. K. (2019) Problem Solving in Genetics: Content Hints Can Help. *CBE Life Science Education 18*(23): 1-13

36. John *et al.* (2019) Effects of Concept Mapping and Demonstration Method on Senior Secondary two Biology Students' Achievement in Genetics in Jos North, Plateau State. *KIU Journal of Humanities* 3(4): 177-182

37. Karagöz, M., & Çakır, M. (2011). Problem Solving in genetics: Conceptual and Procedural difficulties. *Educational Sciences, 11*(3) 1668-1674.

38. Karsai, I., & Kampis, G. (2010). The crossroads between biology and mathematics: The scientific method as the basics of scientific literacy. *BioScience 60*(8), 632-638

Kiger, M. E., & Varpio, L. (2020). Thematic analysis of qualitative data: AMEE Guide No. 131, Medical Teacher, DOI: 10.1080/0142159X.2020.1755030

39. Kilic, D., Taber, K. S. and Winterbottom, M. (2016). A Cross-National Study of Students' Understanding of Genetics Concepts: Implications from

Similarities and Differences in England and Turkey. *Education Research International* (11): 1-14

40. Kouicem, K. (2020). Constructivist Theories of Piaget and Vygotsky: Implications for Pedagogical Practices. *Psychological and Educational Studies* 13(3): 359-372

41. Klug, W. S., Cummings, M. R., Spencer, C. A., and Palladino, M. A. (2012). Concepts of Genetics (10th Ed) San Francisco: Benjamin Cummings.

42. Liu *et al.* (2019) Effect of Problem Based Learning in Pharmacology Education: A Meta-analysis. *Studies in Educational Evaluation,* 60(May 2018), 43-58.

43. Li, Y., Zhang, S. (2022) Qualitative Data Analysis. In: Applied Research Methods in Urban and Regional Planning. Springer, Cham. Retrieved June 20, 2022 from

https://doi.org/10.1007/978-3-030-93574-0_8

44. Makowski, E. (2019). China Sentences Gene-Editing Scientist to Three Years in Jail. Retrieved January 25, 2021, from

https://www.the-scientist.com/news-opinion/china-sentences-gene-editing-scientist-to-three-years-in-jail-66881

45. Mohan, R. (2010). Innovative Science Teaching for Physical Science Teachers. 3rd Ed. New Dehli: PHI Learning Private Ltd.

46. Mpeta, M., de Villiers, J. J. R., & Fraser, W. J., (2015). Secondary school Learners' response to the teaching of evolution in Limpopo province, South Africa. *Journal of Biological Education, 49*(2), 150-164.

47. Nusantari, E. (2014) Genetics Misconceptions on High School Textbook, the Impact, and Importance on Presenting the Order of Concept through Reorganization of Genetics. *Journal of Education and Practice,* 5(36), 20-28.

48. Olanrewaju, O. S. & Atagana, H. I. (2012) The implementation of action research for the improvement of the teaching of genetics in South African high schools. Retrieved January 25, 2021, from

http://uir.unisa.ac.za/bitstream/handle/10500/22380/Oluwadare%20Samuel%20Olanrewaju%20%26%20H.I%20Atangana.pdf?sequence=1&isAllowed=y

49. Osman *et al.* (2017) An Investigation of Lebanese G7-12 Students' Misconceptions and Difficulties in Genetics and Their Genetics Literacy. *International Journal of Science and Math Education* 15: 1257-1280

50. Pillay, C. M. (2011). The difficulties faced by some teachers with strong religious beliefs when they teach evolution. Retrieved January 25, 2021, from

http://wiredspace.wits.ac.*za/handle/10539/11410.*

51. Pobiner, B. (2016). Accepting, Understanding, Teaching and Learning (human) Evolution: Obstacles and Opportunities. *American Journal of Physical Anthropology* 159(561): 232-274

52. Redfield, R. J. (2012). "Why do we have to learn?" - A new genetics for 21st century students. *PLoS Biol. 10:* e1001356.

53. Rehman,A. A. & Alharthi, K. (2016). An introduction to Research Paradigms. *International Journal of Educational Investigations 3*(8): 51-59

54. Rodriguez *et al.* (2018). Motivational active learning: An integrated approach to teaching and learning process control. *Education for Chemical Engineers 24*. 7-12

55. Satterthwait, D. (2018). Making biology count: integrating mathematics into the teaching of inheritance. *Journal of Biological Education, 53*(1), 92-97

56. Sharma, G. (2017) Prons and cons of different sampling techniques. *International Journal of Applied Research, 3*(7) 749-752

57. Steadter, T. (2017). 10 Amazing Things Scientists Just Did with CRISPR. Live Science. Retrieved January 25, 2021, from

https://www.livescience.com/59602-crispr-advances-gene-editing-field.html

58. Šorgo, A. (2010). Connecting biology and mathematics: first prepare the teachers. *CBE-Life Sciences Education 9*(3), 196-200.

59. Taherdoost, H. (2016). Sampling Methods in Research Methodology; How to Choose a Sampling Technique for Research. *International Journal of Academic Research in Management* (IJARM) 5(2), 18-27

60. Thörne K. (2012) Teaching Genetics - a Linguistic Challenge. A classroom study of secondary teachers' talks about genes, traits, and proteins. Universitetstryckeriet: Karistad.

61. Topcu, M. S., and Sahin-Pekmez, E. (2009). Turkish Middle School Students!"Difficulties in Learning Genetics Concepts. *Journal of Turkish Science Education 6*(2) 55-62

62. Wang, J. R. (2020). Optimising E-learning in Genetics: Creating and Comparing Three Categories of Multimedia. Retrieved January 25, 2021, from

https://banyanvisuals.com/wp-content/uploads/2020/03/JWang_Thesis.pdf

63. Wieman, C. E. (2014). Large Scale Comparison of Science Teaching Methods sends Clear message. *Proceedings of the National Academy of the United States of America* 111(23): 8319-8320

64. Yew, E. H. J. and Goh, K. (2016). Problem-Based Learning: An Overview of its Process and Impact on Learning. *Health Professions Education.* *https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.hpe.2016.01.004*

ANNEXTURE 1

QUESTIONAIRE(EDUCATOR)

This survey is aimed at finding out about the difficulties experienced by educators in teaching genetics and genetics related topics and the difficulties experienced by students in learning genetics and genetics related topics. The study is particularly interested in the topics that students find most difficult. The questionnaire is anonymous, and the information gained will help build a research programme into the difficulty's students and educators experience in learning and teaching genetics and genetics related topics, respectively. You are kindly requested to spend a few minutes answering the questions that follow. Thank you for your participation.

Question 1

Please look at the genetics and genetics related topics listed below and based on your teaching experience indicate by circling the number 1 to 5 how difficult the students find the topics to understand.

Topic	LEVEL OF DIFFICULT FOR STUDENTS				
	1 very easy	2 easy	3 average	4 difficult	5 very difficult
Meiosis	1	2	3	4	5
Deoxyribonucleic Acid	1	2	3	4	5
Ribonucleic Acid	1	2	3	4	5
Genes	1	2	3	4	5
Inheritance and Variation	1	2	3	4	5
Monohybrid crosses	1	2	3	4	5
Dihybrid crosses	1	2	3	4	5
Sex Chromosomes	1	2	3	4	5
Mutations	1	2	3	4	5
Origin of ideas about origins	1	2	3	4	5
Artificial selection	1	2	3	4	5
Darwin's Theory of Evolution by Natural Selection	1	2	3	4	5
Formation/ emergence of new species	1	2	3	4	5
Mechanisms for reproductive isolation	1	2	3	4	5
Evolution in present times	1	2	3	4	5
Evidence of common ancestors for living hominids	1	2	3	4	5
Out of Africa hypothesis	1	2	3	4	5
Importance of the Cradle of Humankind	1	2	3	4	5
Alternatives to evolution	1	2	3	4	5

Question 2

Account for why students are finding the topics you have rated 4 or 5 in question 1 difficult

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Question 3

What can be done to overcome the difficulties students experience in learning genetics?

_____

_____

_____

_____

_____

_____

_____

Question 4

Please look at the genetics and genetics related topics listed below and based on your teaching experience indicate by circling the number 1 to 5 how you as an educator find the topics difficult to teach.

Topic	LEVEL OF DIFFICULT FOR EDUCATORS				
	1 very easy	2 easy	3 average	4 difficult	5 very difficult
Meiosis	1	2	3	4	5
Deoxyribonucleic Acid	1	2	3	4	5
Ribonucleic Acid	1	2	3	4	5
Genes	1	2	3	4	5
Inheritance and Variation	1	2	3	4	5
Monohybrid crosses	1	2	3	4	5
Dihybrid crosses	1	2	3	4	5
Sex Chromosomes	1	2	3	4	5
Mutations	1	2	3	4	5
Origin of ideas about origins	1	2	3	4	5
Artificial selection	1	2	3	4	5
Darwin's Theory of Evolution by Natural Selection	1	2	3	4	5
Formation/ emergence of new species	1	2	3	4	5
Mechanisms for reproductive isolation	1	2	3	4	5
Evolution in present times	1	2	3	4	5
Evidence of common ancestors for living hominids	1	2	3	4	5
Out of Africa hypothesis	1	2	3	4	5
Importance of the Cradle of Humankind	1	2	3	4	5
Alternatives to evolution	1	2	3	4	5

Question 5

What are the causes as to why some genetics and genetics related topics have been rated 4 or 5 in question 4?

Question 6

What can be done to overcome the difficulties educators experience in teaching genetics?

ANNEXTURE2

QUESTIONNAIRE(STUDENTS)

This survey is aimed at finding out about the difficulties experienced by students in learning genetics and genetics related topics. The study is particularly interested in the topics that students find most difficult. The questionnaire is anonymous. Please do not write your name on this questionnaire. Thank you for your participation.

Question 1

Please look at the genetics and genetics related topics listed below and based on your learning experience indicate by circling the number 1 to 5 how difficult were the topics to understand.

Topic	LEVEL OF DIFFICULT FOR STUDENTS				
	1	2	3	4	5
	very easy	easy	average	difficult	very difficult
Meiosis	1	2	3	4	5
Deoxyribonucleic Acid	1	2	3	4	5
Ribonucleic Acid	1	2	3	4	5
Genes	1	2	3	4	5
Inheritance and Variation	1	2	3	4	5
Monohybrid crosses	1	2	3	4	5
Dihybrid crosses	1	2	3	4	5
Sex Chromosomes	1	2	3	4	5
Mutations	1	2	3	4	5
Origin of ideas about origins	1	2	3	4	5
Artificial selection	1	2	3	4	5
Darwin's Theory of Evolution by Natural Selection	1	2	3	4	5
Formation/ emergence of new species	1	2	3	4	5
Mechanisms for reproductive isolation	1	2	3	4	5
Evolution in present times	1	2	3	4	5
Evidence of common ancestors for living hominids	1	2	3	4	5
Out of Africa hypothesis	1	2	3	4	5
Importance of the Cradle of Humankind	1	2	3	4	5
Alternatives to evolution	1	2	3	4	5

Question 2

Give reasons why you found the topics you have rated 4 or 5 in question 1 difficult or very difficult?

_____

_____

_____

_____

Question 3

What can be done to overcome the difficulties students experience in learning genetics?

ANNEXTURE3

Province of the
EASTERN CAPE
EDUCATION

EDUCATION SOCIAL SUPPORT SERVICES – PORT ELIZABETH DISTRICT
46 Park Drive • St Georges Park • Port Elizabeth • Eastern Cape
Private Bag X3915 • North End • Port Elizabeth • 6056 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)41 – 508 8311 • Fax: +27 (0)41 – 508 • Website: www.ecdoe.gov.za

Dr. D. J Swartz (Educational Psychologist)

2018-04-23

Mr. L. Silumesi
3 Tenth Street
Orange Grove
2192

Dear Sir

PERMISSON TO CONDUCT RESEARCH IN SCHOOL

I acknowledge receipt of your request to conduct research at High Schools in the Nelson mandela Education District, within the field of Life Sciences towards your Masters Degree in Education. Your research involves an investigation of the teaching and learning difficulties and their causes in genetics and related topics at Grade 12 level

Permission for your research is herewith granted, with the provision that a bound copy of the thesis will be provided to the department upon completion. Furthermore, the department wishes you well with your research.

Please do not hesitate to make contact if you need further assistance.

Yours sincerely

Dr. Deon Swartz

ISEBE LEMFUNDO NEMKCUBEKO
DEPARTMENT OF EDUCATION
23 APR 2018
Education Social Support Services
DEPARTMENT VAN ONDERWYS

PGDP EASTERN CAPE

building blocks for growth

Ikamva eliqaqambileyo!