CONCEPTUAL UNDERSTANDING OF GENETICS AMONG STUDENT TEACHERS

BY

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DECLARATION

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I hereby declare that this research study: *Conceptual Understanding of Genetics among Student Teachers*, is my own work both in conception and in execution. All the sources that I have used or quoted have been acknowledged by means of complete references.

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DEDICATION

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ABSTRACT

This study sought to determine the level of competency in the knowledge, understanding and problem-solving skills in genetics by student teachers. The study also explored the student teachers' awareness of the application of genetics technology in their communities. The method adopted for the study was an integration of both quantitative and qualitative approaches in a way that the two approaches complemented each other. As a result of this approach, in some cases actual statements from the student teachers were used and exhibits of models they made were included to give a more concrete presentation of the student's levels of achievement in the areas of genetics tested.

The student teachers of the classes of 1995, 1996 and 1997, were used as guinea pigs in the validation and reliability testing of the instruments. A class of 1998 consisting of twenty five students were used for the actual experiment. Through the three years when the instruments were being refined, they were kept securely so that subsequent groups never got access to the instrument, except during the test period. After test sessions, the instruments were locked away. The test instruments included a written theoretical test, a practical test, and questions on the sexual harassment of girls by male teachers. There was also a non-scheduled interview with six subjects who were rich sources of misconceptions.

The findings of the study suggest that the overall performance of subjects in tasks that tested higher order learning in genetics was poor. The subjects did better in probes that tested lower order cognitive levels such as recall.

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The subjects showed difficulty particularly in understanding the process of meiosis but were quite comfortable with questions on mitosis.

There was a significant positive correlation between the subjects' knowledge and understanding of meiosis and ability to find solutions to genetic problems. The understanding of genetics was found to be critical in the successful solution of genetics problems.

The subjects displayed a very high proficiency level in the knowledge of heuristics for solving genetic problems. However, their procedural knowledge did not translate into abilities to solve genetics problems. There was a very low positive correlation between knowing heuristics and ability to solve genetics problems. No significant positive correlation between knowing genetics heuristics and the subjects' abilities to solve genetics problems was found.

The study found no significant difference between male and female subjects' achievement scores with respect to the selected concepts tested in the theory and practical tests.

The theory, practical test and the questions on sexual harassment revealed that subjects had misconceptions with reference to understanding certain concepts in genetics.

During practical work, student teachers showed a lack of interpretive and analytical skills. This was evident in that some models which were supposed to show a pair of homologous chromosomes showed more than one pair. The instructions in the practical directed subjects to use alleles A and a, but some subjects used A, B and Rr. This lack of ability to interpret simple instructions tended to point to poor language facility.

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While the majority of subjects rejected outrightly, the sexual harassment of school girls, other subjects thought some girls court rape by the way they dress.

The subjects in the research viewed rape as:

- ★ a violation of human rights of another person;
- ★ as a traumatic experience for the victim;
- as an act that has a life-time stigma attached to it for the victim.

During the writing of a plan for solving genetic problems (heuristics) the cooperative pairs that discussed their plans in English, finally gave a more coherent and logical presentation than those pairs who first discussed in Zulu followed by a translation. Most of the subjects who translated their responses tended to give direct translations which did not always convey accurately what they meant.

The subjects were found to be aware of genetic fingerprinting technology and its use in convicting rapists. This study showed that subjects had been exposed to biosocial issues related to technology in genetics.

CHAPTER ONE

ORIENTATION OF THE STUDY

1.1 **INTRODUCTION**

It is generally observed today that parents, want reliable and effective methods of instruction for their children. They want sound approaches that will produce good results in terms of providing learners with skills that will enable them to compete successfully in a technologically and scientifically dominated society. Parents therefore want their children to be taught by teachers who are effective communicators, in control of the subject matter, concepts and process skills they are required to teach. In describing a new vision for teacher education, Gultig (1995) suggests that teachers will need to be flexible, dynamic, thoughtful and able to work with change. The hallmark of competent teachers will be their ability to reflect on their teaching strategies and to introduce suitable intervention strategies to meet needs of their students.

This research will address one of the critical areas, of investigating students conceptual understanding of genetics. Not much has been done in this area in South Africa particularly with reference to African student teachers at university level . A lot of research has investigated difficulties encountered by students in mastering concepts in genetics (Wood-Robinson, Lewis, Leach and Driver 1997). This has resulted in several inventories of misconceptions or alternative conceptions which students have acquired in genetics. While most studies have focused on high school and first year students, not much has been done to find out whether or not prospective teachers also have misconceptions. An opportunity has therefore been missed to find out the likelihood of these misconceptions coming from teachers. Lack of continual classroom-based research might result in missed chances to correct existing misconceptions before student teachers complete their diplomas.

Human beings, even without science education have long known that many characteristics of organisms are passed on from generation to generation. Old women in rural African societies of South Africa have always used similarities between a new born illegitimate child and the father to confirm the offspring as belonging to their son. The study of genetics in schools, colleges and universities has therefore, hopefully, led to scientific understanding of how genetic traits are passed from one generation to the next. The scientific understanding of genetics principles had also led to the application of genetics in industry. For instance, in modern times, genetic engineering is used to improve the quality of crops and domestic animals (Dorit, Walker and Barnes 1991). Another interesting application of genetics to solve problems is when deoxyribonucleic acid (DNA) is used to prove conclusively that a suspect is guilty of rape and in cases of establishing paternity in cases where there is a dispute. Vernon a journalist for the South African paper the "Sunday Times" of the 21st 1999 announced that the police in South Africa had decided to use DNA to solve the problems of crimes. The intention of the police to extract DNA from the suspect resulted in a debate where some people thought this was in order and acceptable if it would solve the problem of crimes. However, there were those who debated that this action would be a great violation of human rights constitutionally.

Genetics is therefore a study that affects different aspects of our lives. The DNA fingerprinting technique is becoming very important in forensics. A DNA fingerprint represents a characteristic "snapshot" of the unique genome of an individual, allowing it to be distinguished from that of every other individual in the population. The quantity of DNA needed to analyze using polymerase chain reaction (PCR) is exceedingly small. This amount of DNA can be easily obtained from a single spot of dried blood, from the cells clinging to the base of hair shaft, from skin fragments under a victim's fingernails or other small tissue samples collected at a crime scene.

The Human Genome Project is one example which involves global collaboration and is evidence of the importance the international community has placed on genetics. The Human Genome Project is the first internationally co-ordinated effort in the history of biological research (Hildebrand, Torney and Wagner 1994). The aim of the Human Genome Project is to determine the complete sequence of the nearly 3 billion base pairs that constitute the human genome, and in it's course, to identify the 100 thousand or so genes that define the human species. The purpose of the huge Human Genome Project is to learn the DNA sequences that determine each organism's phenotypic characteristics and guide it's development. The information that will be obtained is critical for expanding and refining our understanding of cellular and organismal functions. The analysis of human genes in which mutation has led to disease is a primary objective of the Human Genome Project. Hildebrand et al (1994) reported that the Human Genome Project is already providing a flood of scientific valuable genetic information. That information could promote advances in diagnosis, prevention and therapy of genetic disorders. Genetics has now become a topic openly debated in the print media. The interest arises from the fact that genetics affects people directly. Knowledge of the structure and function of the genetic material has been found to be essential to an understanding of most aspects of living organisms (Suzuki, Griffin and Lewontin, 1989). Allen (1993), writing for *The Star* of the 25th February, stated that the heart of the Genome Project is to determine the exact sequence of the 100 000 genes which lie scattered along the deoxyribonucleic acid (DNA). The successful completion of research on the Genome Project will have a tremendous impact on the lives of all human beings. This project may produce genetic information capable of predicting potentially serious diseases which individuals might contract later in life. Therefore, the social impact of genetics on society justifies the need for all school leavers to have a good conceptual understanding of genetics or to be "genetically literate". It also underscores the need for all biology teachers to understand genetics and to teach it effectively.

The subject of genetics seems to permeate every aspect of society. Hayword (1991) has declared that genetics is a fundamental biological science which affects us all. This could be a good reason for the growing international interest in research involving students' understanding of genetics. Brenner (1990) suggests that since the discovery of the structure of DNA by Watson and Crick in 1953, molecular genetics has won itself a central position in the framework and understanding of living processes. It therefore seems advisable that students have a clear conceptual understanding of genetics in order to fully understand physically disabled individuals such as albinos, Down's Syndrome cases and haemophiliacs found in their communities.

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The flourishing research interest in genetics, particularly in developed countries, motivated the researcher to investigate this topic in a South African setting. South Africa is generally viewed by other countries as both developed and undeveloped because of the majority of its black citizens, the indigenous people who are still affected by extreme poverty. This research dealt with some of the students who came from these poverty stricken areas in South Africa. Labelling is not a good thing because it tends to become self-fulfilling, but the students in the research have always been referred to as disadvantaged students. The term only refers to the type of schools they went to which had very minimal resources. The term also refers to the poverty-stricken areas they lived in but does not refer to their cognitive abilities.

In genetics, students learn certain aspects of genes and their mode of transmission from generation to generation. Such knowledge should help students to understand problems of genetical nature better rather than relying on superstitions and other mystical explanations. Human intrusion into the genome already raises many ethical questions which need to be addressed wisely by well- informed citizens. In genetics students learn accurate scientific ways of explaining the genetic defects that may be found in their families and communities.

Genetics is one of the biosocially important topics prescribed in the grade 11-12 syllabus for South African schools. Grade 11 is equivalent to 'O'-level in the British system. The study of genetics is socially important because it affects people in a visible and sometimes emotional way. For example, as soon as children are born parents look for any significant genetic defects. It is therefore important that biology teachers think of the social impact of the understanding or lack of genetics understanding on the quality of life of their students. In all societies there are albino children whose existence may be explained in mystical or religious ways. A considerable number of African cultures believe that one gives birth to an albino as a disciplinary measure from God. The very Zulu name for an albino *(isishaywa)* implies one who has come as a punishment to parents for their sins. Another belief is that albinos do not die, but simply disappear. These cultural explanations are bound to interfere with the scientific explanations that students learn at school, and do very little to help albino children adjust to their condition.

Another example of misunderstanding of genetics is that of men who blame women for failure to bear male children or failure to produce an heir. The scientific explanation determining the sex of a child, is that the female carries 2 X chromosomes while a male carries a X and Y chromosomes. After meiosis the mother can only contribute one X and the father either an X for a girl or Y for a boy. Although in African societies a woman is blamed for not giving birth to male children, in scientific terms the man must be blamed. It is only men who carry the Y chromosome that gives rise to a boy. Attempts to explain these examples are dependent upon a good understanding of genetics. It was therefore the researcher's belief that there was a need to investigate the genetic literacy of senior secondary teachers in their professional training year. Genetically literate teachers will obviously play a major role in educating future citizens.

Teachers can only be effective in the classroom if they become confident about their subject content. Confidence with one's subject matter promotes creativity with the way one presents lessons, since one is not afraid to be embarrased clever learners.

Russel(1993) states that if teachers lack adequate science background they may miss the significance of ideas that children bring to the classroom. African schools are staffed by teachers who seem to be very poorly prepared for the task of teaching (Anstey 1997, Cooke 1997). One of the reasons for this is the lack of effectively mastered skills in the different disciplines they teach (Sanders 1993, Gultig 1995). There is therefore a need to develop diagnostic monitoring tools consisting of criterion-referenced tests (CRTs) which should be administered and followed by remediation, in order to raise all the participants to the required standard. These should aim to pinpoint any problems student teachers may experience in mastering the concepts they will be required to teach in future.

1.2 BACKGROUND TO THE PROBLEM

This research study had its origins in 1994 when it was realised that student teachers in their professional training year had difficulty solving basic genetic problems. It was not clear why these students experienced difficulties and what intervention could be employed to assist students. A second motivation was a television documentary in which qualified nurses in Venda were visiting rural families with children who had genetic defects. Their role was to counsel families to deal with the children's disabilities and to reassure them that the disabilities were not brought about by punishment from God, by witchcraft or other mystical powers. This documentary made it appear quite urgent that schools should do more in terms of making sure that they produce school leavers that are "genetically literate".

Genetics as a topic lends itself well to making both teachers and pupils aware that science and its applications raise issues that impact on society, economics, politics, ethics and religion. A genetics course taught for conceptual understanding prepares pupils for adult life in that it discusses issues that they will face in real life.

The researcher was also involved in in-service programmes that offered support to teachers in their schools. The support involved workshops on strategies of teaching, curriculum development, issues of understanding content, authentic assessment and classroom material support. The workshops covered teachers in the Newcastle, Ulundi and some schools around Empangeni. Teachers from all these schools specifically requested help with teaching genetics to grade 11. It was very clear that genetics as a topic is not only a problem to learners but to teachers as well. With matric failures so high in Kwa-Zulu Natal, it was felt that it is important to find out whether the problem is in the way teachers are trained or this is caused by other factors. There should be ways of finding out whether teachers come out confident in the content they have to teach. Having teachers who are competently qualified in what they teach will not automatically solve all the problems but it would be a step forward in solving some of the problems affecting poorly performing schools.

Employment prospects have also been opening up in the fields of genetics, molecular biology and biotechnology. It therefore seemed an opportune time to investigate whether or not present teaching strategies are producing teachers who have a sound conceptual understanding of genetics. The study concentrated on the understanding displayed by student teachers during the year 1998 at the University of Zululand.

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Many of the African schools in South Africa offer biology as a science course in grades10, 11 and 12. Most schools in the black communities cannot offer physical science because of lack of qualified personnel, facilities and appropriate equipment for the effective teaching of this subject. The main science option offered in African schools is biology. Thus students could learn problem- solving through genetics, particularly because about 85% of African students elect biology as their science option (Gouws 1997). Many researchers (Longden 1982, Stewart 1982, Browning and Lehman 1988, Whackling and Lawrence 1988, Brown 1990, Kindfield 1994, Moletsane and Sanders 1995) confirm that genetics offers plenty of problem -solving opportunities for students. They also agree that concepts in the biological theory of genetics are abstract and very difficult for students to grasp. However, students can master problem-solving skills if they are taught by teachers who are themselves competent in problem-solving in genetics. This investigation therefore looks at the competency of student teachers to deal with a range of skills and concepts taught in a grade 11 basic genetics course. Particular emphasis was placed on investigating their ability to solve simple genetic problems. This is important because there has been a shift in educational circles from rote learning to problem solving. It was therefore crucial to test whether or not learning genetics in the science faculty has led to the ability on the part of students, to use their knowledge to respond to genetics questions competently and to show their ability to apply it when necessary to solve problems.

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This study was prompted by concerns publicly debated in the print media about how teacher education institutions are producing poorly trained teachers. Articles that have appeared in the local papers have been so critical of teachers that it has been impossible for educators to ignore the criticism. The media outcry became an inspiration to investigate one aspect of the curriculum that is critical in biology education, particularly because it involves mastery of problem- solving skills. Anskey (1997:8) wrote an article in the Sunday Times entitled, 'Teachers send the pupils on the road to nowhere', that mathematics and science teaching in South Africa is disastrous. A similar article appeared in 'The Star', in which Cooke (1997:8) drew attention to the fact that many mathematics and science teachers are unqualified. Science educators have also been disturbed by the fact that many teachers harbour misconceptions or alternative conceptions about various science concepts (Adey and Shaver 1994, Sanders 1993). It is now usual to hear the public and employers expressing concern at the apparent low level of thinking manifested by students at the end of their schooling. This outcry about poor standards involves both teachers and their students, creating a vicious circle. There was therefore a need to start engaging in research beginning at micro-level, that would offer ideas on appropriate strategies of intervention to rehabilitate our ailing education system.

The effective teaching of genetics can be enhanced by research which investigates how students cope with learning science concepts. The researcher was interested in developing a tool that could be used to monitor the development of concepts, science process skills and general competencies required for effective problem-solving in genetics. Genetics

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was chosen as a focus point because it is a topic that offers a lot of opportunities where students can practice realistic problem solving. Genetics is also one of those topics that are relevant to our daily lives. For instance when someone in the family suffers from diabetes or has a heart attack the family tree is immediately traced as to see who of the ancestors had these diseases. Although the problem solving skills gained in genetics relate to a specific domain of learning, one hopes the skills gained in learning how to approach problem solving in genetics would be transferable to other areas of life. The researcher would use this tool to get a picture of the status of knowledge and the understanding of genetics concepts held by student teachers. Monitoring tools are important in any educational system because they uncover problems which, when solved, lead to the improvement of the education system.

1.4 **STATEMENT OF THE PROBLEM**

Teachers cannot function effectively if they are not sure of the content of their subject. It is therefore important to make sure that during the professional year in teacher education, the programme monitors their proficiency in the subjects they will teach. In the grade 11 and 12 biology syllabus, there are topics which have already been identified as difficult to grasp. Among these topics are genetics, biochemistry, diffusion and osmosis, amino acids and translation, energy and respiration (Radford and Bird-Stewart 1982, Longden 1982, Fisher 1985, Sanders 1993, Kindfield 1994, and Odom and Barrow 1995). These topics involve abstract ideas, complex specific terminology, and a considerable need for higher order reasoning and problem- solving.

Historically black universities (HBUs) often have a population of students who have passed through a poor schooling system and therefore lack the basic learning skills required at the tertiary level. Two years of content learning at the university does not guarantee a mastery of the competencies required to teach at high school level. Commenting on the lack of mastery of concepts by students, Fitz-Gibbon (1996) argues that we require sensitive systems performance indicators that can be used as feedback information to producers of education at a local level, leading to improvement in education. This research study attempted to identify performance indicators which could be used as feedback to gauge the conceptual understanding of genetic and problemsolving skills in genetics acquired by student teachers.

Teachers who are confident about their subject content are likely to be more comfortable in encouraging their students to learn by inquiry and discovery methods. Teachers who are not confident about their subject matter prefer teacher- dominated methods of teaching which stifle creativity and critical thinking. This view is supported by Osborne and Freyberg (1985) who state that teachers who are themselves insecure in their knowledge of science can find the uncomplicated transmission of knowledge attractive. Transmission styles of teaching are authoritative and usually do not allow students to ask questions. The passivity of learners protects the teacher from awkward questions he/she might not be able to answer because of poor mastery of content. Teachers with extremely poor content do not realise that they can learn something with students because no one really expects teachers to be walking encyclopeadias. Present assessment methods also leave much to be desired, with a lot of questions in the matriculation examination testing for recall (Isaacs, 1993). It is important that completing student teachers are able to develop evaluation instruments that test for a variety of skills and competencies such as problem solving.

1.5 AIMS OF THE STUDY

This study sought to explore student teachers conceptions about genetics. More specifically, the study sought to identify difficulties student teachers have in dealing with genetics concepts they have to teach in the grade 11-12 of the South African matriculation biology syllabus.

The second aim of the study was to develop diagnostic tools to use in investigating student teachers conceptions of genetics. In pursuance of the aims of the study, investigations were carried out using diagnostic tools developed for the research to answer the following questions :

- Do student teachers have misconceptions or alternative conceptions about some genetic concepts?
- 2. How competent are student teachers in their mastery of knowledge and understanding of basic genetic concepts?
- 3. Are there any significant differences in the achievement scores of male students versus female subjects with respect to understanding genetics concepts.?
- 4. In view of the potential usage of genetic fingerprinting technology in crime detection, what are the subjects' opinions about the raping of female students by male teachers ?

5. How conversant are the subjects with genetic fingerprinting and its utility in criminal investigation?

Hypotheses were designed to answer questions 1-5 above, as follows:

- There will be no student teachers manifesting existing misconceptions regarding concepts of genetics.
- There are no student teachers who will show non- mastery of the concepts tested by the diagnostic tools.
- There are no significant differences between male and female achievement scores in all areas of genetics tested.
- All student teachers will have heard about genetics finger printing technology and
 its use in criminal investigations.

The majority of the questions were addressed by using quantitative descriptive or inferential statistics. However, some questions were addressed by use of qualitative answers obtained from diagrams or models made by candidates to illustrate their understanding of certain genetic concepts and by non scheduled interviews.

1.6 **SIGNIFICANCE OF THE STUDY**

Research studies investigating the understanding of genetics in South Africa have concentrated on school students or first year undergraduates (Longden 1982, Pearson and Hughes 1988, and Moletsane and Sanders 1997). Very few studies have focused on

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student teachers. The study should contribute towards an understanding of whether student teachers leave training institutions with misconceptions that have not been adequately addressed before they are certificated. The crucial question could be what competency level do teachers have in their various courses at the point of certification? The researcher also hopes that the instrument developed to investigate specific competencies of teachers in genetics will also be used with future student teachers in dealing with basic genetic problems. Such a diagnostic tool is important for identifying problems experienced in the understanding of genetics. A diagnostic tool, though not perfect, is likely to also enable instructors to engage in more focused teaching using suitable intervention strategies.

This study could also serve as an eye- opener to student teachers so that they understand how a diagnostic tool for effective monitoring of learning can be designed and used to enhance learning. There is a dearth of action research occurring in the classroom by people who are in touch with students' learning and who are therefore best equipped to conduct such work. One hopes that this research will also serve as a model of the kind of research teachers can do in their own classrooms.

1.7 **DELIMITATION**

This study will be limited to student teachers at the University of Zululand. Geographically, the University of Zululand is situated near the north coast of KwaZulu-Natal Province, 25 kilometres from Empangeni and 41 kilometres from Richards Bay (see

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appendix 1 for exact location). The University of Zululand is situated in a semi- rural setting and has a population of approximately 7000 students each year. The students involved in the study come from all over the Republic of South Africa. They were all registered for the Senior Secondary Teachers Diploma (SSTD), a third year level course in the teacher education programme.

The problem investigated in this study is restricted to the conceptual understanding of basic genetics, covering topics found in the matriculation syllabus. The sub-sections of genetics covered in this research as they appear in the grade11 syllabus are as follows:

- 1. Cell Division and Genetics
- 1.1.1. The role of the nucleus.
- 1.1.2. Structure and functions
- 1.1.3. Nucleic acids : DNA, RNA
 - a) Practical study of DNAstructure
 - b) Replication
- 1.2. Cell Division
- 1.2.1. Mitosis
- 1.2.2. Meiosis
- 1.3. Genetic Mechanisms Involved in Inheritance
- 1.3.1. Introduction and terminology of genetic mechanisms
- 1.3.2. Gametes as vehicles of inheritance
- 1.3.3. Dihybrid crosses
- 1.3.4. Gene mutation

The section of the syllabus which has not been addressed in this research is part C under topic 1.1.2 (see appendix 2) which is the role of protein synthesis. The researcher felt this section could form a topic for future research on its own.

1.8 LIMITATIONS

The researcher wishes to note the following limitations of this study.

- The criterion- referenced diagnostic test and practical work will only cover a limited subsection of the genetics topics prescribed for matric. Some areas that have been identified by various researchers in Australia, Botswana, the United Kingdom, the United States of America, South Africa and many other countries, as giving problems to students will be included.
- 2. The research was conducted during the student teachers' third year of training, too late to identify misconceptions they may have acquired in high school. In South Africa there are huge disparities in terms of material and human resources in different African schools. Some schools are adequately equipped while others have very few resources and adequately qualified personnel. Students of poor schools which form the majority of the intake of the University of Zululand join their learning programmes very ill- prepared for the tasks ahead. The kind of learning foundation these students bring from their different schools is likely to impact on their future achievement. An ideal situation would have been to apply the diagnostic test at the beginning of the training in first year and again in their

third year of professional training. This would have made possible the measurement of the university's input in developing the conceptual understanding of genetics among the student teachers.

1.9 **DEFINITION OF TERMS**

This section will attempt to define the meaning of terms and phrases used in this research.

Comprehension: Comprehension has been defined by Hiebert and Lefevre (1995) as a central aspect of meaningful learning. It involves a complex interaction among different levels of information processing influenced by external and internal conditions. External conditions that influence comprehension are learning media that are used to facilitate the formation of a concept and internal conditions, include prior knowledge (Schnotz and Ballstaedt 1995). Acquisition of information always occurs against the background of previous knowledge. Students who have learnt with comprehension can apply past knowledge in appropriate ways and use it to lay the foundation for the next stage of learning.

In order for an individual to comprehend new information, that person has to go through three basic processes: assimilation, accommodation, and equilibration. *Assimilation* refers to the integration of new data with existing cognitive structures. *Accommodation* is the adjustment the individual makes when incorporating external reality or new information. *Equilibration* refers to adjustment of the cognitive structure to new situations and the continuing processes of readjustment between assimilation and accommodation (Gredler
1992). Failure to comprehend information results when students lack the necessary background schema for assimilating new material or when students possess the requisite schema but fail to activate them (Hamilton and Ghatala 1994).

Science process skills: In scientific inquiry which is a search for tentative ways of explaining phenomena in our environments, scientists use process skills. Science process skills are tools that are available to the scientist when investigating phenomena. They are both theoretical and practical tools used to achieve a clearer description of the phenomena studied. Scientists put a strong emphasis on the processes involved in reaching conclusions during an investigation. The process skills used to arrive at a conclusion can either validate or invalidate data collected (Sund and Trowbridge 1973, and Young 1986).

According to Sund and Trowbridge science process skills can be classified into five categories as follows:

1. Acquisitive skills.

Skills under this category include listening, observing, searching, inquiring, investigating, gathering data and research.

2. Organisational skills.

Under this category examples of skills are recording, comparing, contrasting, classifying, organizing, outlining, reviewing, evaluating and analysing.

3. Creative skills.

Creative skills involve the ability to plan ahead, designing a new problem or a new approach to solve an existing problem. Inventing (which could refer to designing a new device or technique) and synthesizing are also creative skills.

4. Manipulative skills.

Manipulative skills refer to the ability to handle instruments in an appropriate manner and to use them accurately.

5. Communicative skills.

Scientists have to be able to state clearly what they have observed or discovered. Sometimes they write their observations, while at other times they have to report their findings verbally. Scientists have specialised means of communication such as using drawings, diagrams, or graphs to make their points clear. There is therefore a range of basic skills which the student teachers should have learned in their laboratory work. The development of these skills called science process skills starts in grade 4 in the South African schools and continues all the way up to university level. It is the researcher's concern to find out if student teachers have mastered these skills and whether they can use them appropriately in problemsolving situations. The outcomes-based education also requires students to demonstrate a mastery of relevant science processes which they can use to solve problems in real life situations. **Concepts**: Concepts have been defined as mental representations or categories of, for example things, actions or situations. Concepts allow people to sort stimuli with similar characteristics into categories (Hamilton and Ghatala 1994). Concepts have also been said to represent fundamental elements of all content areas (Tennyson 1995). Classrooms with effective learning environments provide cognitive strategies which facilitate the learning of new concepts and consolidate the students' ability to use the new concepts to solve unfamiliar problems. When a student has learnt a concept he/she can be assumed to know when and how to apply it.

Vygotsky, as cited by Gredler (1995) is said to have identified two levels of concept development. The first level is where concepts are spontaneously developed through perceptual and practical experience in everyday activity. The next level is the development of 'scientific' concepts which are theoretical, structured and depent on the use of language and learning. The scientific concepts are described as powerful because they can be applied to different contexts in the field of learning. They can, however, be easily cut off from experience and become unconnected with the concepts of everyday life. When this happens the concept may lose its true meaning to the learner. It is for this reason that learning should include cognitive activators which encourage learners to explain concepts to others and develop a shared understanding of the meaning (Fisher 1995).

Sometimes students fail to develop an accurate scientific conception of the phenomena studied. This results in individuals holding erroneous information that has been referred to by various authors as misconceptions or alternative conceptions (Westbrook and Marek 1991, Lawson, Baker, DiDonato and Verdi 1993, Sequera, Leite and Duarte 1993, and Lawrenz and Gray 1995).

The definition of concepts by Hamilton and Ghatala(1994) as mental representations or categories of, for example, things or situations is consistent with the notion that concepts are formed by individuals. That concepts are personal constructs makes it possible to investigate differences among the concepts held by different individuals. While many educationists believe that concepts are personal constructs, Vigotsky (1986) indicated that the concepts formed by individuals are personal but socially mediated since no one learns in a vacuum.

Diagnostic monitoring: This operation defines the act of using a variety of tests and faceto- face interviews to identify areas where certain students have conceptual problems, and also to identify particular skills they have mastered and those that require greater emphasis.

Criterion Referenced Tests: These kinds of tests assess a student's performance in a domain of skills which are clearly defined. They are characterized by an assemblage of different kinds of evidence of what a student can do.

Black: In this research the word black has been used for all people who are not white in South Africa. It is a political definition rather than a descriptive term and refers to all those who were discriminated against in the apartheid era.

African: Black indigenous people of Africa as opposed from Coloureds, Indians and Whites.

1.10 ORGANISATION OF THE STUDY

In chapter one the researcher described the orientation of the study, which includes background to the problem, motivation of the study, a statement of the problem, the aims of the study, the delimitation, and limitations of the study and finally a definition of terms.

Chapter two deals with a literature review and research studies on the understanding of science concepts by students and serving teachers. The roles of diagnostic tools in education and of culture in learning will also be examined.

Chapter three discusses the status of the teaching of genetics in South Africa and in developed western countries. The outcomes-based education is also discussed in the context of the role it may play in transforming education in South Africa. The prominent role played by the study of genetics in society will be highlighted and reasons why school leavers should be 'genetically literate' will be underscored.

Chapter four deals with the research design and includes, the development of the research instrument, the diagnostic criterion- referenced test and its validation, and procedures for the analysis of data.

Chapter five describes the presentation analysis and interpretation of the findings. Chapter six reviews the study, draws conclusions and provides recommendations. This chapter also provides directions for future research.

CHAPTER TWO

ORIENTATION OF THE STUDY -

2.1 INTRODUCTION

A primary objective of the educational enterprise is to teach students so that they understand science and are able to use it to solve real life problems. Understanding science is a loaded phrase which needs to be discussed for the purpose of clarity. When a student has learnt science with understanding he/she is able to apply the knowledge appropriately in diverse situations to solve problems. On the other hand, students who memorise various facts and formulas without understanding, acquire inert knowledge which is not flexibly usable (Frederick and Larkin 1991). The study aims to investigate whether student teachers conceptually understand concepts and processes of genetics and whether they have misconceptions or alternative frameworks. It is important to know whether or not student teachers have gained an accurate understanding of science concepts before they receive their teaching (diplomas).

This chapter will deal with learning and teaching theories that constitute the framework of this research. It is important to discuss them to inform readers as to their meaning as used by the researcher. Finally, the theoretical orientation of this study will be discussed with reference to theories that have contributed to our understanding of learning and teaching.

2.2 LITERATURE REVIEW

Learning can be defined in qualitative or quantitative terms. Cole (1990) describes quantitative learning as increasing one's knowledge of facts which could be isolated specific bits of knowledge. People who hold this conception of learning think that a good scholar is one who memorizes a lot of information. However the ability to memorise chunks of information does not mean that these people can apply their knowledge successfully to solving problems.

Qualitative learning involves understanding the meaning of concepts in the specific domain of learning. According to Brainsford and Stein (1984) qualitative learning involves relating what is learnt, that is, new information to prior knowledge and being able to apply the integrated knowledge to new situations. Another aspect of the qualitative conception of learning is that it involves seeing something in a different way and in this sense learning broadens one's outlook.

In this research a small part looks at learners' knowledge and understanding of genetic terms. Knowledge in this case does not only refer to knowing discrete genetic terms without understanding their connection to the rest of the concepts of genetics. Actually only those subjects that could link genetic terms coherently to other areas of genetics could come up with appropriate genetic terms. The research also investigated subjects' qualitative conceptions of genetics which would expose their understanding or

misunderstanding of concepts in genetics. The research would also investigate the subjetcs ability to apply their knowledge to solve basic problems in genetics. Testing of both qualitative and quantitative types of learning shows that the two levels of learning are not antagonistic but feed each other. Bransman and Stein (1984) state that we cannot form a view of something until we know the facts. The problem only arises when people stop at the facts and not emphasize meaning and interpretation of phenomena.

2.3 THE ROLE OF MEMORY IN LEARNING

Memory is involved whenever information is stored over time, it is therefore a critical part of all cognitive processes. Some of our understanding of the nature of memory and learning is based on the information processing theory (Sprinthall and Sprinthall, 1990). This theory is based on the understanding that the human brains are similar to computers, they put information into storage, keep it there and take it out at a later time. The Atkinson-Shriffin model views memory as consisting of 3 memory stores ie. sensory memory, short-term memory and long-term memory. The levels of the information processing approach imply that the way we process material influences how well we recall it. Short term memory (STM) refers to the information we are currently using. The STM has a limit to the amount of information it can hold. Long term memory (LTM) has the potential of holding encoded information for a life time. According to Matlin (1983) we can analyse information in many different ways, from the shallow sensory kind of processing to deeper kinds of processing which lead to more permanent retention of the material the learner understands. Teachers are always concerned about devising strategies to help students remember what they have learned, particularly for examinations purposes. Memorising something that has meaning is always much better than memorising something one does not understand. Encoding is the process of putting new (incoming) information into the information processing system, which is in our brains and preparing it for storage in the long-term memory. The following are some of the strategies that were advocated by Sprinthall and Sprinthall (1990) and Schunk (1991) to observe in order to promote encoding :

- Organising knowledge in such a way that the material to be learned is categorised into classes that make sense to the learner.
- 2. The learner must relate new material to the existing knowledge base. Memory is therefore an active component in the development of new concepts. Previously stored information provides the context for the interpretation of new stimuli and the new information can influence interpretation of stored knowledge. The last point underlies the realisation by educationists that children bring pre-knowledge to the classroom which influences how they learn new concepts. Anderson (1990) also describes the process of elaboration which is the process of expanding upon new information by adding to it or linking it to what one knows. The author

argues that even when the new information is forgotten, people often can recall the elaborations.

3. The use of mnemonics has also assisted students to remember information. Mnemonics devices are described as visual imagery, peg words, and rhymes which can be used as memory aids for learning new information All the elements which are suggested to aid information retrieval have one thing in common, that the encoded information must be meaningful to the learner.

2.3.1 CRITICISM OF THE INFORMATION PROCESSING THEORY

A comparison between the brain and a computer, as the information processing theory seems to suggest, must start with the obvious fact that a brain is a living entity, while the computer is not. The complex network of nerve cells we call the brain is not a fixed structure like a computer. In fact the brain is both functionally and structurally changed by past experience. Experience causes the brain-branching pattern of nerve connections to acquire greater complexity. Brain neuron connections which have not been challenged by experience retain simpler patterns and lower functional ability (Youngson 1994). The other major difference between the computer and the human brain lies in the enormous perceptive capacity of the brain, with its associated sense organs, compared with that of the computer.

Computers are not useful without detailed programmes of instructions for their operation. The brain with its range of activities does not perform different functions in accordance with different programmes. The major subdivisions of brain functions are movement, sensation, speech, vision, hearing, and are subserved by particular known parts of the brain, and these are connected by bundles of nerve fibre to the effector or sense organ concerned as well as to other parts of the brain. Computers are driven into operation by running a programme while the brain is activated largely by stimuli entering it by way of the sense organs.

Scientists have made great leaps forward in the understanding of how the brain works and many have agreed that it has similarities with the most advanced computers. However, a number of scientists believe that a computer will never display the characteristic of the human brain such as self-awareness, emotion and psychological problems.

2.4 **OPERANT CONDITIONING IN THE CLASSROOM**

Our understanding of learning has been enhanced by various contributions from educational psychologists. Skinner is one such behaviourist psychologists who maintained that all learning could be accounted for in terms of operant (also known as instrumental) conditioning (Schunk 1991). The word operant refers to any behaviour that operates on the environment in order to bring about reinforcement. Skinner belonged to the Behaviourist School because he and others considered observable behaviour as the only

valid data in psychology. According to Sprinthall and Sprinthall (1990), traditional behaviourism adhered to three underlying principles, that is, that organisms enter the world and come into any new situation as blank slates upon which experience writes. The behaviourists also believed that learning of animals is the same as that of human beings and that the animals' way of learning could be easily extrapolated to the human condition. The third underlying behaviourist principle was that any response an organism was capable of producing could be linked through training with any stimulus the organism could be made aware of. The learner was therefore seen as a recipient of environmental stimuli to which he responded automatically. In real life learning is not as simple as was viewed by behaviourists, because the human brain can select stimuli it will respond to. The very well developed human brain is not likely to respond in the same way as brains of rats and pigeons.

Skinner's operant conditioning operated on a few basic rules. He distinguished between operant conditioning which concerned voluntary responses or operants and classical conditioning which dealt with involuntary responses to stimuli. Operant conditioning also involved discouragement by punishment of undesirable behaviour, but not physical punishment. Skinner strongly opposed punishment as a means of changing behaviour (Sprinthall and Sprinthall 1990). It is also interesting to note that corporal punishment has also been banned in South African schools.

Teachers are now supposed to use other persuasive methods to get desired behaviour from learners. According to the basic principles of operant conditioning only two conditions are necessary for learning to occur : First the response must be made; second it must be followed by positive reinforcement.

Reinforcement is the key concept of operant conditioning. It is the major distinction between operant conditioning and classical conditioning. Reinforcement falls into two categories, positive and negative. Positive reinforcement refers to any consequence or effect of a particular act that increases the probability of that act reoccurring. It is a matter of presenting something to increase a behaviour. When doing a certain thing negative reinforcement is followed by the avoidance of something that the individual finds unpleasant. Negative reinforcement should not be confused with punishment. Like positive reinforcement, negative reinforcement increases desired behaviour. Operant conditioning is based to some extent on the law of effect formulated by Edward Thorndike (1927). According to the law of effect any behaviour which has pleasant consequences is likely to be repeated.

2.4.1 SKINNERIAN LEARNING IN THE CLASSROOM

There are several main concepts in Skinner's view of learning: operants, reinforcement and shaping. In the classroom an operant is a response or a type of behaviour of a student; an action he performs, a word he says, or a statement he makes. It is called operant

because it is behaviour that operates upon our environment to generate consequences. Receipt of a reward or praise after giving a correct answer is called reinforcement. Reinforcement must be immediate because a delay diminishes its effectiveness. According to Skinner, learning occurs when given a certain set of conditions, the individual behaves in a certain way and is immediately given a reward for that behaviour. A reward is dependent on behaving in the desired way. The individual will behave in a similar way again because of consequences that have followed positive reinforcement in the past.

Most of what is learned in the school consists of complex sequences instead of a simple response. A more complex behaviour can be taught through a process that Skinner termed as shaping. Shaping consists of reinforcing each closer approximation of a desired behaviour and withholding reinforcement when the approximation does not represent progress. Gradually, by rewarding one successful approximation after another, the teacher will lead the student to the correct way of performing the skill. For the teacher, the essential steps to a shaping programme are :

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1. Targeting a desired behaviour

2. Fixing a borderline

3. Selecting appropriate reinforcement

4. Analysing the tasks and sequencing the segments and

5. Applying the reinforcements systematically.

There are current approaches in education that come directly from Skinner's view of learning. The most notable are behavioural objectives, task analysis and programmed learning. Programmed instruction was pioneered by Skinner and involves work that is broken down into its component parts with each part further broken down into smaller units which the student goes through, filling in a word to complete a statement and then immediately finding out the correct answer. The programme is designed in such a way that the students get the majority of the tasks correct. Although programmed instruction can be used successfully in the classroom, it has its limitations particularly if one aims to develop problem solving skills and deeper forms of learning like application, synthesis and evaluation. The programmed learning part of Skinner's theory therefore had no part in this research because the research needed strategies that would reveal higher forms of learning in subjects .

Skinner's emphasis on specific observable behaviour has influenced the research in that tasks to be done by subjects are stated in behavioural terms. For instance, subjects have to show how they have solved genetic problems. They also have to demonstrate their ability to read and follow instructions in a practical test, to produce an accurate representation of chromosomes at the metaphase stage I of meiosis. Emphasis on clearly stated behavioural objectives is a primary part of the operant conditioning model. When objectives are phrased in terms of specific tasks to be mastered and which can be

measured in terms of observable behaviour, the task of evaluation becomes easier. Research shows that learners provided with behavioural objectives show better verbalism and recall of verbal information compared with learners not provided with such information (Faw & Waller, 1976; Hamilton, 1985).

2.4.3 CRITICISM OF SKINNERS THEORY OF LEARNING

Although Skinner's model of behavioural objectives has been used in the research it has its disadvantages as no theory is perfect. For instance, in Skinner's insistence on including only what is based on observed behaviour, he ends up studying an "empty organism". The learner as an individual is not even mentioned in Skinner's model except the learner's behaviour. According to Hergenhahn (1993) most Stimulus Response (S-R) theorists assume a passive organism that builds up responses to those events. In this case environmental events are stimuli (S) which are followed by responses (R) to those events. In the research subjects are perceived as active individuals that construct learning for themselvs. Both Skinner's principles of operant conditioning and reinforcement in programmed learning are based on an approach to classroom learning that is more verbaloriented than thought oriented. Learners are therefore likely to stay more on the surface rather than arrive at a basic explanation of the higher types of learning. It is almost impossible to conclude discussion of contributions to educational psychology without considering Piaget's work. Piaget's work introduced a new and significant theory regarding the process of cognitive growth stages. The stages are defined by the system of thinking employed and by the learners age (Gorman 1972). Piaget believed that children pass through four periods of mental development. During the first sensory motor stage from birth to about two years, learning is tied to immediate experience. Children obtain a basic knowledge of objects through their senses; they can be seen touching and tasting things all the time.

One of the terms used by Piaget in describing mental development was schemata. Schemata was defined by Piaget as the potential to act in a certain way, for example, reflexes of a new born child such as sucking, looking, reaching and grasping (Hegenhahn 1993). The schemata was a very important term in Piaget's theory because it was thought to be an element in the organism's cognitive structure. The schemata available to an organism is supposed to determine how it will respond to the physical environment. In the second phase called the pre-operational stage, from about 2-7 years of age, children develop such skills as language and drawing ability. The third stage of concrete operations which approximately covers children with ages 7 to 11 is characterised by the beginning of logical thought. For instance children learn to organise knowledge, classify objects and work on thought problems. According to Martin, Sexton, Wagner and Gerlovich

(1998) during this stage thought becomes internal, rational and reversible. Learners at this stage learn better with real (concrete) objects than with abstract ideas.

The last stage of cognitive development is the period of formal operations which lasts from about 11 to 15 years of age. The formal operations period is an important stage of thinking since it represents the highest level of cognitive growth. Gorman (1972) describes three types of thinking that occur at this stage as follows:

- Hypothetic- deductive thinking : the learner can start with possibilities and reason or experiment from there.
- Abstract thought : the learner can form pure abstractions and think on an abstract verbal level. Abstractions are ideas about qualities and characteristics viewed apart from the objects to which they refer.
- 3. Formal thought: the learner is able to distinguish the form from the content of a statement and consider the form of reasoning aside from the specific content.

Experience with working with children has shown that although learners may operate at a stage appropriate to their age, sometimes they are capable of operating at the next level of thinking. Learners also do not all reach the same level of thinking at the same age. There are children who mature quickly while others are slow. For instance, many tertiary school students are found still operating at concrete level. There is also the possibility of individuals operating at different levels in different areas of learning.

Sprinthall and Sprinthall (1990) suggest that a basic Piagetian concept denotes activity as a central ingredient of intelligence at all stages. Describing the process of learning, Piaget suggests that when new information is presented that does not fit in with the learners current understanding; a knowledge disturbance is created. When the learners take in such new information the act represents accommodation. The next phase in learning involves making the new concept fit with previous knowledge in a process referred to as assimilation. The last phase which is equilibration involves a balancing of accommodation and assimilation. It is believed that when learners are given a chance to interact with learning materials this gives learners a chance to go through accommodation, assimilation and equilibration. Piaget's stages of cognitive development have contributed to our understanding of the fact that children are different from adults. For instance, we know that younger children have a very short attention span and need a lot more variety of hands- on approach in their leaning programme. An approach that is hands-on with an emphasis of minds-on is also encouraged for students at tertiary level. The minds-on aspect implies development of of higher cognitive skills like critical thinking, problem solving and creativity.

2.5.1 CRITICISM OF PIAGET'S STAGES OF COGNITIVE DEVELOPMENT

Many people are of the view that Piaget was so absorbed by the child's active search for knowledge that he ignored external motivation or teaching. While it is comforting to think that children develop their own schemes when they are ready, this concept implies that

teachers should not intervene when a child seems uninterested in learning science because it is perceived to be difficult. To some extent, the "back to basics" movement in American education was a reaction against Piagetian ideas carried to their logical extremes. Americans felt that there was a need to go back to traditional ways of teaching mathematics and spelling, ways that had proved to be effective in teaching numeracy and literacy. In addition, Piaget's emphasis on the four distinct stages of cognitive development may be misleading. Several researchers believe that cognitive growth is less stage-like, and more uneven, than many theorists have pictured it to be (Flavell, 1963 Schultz, 1982; Gelman, 1979). Even some of those who most admire Piaget believe that he underestimates the role of society and home in fostering cognitive development. It is partly for this reason that Jerome Kagan (1971) has called Piaget "a development idealist". Many psychologists believe that culture and education can be crucial in providing the proper mix of equilibrium and disequilibrium to help a person develop. In Bruner's (1973) words, "Some environments push cognitive growth better, earlier, and longer than others." and he said that it makes a huge difference to the intellectual life of a child simply that he was in school. John Dewey as cited by Sprinthall and Sprinthall (1990) used the phrase "some organism in some environment". Dewey's idea was that one could not study learning in the abstract and ignore the broader context, or the environment in which that learning takes place.

According to Fischer (1980) the conception of cognitive development that has influenced education the most, has been the Piagetian theory of stage structure. But inspite of its wide acceptance in educational circles, Piaget's structuralist stage model has it's shortcomings. For instance not all children reach the cognitive stages at the same age. Other adults are found to be operating at concrete level and unable to operate at the formal level. Some children are precocius and once in a while there are children who have been able to handle formal operation stage material at 8-10 years old or under.

Piaget's view of abstract universal structure of knowledge, virtually unaffected by individual differences, the contexts and cultures in which people construct the knowledge, is highly unlikely. For instance Jegede (1995) in his paper on collateral learning and the eco-cultural paradigm in science and mathematics education, discusses how learning takes place and its dependence on the environment as its source of information. The author makes a special reference to African students who come to science classrooms with their traditional worldviews. An example of this world view has been described with reference to the fact that some African societies believe that albino children are born to those who are punished by God. It is likely that Western worldviews presented by the school and indigenous knowledge make learning particularly more difficult for African students.

The high failure rates in African schools in South Africa is attributed by various individuals to contexts in which learning takes place in these poorly resourced schools.

The higher pass rates in former white and Indian schools is attributed to better resources and learners being first language speakers of the medium of instruction. The contexts in which learning takes place are therefore very important in deciding the quality of learning that will take place. Educationists now believe that the context in which knowledge is constructed affects the process of construction and the organization of the resulting knowledge (Gredler 1992). A valuable aspect of Piaget's theory is his constructivist approach to learning whereby he acknowledges that knowledge acquisition is an action based self regulating, constructive process. Practical work is encouraged in biology and physical science classrooms in recognition of the fact that learning is facilitated when learners interact with carefully selected materials which will lead to learning. Practical work also offers students opportunities to practise process skills, without which it is impossible for learners to study their environments in a sytematic way. In the research, practical work was included as another way of discovering if subjects could interpret instructions and produce an accurate model of a pair of heterozygous homologous chromosomes at metaphase stage of meiosis. Demonstration in practical terms what one can do is a very important aspect of assessment these days.

Gorman (1972) suggests that Piaget had studied the thought processess of children for over fifty years. Piaget's approach was qualitative as distinguished from the quantitative approach. He was interested not so much in how well the children scored on mental tests but in the processes they used in arriving at their answers, especially incorrect answers. In the research, Piaget's idea of investigating process skills used by subjects in solving problems has been used in a genetics problem solving context. Subjects had to write heuristics for solving a genetics problem and use it in solving a given problem. Following processes that subjects use in solving a problem it was assumed that the instructor would understand the subjects' cognitive problems and therefore be in a position to help subjects more efficiently. Piaget has however, been criticised for not emphasizing the importance of social interactions in the learning process. He argued more for the position that mental growth is inseparable from physical growth but did not explain the role of society in development. Educators now believe that the human being is immersed right from birth in a social environment which affects his mental development just as the physical environment does (Ellis & Gauvain 1982).

2.6 AUSUBEL'S MEANINGFUL RECEPTION LEARNING

Ausubel presented a theory of meaningful reception learning (Ausubel 1968). He contended that the acquisition of subject-matter knowledge is primarily a manifestation of reception learning. In his view the principal content of what is to be learned is typically presented to the learner in more or less final form. This line of thought means that the learner is simply required to comprehend the matter and to incorporate it into his cognitive structure so that it is available for further use, for instance, to solve problems. Ausubel advocated using expository teaching that presents information to students in an organized and meaningful way. Meaningful learning refers to the learning of ideas, concepts and principles by relating new information to knowledge in memory (Ausubel 1977; Faw and

Waller 1976). According to Ausubel (1968) learning is meaningful when new material bears an arbitrary relation to relevant concepts in long-term memory, that is, new material expands, modifies, or elaborates information in memory. In any class whether students find learning meaningful or not will depend on their prior learning.

2.6.1 THE RELEVANCE OF AUSUBEL'S THEORY TO TEACHING FOR UNDERSTANDING

Learners should be taught in such a way that they understand what they are learning. . Learning by rote without establishing meaning does not lead to effective learning. It is also important that instructors build on what the learners already know. This explains why it is good practice for teachers to establish what the learners know before presenting new learning material. Tarnir and Goldming (1974) supported this view by stating that what pupils learn from lesson activities depends not only on the nature of the tasks set but on the knowledge schemes that pupils bring to these tasks. According to Schunk (1991) Ausubel's model requires much teacher-student interaction. Teachers verbally present new material but student responses are continually solicited. Concepts being taught are exemplified in different ways by being built on one another so that students possess the requisite knowledge to benefit from the teaching. Research by Ausubel (1978) also showed that advance organizers, which are devices that help connect new learning to prior learning, promote learning. Mayer (1984) states that organizers are useful with lessons that are designed to teach relationships among concepts. Faw and Waller (1976) also suggest that organizers are effective with difficult academic content when an analogy with familiar content is appropriate.

2.6.2 RELEVANCE OF AUSUBEL'S THEORY OF LEARNING TO THE RESEARCH

Students who have gone through their academic work in a meaningful way should be able to demonstrate competence in the mastery of different learning areas because what they learnt had meaning for them. They should be able to apply previous knowledge to solve problems graded on appropriate level to what they learnt. For instance, Mayer (1979) . reports research with college students who had computer programming experience. These students were given programming materials to study. One group was given a conceptual model as an organizer, whereas the other group received the same material without the model. The advance organizer group performed better on post-test items requiring transfer of learning to items different from those discussed in the instructional material. The idea was that Ausubel's organizers could help students relate new materials to a broader set of experiences, a process which facilitates transfer of learning.

2.6.3 LIMITATIONS OF AUSUBEL'S THEORY OF MEANINGFUL LEARNING

Although Ausubel endorsed the view held by many science educators that learning should be meaningful, that is, it should focus on students' learning with understanding, he underplayed the role of social interaction and culture in the learning of science. Educators now believe that the learning of science is affected by the society we live in which dictates cultures as well as our personal values. Even one classroom consists of diverse cultures and individuals who make sense of what is taught in different ways. This is the reason why on evaluation, teachers find that some individuals did not get an accurate scientific view of what was taught while others did.

2.7 INQUIRY AND DISCOVERY LEARNING

There are teaching methods which are said to help learners to construct meaning of what . they learn. Martin, Sexton, Wagner and Gerlovich (1998) state that learners learn by inquiry and by constructing meaning from experiences called discoveries. An understanding of inquiry and discovery learning is important if one is to help learners discovery and concept construction. According to Bernie and Ryan (1984(inquiry refers to an effort to discover something new to the inquirer. The two authors also stress that the knowledge "discovered" by the inquirer may not necessarily be new to the world. Bruner (1961) described discovery learning as referring to obtaining knowledge for one's self. Learners discover knowledge and construct meaning on their observations when they are given opportunities to investigate problems and to make their own observations and state their own conclusions. Discovery learning involves formulating and testing hypotheses rather than simply reading or listening to teacher presentations. If a learner acquires a new fact, principle or solution through the inquiry he is likely to learn more effectively and meaningfully.

Sprinthall and Sprinthall (1990) present Bruner's theory of instruction as having had four majors principles. The principles are motivation, structure, sequence and reinforcement. Motivation specify conditions that pre-dispose an individual to learn. Sometimes even the nature of a science activity motivates learners to want to learn by solving an exciting problem presented to them. Ptofell & Alessi (1995) describing the curriculum development process state that science activities are crucial in deciding whether the curriculum will be a success or not. Successful learning activities will appeal to learners and stimulate them to learn. Bruner was, however, more concerned, first, about intrinsic motivation which is a result of learner's natural curiosity. Science teachers ought to exploit the natural curiosity of learners during discovery learning activities, but what happens in most cases is that methods of teaching used tend to stifle the promotion of curiosity. For instance, teachers normally do not allow learners to experiment with their own ideas on worksheets that learners use during practical work. The worksheet then becomes a recipe for carrying out the experiment, in the same way one follows a recipe to bake a cake. This type of practical work or 'disovery' does not lead to thinking and problem-solving qualities we wish to develop in biology students.

Explaining the second principle which is structure, Bruner suggested that if appropriately structured any idea or problem or body of knowledge can be presented in a form simple enough so that learners can understand it. The principle of simplifying content for easy understanding is used by teachers all over the world. Many innovative learning packages are available in the market which claim to be simplified versions which facilitate learning

of difficult topics. In the research the worksheet (appendix 3) was a hands-on activity which was supposed to facilitate revision of mitosis and meiosis and that it hopefully facilitated understanding of the two processes.

The third principle refers to **sequence** which involves steps through which a learner passes in leaning about a particular subject. Bruner described 3 steps through which a learner passes ie. The **Enactive** representation which requires physical action by the learner, the **iconic** stage where children can describe objects without notation and the **symbolic representation** stage where learners translate experience into language. The principle of physical action in the learning of children is now accepted in education circles. Children are said to learn better by doing. The principle of learning by doing was also accepted by Piaget when he described the concrete stage of development where learners show the understanding of functional relationship in a problem that is concrete. Learning in a concrete way is in fact not restricted to children but adult learners also benefit from use of models which represent abstract knowledge they learn. Models, however, also have their disadvantage when children and even adults think they represent the real thing.

Bruner also referred to a significant step where learners translate experience into language. Language is a very powerful tool through which human beings represent their thoughts and communicate with other human beings. Language is also very important in learning science or any other subject. Writing on language policy in education, Chick (1992) suggests that the choice of languages that are promoted affects the life chances of people. The native speakers of the medium of instruction are at an advantage in the teaching learning process. For instance, learners in this research learned biology in English which was their second language. They had difficulty in expression which was evident in the way they expressed their ideas on paper and the way they mis-interpreted simple straightforward instructions. For learners who are taught in a foreign language, there is an additional difficulty of learning a third language of science. Bullock (1982) states that reading science is difficult and most challenging because the language of science is difficult. Science words are not only difficult to spell but to pronounce as well, for instance, deoxyribonucleic acid (DNA) in genetics.

Bruner's theory contributed to instructional methods in that his theory encourages reflection whereby a teacher thinks about how a given subject can best be taught. Student teachers in training are usually encouraged to start with things that are familiar to learners and move to unknown concepts when they teach. According to Abruscato (1982) if one takes Bruner's work into consideration when planing lessons, one would proceed from the specific to the general, from simple to complex and from concrete to the abstract. In the research, subjects were helped with their revision of mitosis and meiosis by going through a guided discovery type of exercise (appendix 3) which led them to comparing the two processes. The activity the subjects went through was designed to help them to understand the differences between mitosis and meiosis instead of just memorising them, as they may have done previously .

One of Bruner's significant contribution to education was his insistence that learning must be based on understanding and meaning rather than on concentrating on facts and details only (Sprinthall and Sprinthall, 1990).

Abruscato (1982) discusses practical applications of using Bruner's ideas in the classroom. For instance, he advocates the emphasis of the basic structure of new materials by using demonstrations that reveal basic principles. He also suggests that of many examples of the concept being taught, be given, thus helping learners to construct coding systems and applying new learning to many different situations and kinds of problems. In specific terms, Bruner was also referring to the tendency of teachers to teach facts which learners memorise by rote without finding links to other pieces of information they already know. Such pieces of information not linked to prior learning are easy to forget because they are not rich in networks in the mind.

The relevance of Bruner's theory of learning to the research is that subjects should be able to break down parts of a problem into steps that can be solved step by step. Simplification of a problem is the first step toward obtaining a solution.

2.8 CONSTRUCTIVISM IN EDUCATION

Constructivism has become a popular catchword in education. Some teachers believe they understand constructivism when they do not because it is a complex and sophisticated theory. The conceptualization of constructivism is also complicated by the different types of constructivism that are debated. Constructivism is a theory that assumes knowledge cannot exist outside the mind of thinking persons. Novak (1988) defines constructivism as the notion that humans construct or build meaning into their ideas and experience as a result of their effort to understand or to make sense of them. People who support constructivism believe that the key element of the constructivist theory is that people learn by actively constructing their own knowledge. Piaget's ideas of learning come in when new learning causes destabilisation or dissonance in the mind. The process of comparing the new information to previous knowledge leads to a new understanding. One needs to mention that the constructivist perspective is grounded in research and theories of Piaget, Vygotsky, Bruner and the philosophy of Dewey (Martin et al 1998). There is therefore a number of interpretations of constructivism which will be discussed to highlight differences among them.

2.8.1 SOCIAL CONSTRUCTIVISM

Constructivism seems to be fad in learning circles these days, particularly because of the belief that learning is accomplished at the individual level. The Personal Constructivist Theory was first expounded by Kelly in 1955. Kelly's theory views knowledge as the product of interaction of individuals with their experiences, resulting in a highly personal system of interpretation. Learning in the constructivist paradigm is an active process of constructing meaning facilitated when instructors create an environment that forces

students to be physically and mentally engaged. Because content does not pass from instructor to student without modification in the student's minds, the instructor soon finds out that some students did not understand the lesson or interpreted certain complex concepts inaccurately. Although knowledge is constructed by individuals one must not forget that it is socially mediated. Henning and Fourie (1997) also confirm that although knowledge is individualized the mediational and contextual forces which facilitate its viability are dialogic and societal.

Vygotsky shared the fundamental constructivist assumption that learners have to construct their own knowledge but he also added another crucial dimension to the theory of learning by pointing out the importance of social interaction on learning (Vygotsky 1962,1978). According to Borasi (1996) for Vygotsky psychological development did not precede instruction as is the case with Piaget but depended on it. Vygotsky is one of the first psychologists to stress the importance of instruction whether it was informed through parents or through the school. According to Vygotsky (1986) knowledge is constructed in social setting which obviously include culture. Vygotsky as cited by Cole (1992) hypothesized that up until roughly the age of 2 years the natural (phylogenetic) and culture (historical) lines of development develop along separate lines. Vygotsky postulated that as the child acquired language the natural and cultural lines begin to intersect to change the nature of both speech and intellect. According to Vygotsky, it seems he believed that the nature of the child's development changes from being mainly biological to being socio- historical.

Vygotsky has been criticised for suggesting that socio-cultural factors are not important in early infancy. His position was that the biological influence was prominent in early infancy and only recognized the socio-historical aspect once the child had acquired language. Vygotsky is criticised for this stand because as Cole (1992) puts it, Vygotsky failed to understand the way in which even very small infants incorporate cultural constraints as basic constituents of their developing selves. This means that as the child grows, he is affected from infancy by the culture into which he is born. Gedler (1992) in his effort to explain his view of Vygotsky's socio-historical theory of psychological development states that culture does more than provide the setting in which learning occurs. The author contends that the very structure of social function determines that structure of individual psychological functioning. Taking the notion of the importance of culture in learning to its logical conclusions, one can say that a learner learns to think in ways that are directly fostered and developed by his culture. For instance, an African toddler in South Africa would take something he is given with both hands as a sign of respect instilled at a very young age while infants of other cultures use any one hand.

2.8.2 RADICAL CONSTRUCTIVISM

Radical constructivists according to Martin et al (1998) do not believe that the world is knowable. Borasi (1996) describes radical constructivism as essentially a theory about the limits of human knowledge, a belief that knowledge is a necessary product of our own cognitive acts.

We construct our understanding through our experiences and the nature of our experiences are influenced profoundly by our cognitive lenses or perspectives.

Radical constructivism implies that our understanding in general, including that of science, depends on how we make personal sense of the world. If this is true this literally means that there are as many ways of understanding as there are people. If this were true we would not have an agreed accurate way expressing scientific concepts. There would also be no concerns about learners having misconceptions about science, any idea expressed by learners would be valid. Horn (1997) also criticises radical constructivism by saying that it makes it unnecessary to weigh one's own theory and it's paradigmatic presupposition in the light of all the evidence.

2.8.3 CONSERVATIVE CONSTRUCTIVISTS

Conservative constructivists according to Martin et el., (1998) use constructivist principles to help learners construct accurate and useful conceptions and webs of conceptual understanding. Conservative constructivists use activity-based and problembased learning experiences and teacher intervention to promote accurate understanding of science. For instance, in the research study, the aim is to discover general problems respondents have with understanding genetics. The information gathered on difficulties respondents had could be used to design better curriculum materials to address conceptual difficulties respondents had in solving genetic problems. Teachers are always looking for strategies that will enhance meaningful learning for their learners. One of these strategies is to use co-operative learning. Co-operative learning is the instructional use of small groups so that students work together to maximise their own and each other's learning (Jacob and Mattson 1987, Holt, Chips and Wallace 1992). In co-operative learning students work together in small groups on tasks that require co-operation and interdependence among all individuals in each group. There are different types of co-operative learning groups that can be formed in the classroom. For instance, informal co-operative learning groups are temporary ad hoc groups that last for only one class period. In-formal co-operative learning groups, can ensure that misconceptions, misunderstandings and gaps in understanding are identified and corrected and that learning groups enable the instructor fo listen to students' discussions and get direction and insight of how well students grasp the concepts being taught.

Miller (1987) states that some advantages of co-operative groups are that one is helped in clarifying task rules, there is also support of other thinking individuals. One gets help in remembering the task rules and goals than would have been the case if one was working alone. There is the possibility that also a group or pair of people working together are likely to posses a larger repertoire of cognitive and problem solving skills than an individual. When justifying the use of co-operative learning with students from diverse

linguistic and cultural backgrounds Holt (1992), states that learning co-operatively in teams where "all work for one" and "one work for all" gives students the emotional and academic support that helps them persevere against the many obstacles they face in school.

2.9.1 CRITICISM OF CO-OPERATIVE LEARNING

Many researchers have discussed the benefits of co-operative learning, some of these benefits have been presented in the research. There are, however, no clear guidelines of how co-operative learning promotes cognitive development and enhances learning. Miller (1987) states that most of the explanations of the benefits of the working in co-operative groups emphasise communication, in particular verbal communication and especially discussion, dissent and argumentation. The role that dissent and argumentation play is that they may create cognitive conflict in the minds of persons in the group which may lead to cognitive restructuring and evaluation of one's beliefs.

2.9.2 RELEVANCE OF CO-OPERATIVE LEARNING FOR THE RESEARCH

In the research informal co-operative learning groups (pairs) were used to get the subjects to write down heuristics they use when solving problems in genetics. Co-operative groups were used in the belief that two individuals will remember more than one person. It was therefore a strategy to encourage more input from the two individuals so that the researcher gets a better insight of what the subjects knew about genetics heuristics.
2.10 UNDERSTANDING OF SCIENCE CONCEPTS

An increasing number of studies show that although university or college students have been exposed to a lot of information in particular topics, this does not lead to increased understanding (Shymansky, Woodworth, Norman, Dunkhose, Matthews and Tang-Lui, 1993). Many students, particularly in genetics and science in general, hold a lot of disconnected, fragmented knowledge. New knowledge which is not well integrated into one's prior knowledge is not usable. This situation is usually the result of rote learning, which is prevalent in African schools. Rote teaching and learning in African classrooms occur as a result of lack of resources, the overcrowding of classrooms and the frequency of under-qualified teachers. The result is that these students accumulate knowledge which is external and not well integrated with previous knowledge. This type of knowledge is soon forgotten. Learning for understanding is also referred to as learning for conceptual change and refers to knowledge that can be applied to problems encountered in life. Duschl and Gitomer (1991) advocate that in a teaching environment in which conceptual change is encouraged, assessment is designed to foster conceptual soundness rather than an absolute right or wrong answer. This type of assessment would for instance grade the quality of the argument rather than whether it was wrong or right. Creativity would be encouraged because instructors would be looking for students who find novel ways of solving problems.

The way science has been taught in many schools and colleges has made students focus on factual knowledge (Isaacs 1993). Thus knowing science is described in quantitative terms such as how much scientific vocabulary, and how many formulae have been memorised. Knowledge of formulae and science vocabulary, however, does not mean that the information assimilated can be used to solve complex problems. Such knowledge does not form a conceptual structure that can be used to solve problems that the student has not met before. Conceptual change or scientific understanding will have occurred when a person has applied sound scientific concepts to explain specific phenomenon (Lawson, Baker, Di Donato and Verdi, 1993). According to Smith, Blakeslee and Anderson (1993), indicators of conceptual understanding would include accurate description, predictions and explanations of phenomena in the natural world. Explanations require conceptual understanding and give tangible evidence that the student has mastered the concept.

In this study the depth of conceptual understanding possessed by the student teachers will be assessed by means of questions and practical work. Student teachers who have learned genetics by rote will find it difficult to answer questions that assess understanding. They will be found to be lacking in problem-solving strategies because these are not promoted by the transmission style of teaching.

2.10.1 STUDENT TEACHERS' UNDERSTANDING OF SCIENCE

Biology students at university and college level are supposed to have mastered the conceptual understanding of basic genetic processes and principles from their university courses. However, studies have shown that misconceptions exist throughout the educational system from elementary to high school and tertiary level (Westbrook and Marek 1991, Frederick and Larkin 1991, Tema 1992, and Sanders 1993).

Westbrook and Marek (1991) compared students at a variety of educational levels on their understanding of the concepts of diffusion and osmosis. This is a topic which appears across the study of biology as one way of transporting materials. In this study it was found that there was no appreciable difference among the grade levels in the range of sound or partial understanding, of misconceptions or complete lack of understanding of the two processes. Misconceptions exhibited by college students could be traced to the misuse of terminology. Science employs specific terminology which students fail to use with accuracy and precision.

In a South African study on the conceptual understanding of concepts in genetics by first year university students, Moletsane and Sanders (1996) state that many of the students had difficulty distinguishing between chromosomes, chromatids and homologous chromosomes. These are basic concepts which students should have mastered at high school level but they clearly had not done so. Methods of teaching used in schools are

partially responsible for the persistence of erroneous ideas among students. There are not many teachers who use constructivist cognitive strategies to discover their students' misconceptions or alternative frameworks (Sequera, Leite. and Duarte 1993). Constructivist learning is an interpretive process involving individual's constructing of meaning relating to what the individual is learning. New meaning is developed as the student interacts with the material, peers and the instructor. One hopes that the negotiation of meaning leads to a better understanding of the material learned. This, however, does not mean that everyone interprets things the same or gets an accurate scientific view of what is learned. Watts (1991:56) describes six principles of constructivism that he feels should be observed by instructors who believe in constructivism. The author states their approach should be seen to:

provide opportunities to explore and elaborate pupils "naive" ideas and developing understanding of science.

promote active learning and actionable learning, where pupils must put their understanding into practice and use their knowledge.

engender shared teamwork and collaborative group activity within overall social content.

work through the use of open ended investigations, where there are few right answers and approaches to any solution where pluralism rules rule. make science relevant enjoyable, fruitful, plausible and highly motivating.

The basic idea of constructivism is therefore to allow students to take the opportunity to explore what they are learning to discuss with their peers and to come to a common understanding. While constructivism does not guarantee accurate development of scientific concepts, it does give students opportunities to look at the scientific concepts they hold against what their peers and instructor believe. The resulting destabilisation of an individuals' beliefs causes the individual to reassess his belief and to look for more plausible explanations. The implication is that prior knowledge is elaborated and changed on the basis of new meanings negotiated with peers and teachers . In the research constructivism has been used to help student teachers revise the processes of mitosis and meiosis using a worksheet appendix (3). This was done because none of the student teachers had ever had a hands-on and minds-on opportunity to compare the finer differences between the two processes. Secondly, student teachers worked in pairs and came to a negotiated agreement as to what they considered steps they should follow when solving problem in genetics.

According to Martin, Sexton, Wagner and Gerlovich (1998) a constructivist learning and teaching model contains four elements, that is, exploring, explaining, expanding and evaluation. During the exploration phase co -operating groups of students use all appropriate senses to investigate a phenomenon. The teacher interacts with children to discover their ideas and to reflect on them. The ideas generated by the students with the teacher acting as a facilitator are used to construct concepts and meaning that makes sense to the students. In the next phase which is expansion, the teacher helps students to

develop their ideas further through additional mentally challenging exercises or activities. This phase helps learners to refine their ideas and to expand their repertoire of science process skills. The last phase involves the evaluation of learners' conception by carefully assessing if there are changes in learners ideas and whether they have mastered relevant science process skills. The genetics test that was administered to the students teachers aimed at finding out if the respondents had mastered basic concepts in genetics.

In another study by Sanders (1993), erroneous ideas held by white English speaking South African teachers were investigated. The researcher analysed how teachers marked an essay containing errors commonly found among grade 12 students. The critical result found in this study was that an unacceptably large proportion of the teachers surveyed in the study held erroneous ideas about the process of respiration. The results of this study confirm that it is not hard to find instances of teachers harbouring serious misconceptions about topics in which they apparently have an adequate background (Shymansky, Woodworth, Norman, Dunkhose, Mathews and Tang-Lui 1993). There is therefore a great need to strengthen teaching strategies that take account of the misconceptions that students bring to their lessons. In-service programmes should help teachers to discover their own misconceptions so that these are not passed on to pupils. Sequera et al(1993) reports that 77% of professors who teach method courses in Portugal teach the issue of alternative conceptions because of the central place this issue has taken in science education. In the study, student teachers will discover their misconceptions and will be made aware of their competency in solving genetics problems. This student teachers will not only have a theoretical view of what is meant by misconceptions but will actually experience the notion directly by discovering their own misconceptions. One hopes that this experience will sensitise student teachers to the fact that in order to teach science effectively, they should be aware of the world views children bring into the classroom. They should also be aware that children from different cultures may bring different world views to bear on their learning. Effective teaching will mean providing opportunities for students to evaluate their learning and particularly to ascertain if pupils hold accurate scientific concepts. A range of theories and strategies of teaching have been discussed in this chapter which can contribute to help students to engage in meaningful learning. Among these theories is constructivism. Ramorogo (1998) states that constructivism is not a theory of teaching and therefore does not describe teaching. However, teaching approaches can be abstracted from it and used as constructivist teaching techniques, some of which have been described in this chapter.

2.11 DIAGNOSTIC TOOLS IN SCIENCE EDUCATION

All the stakeholders in education look toward educational institutions to produce quality products. In general, quality refers to learners, who in this case are student teachers who will be able to use their knowledge to solve problems in the real world of teaching. To ensure that student teachers gain a conceptual understanding of science there is a need for regular collection of performance indicators using diagnostic or monitoring tools. Fitz-Gibbon (1996:5) defines a performance indicator as an item of information collected at regular intervals to track the performance of a system. In education this would be equivalent to continuous assessment where instructors use diagnostic tools to assess whether students have developed conceptual understanding or still have problems. Diagnostic tests do not only examine pupils' knowledge in terms of how much they have memorized (quantity) but also looks for qualitative understanding. An analysis of the results of a diagnostic test includes the following feedback from (Barnard 1993) Helmke and Schrader (1995):

1. misunderstandings or alternative conceptions which students have and their sources, particularly if students are also interviewed to explain their difficulties.

2. profile of students strengths and weaknesses.

3. discovery of possible causes for the failure to attain competence for all individuals in the class.

It is only after the instructors have identified pupils' conceptual problems in terms of their, nature, breath and depth, as Mammen (1996) puts it, that they can come up with appropriate intervention strategies. Suitable intervention strategies facilitate conceptual change.

2.12

All the student teachers involved in this research come from educationally disadvantaged schools. As a result of rote learning and the transmission style of teaching, to which the student teachers were subjected in disadvantaged schools, a conceptual understanding of science is not likely to have taken place. In this superficial style of teaching and learning, students never get a chance to construct the meaning of the phenomena studied and to assimilate new ideas into their cognitive structures. Rote learning in our schools has become a major concern for both educationists and the ordinary citizens of South Africa.

Sirestarjah (1996:328) in his article about transforming education, confirms that African teachers very often teach science without having understood the subject matter themselves. Under these circumstances the safest way to teach is by the transmission style. Under these conditions, students memorise content from books without understanding, they are passive throughout the lesson; and the asking of questions is not encouraged. The element of passivity is unfortunately also endorsed by traditional culture, according to which respectful children are supposed to be seen not heard. Students who ask questions are labelled as arrogant or are perceived to be challenging the teacher's authority. The major challenge facing African schools is the transformation of teaching from transmission to discovery learning and problem- solving strategies and to encourage learners to engage in what they learn by means of discussions and debates.

Several articles have appeared in the local media on the state of mathematics and science education. Two articles that stood out in significance for the researcher were, first, a report by Barber (1996:1), who reported that, 'Our students finish bottom of the class in maths and science'. This report on South African schools came as a shock to South Africans. The investigation compared South African children with children in other countries, and found that South African children obtained the lowest scores in both mathematics and science. The second article was by Cooke (1997:8), who reported that, "Many new mathematics and science teachers from teacher training colleges were innumerate, ... few could be regarded as either mathematically or scientifically literate." All these articles indicated that there are problems in the teaching of science which educators need to address, and this could be done starting with small-scale classroombased research.

An article by Rayner (1995) in the Southern African Association for Research in Mathematics and Science Education Newsletter stated that schools in the city of Soweto have little in the way of laboratory facilities, and that most science and mathematics teachers are poorly trained. This paper also highlighted the fact that science and technology museums are situated in white areas and managed by English or Afrikaans speaking South Africans. Soweto African children therefore do not have access to these museums because of distance and cultural alienation. Even if these children were able to go to these museums they would be addressed in foreign languages that would not enable them to understand unfamiliar science concepts. These are issues of equity that the South African government will need to address if the majority of its citizens are to master mathematical and scientific literacy.

A second factor which affects the learning of science by students is language. African students in both Francophone and Anglophone areas learn science in foreign languages. In most cases even the teacher is not proficient in the language of instruction. Actually, these students contend with learning two languages, the foreign language of instruction and the precise, sophisticated language of science. Of all these factors that impact negatively on the learning of science by African students, language does seem to be one of the most significant. Waninga (1992:516) confirms this with reference to Papua New Guinea when the author states that, 'The major factor contributing to the failure of many students is the use of English language in the classroom'. Difficulties with English language may also have contributed to the very negative attitude of many African students to studying science.

A lot of educators have described the difficulties experienced by students who are taught in a foreign language. These difficulties include the inability to express their ideas clearly (Bulter 1996; Mammen, 1996; Reinhard, 1997; Rutherford, 1997; and Setati 1997) as well as in mastering science concepts. Makhubu (1997) confirms that the weakness of the formal education system in the delivery of science, technology and mathematics at all levels is a chronic problem which pervades most African countries. Makhubu was addressing the dearth of women science researchers and the poor research output from Africa in general. It seemed clear that unless there is an improvement in the teaching and learning of science in schools and tertiary institutions there will be no improvement in the state of science education in Africa.

In attempting to identify students' competencies in genetics, the researcher has to be careful to distinguish between the language difficulty and the true lack of scientific understanding. The student may have a very clear understanding of certain concepts in his mother tongue but be unable to put them across clearly in the language of instruction. Unfortunately, in most cases, African students have to write their assessments in English. This becomes a major obstacle in expressing their ideas clearly. Ogunniyi (1997) states that examinations in science are presented in a language far beyond the linguistic competence of students. Kamwangamulu (1997) suggested that education in a foreign language has failed to promote literacy, not only in South Africa, but throughout the African continent. The vast numbers of school children who repeat classes and tertiary students who fail at universities show that they neither get proficiency in the language competence nor in the conceptual understanding of relevant concepts taught. High failure rates, lead to the prevalent perception that science is an elitist activity, quite remote from ordinary people's daily lives. In South Africa there is also the problem that some of the students in tertiary institutions are not necessarily university material. So apart from poor linguistic proficiency, poor performance academically may also be attributed to students capabilities.

The respondents in this research are second language English speakers. They had different African cultures because they came from different parts of South Africa. Culture is defined by Tucker (1994) as the ideas, customs, values, skills and arts of a specific group. African cultures do not encourage curiosity, an investigative spirit of constantly asking questions and looking for answers. Science needs students to be curious, to ask questions and to look for answers. There is therefore a mismatch between the two cultures i.e. the African indigenous cultures and the culture of science. Driver's (1989) talks of a culture of science which the author describes as having a unique way of doings things. The rules and norms that govern scientific behaviour were developed by people of the western world who were mainly white and male. Drivers's point about the culture of science was that learners need to be initiated into the culture of science by being given access not only to physical experiences but also to concepts and models of conventional science. Cultural factors affecting learning of the subjects were further compounded by the fact that biology, which is taught in a foreign language, also has unique specific terminology which students have to learn. Gredler (1992) citing Vygotsky, states that "major concepts and ideas as well as the means of communication and ways of viewing the world are created by the culture." It would be interesting to discover how culture affects the learning of the student teachers in a historically disadvantaged university...

Pupils bring to the school their own world views which may affect the learning of science, particularly if traditional world views clash with science. The world view can be described simply as a basic set of beliefs or assumptions accepted by a particular culture. Solomon, (1993) talks about differences in the "life- world knowledge " from one culture to another. The difference in cultures may be brought about by differences in languages and lifestyles.

Peoples beliefs about phenomena in their environment are very much tied down to the negotiated meanings that have developed in that culture. Solomon (1993) also distinguishes between life world knowledge versus scientific knowledge. Life world knowledge is characterized by multiple meanings which are not defined but negotiated socially. Scientific knowledge has concepts which are defined are precise terms. Ogunniyi, Jegede, Ogawa, Yandila & Oladele (1995) describe the world view as " a dynamic cultural framework that determines the likelihood in which a new idea is assimilated into the cognitive structure." Driver (1989) endorses the same view by stating that the constructivist approach realizes that socially and culturally constructed ideas, principles, theories and models cannot all be discovered by individuals though empirical enquiry. Teachers therefore have a crucial role to play as facilitators of learning to initiate learners into the ways of doing things in science. In many classrooms where rote learning is the order of the day, the culture of science which has among other things, an empirical positivistic way of doing things is missing. Social constructivism therefore focuses on the learner and the social processes that mediate learning.

Constructivism as a theory of learning is relevant for the research because it looks at how individuals learn and strongly suggests that learning is done by individuals. The diagnostic test developed for assessing competence in problem-solving in genetics will expose the knowledge and problem-solving competencies of each individual student teacher. Writing on how to diagnose students' learning (Jones & Rickards 1991, Ferguson-Hessler & de Jong 1993, Lavoire 1993, and Meyer 1993) suggest asking students to think aloud, that is, verbalize their ideas as they solve problems. Student teachers can also teach course topics to peers or explain ideas or their procedure to others as they solve problems. Further activities are interpreting data, developing alternative explanations and participating in constructive arguments about phenomena. The feedback that students get from colleagues and the instructor is important in persuading other students to examine their beliefs against scientific concepts. These are some of the strategies the researcher used in the research. The researcher believed that as a result of discussion (constructing knowledge in a social context) new forms of understanding would arise, not only in terms of more accurate scientific knowledge, but also in understanding how science knowledge is constructed.

One important aim of this research was not only to identify students difficulties with basic concepts and processes in genetics but also to address these problems. The researcher therefore endorses Entwistle & Ramsden's (1983) perception of learning, which they describe as changes in conceptions with reference to the quality of a person's understanding and specifically not the quantity of information he can produce on

demand. Student teachers therefore need to acquire personal knowledge of the meaning of concepts in genetics and not simply to repeat other people's knowledge in a rote fashion. Such teachers would in turn, be able to teach their students to learn with conceptual understanding. The strategies of both discovery learning and dealing with misconceptions are referred to by Clough and Clark (1994) as cognitive activators and are believed to activate the constructivist learning model. Cognitive activators help students to develop a repertoire of skills that can be used in problem- solving and these are skills which are not acquired by students in usual lecture courses or in the transmission style of teaching.

2.12.1 ALTERNATIVE CONCEPTIONS

Research has revealed that all students, irrespective of their culture, bring beliefs to the science classroom which are in conflict with the science learned (Arnaudin & Mintzes 1985, Bishop & Mintzes 1990, Gitlin, Bringhurst, Burns, Cooley, Myers, Price, Russell & Tiess 1992, and Addo 1997). However, the perception is that students in developed countries have the advantage of having been exposed to science and technology from birth. Further, perceptions indicate that African students in the third world find that their cultural beliefs tend to alienate them from school science. Students' conceptions which are different from accurate scientific concepts or scientifically inappropriate explanations are referred to as misconceptions (Fisher 1985, Hand & Treagust, 1987, Lawson, Baker, Di Donato & Verdi 1993).

Sanders (1993), however warns against careless use of the term misconceptions. According to her true misconceptions are naive ideas based on everyday experiences. These misconceptions are characterized by stability and resistance to change. Other authors refer to *alternative conceptions*, which are described as conceptions held by students which differ from the scientific conceptions transmitted by the school (Sequera, Leite, & Duarte, 1993). Westbrook & Marek (1991:649) refer to the inaccurate understanding of many scientific phenomena, which is referred to as misconceptions or *alternative frameworks*. A similar definition is given by Smith, Blakeslee & Anderson (1993:112), who confirm that students bring to instruction a variety of conceptual frameworks that are often at odds with scientific ideas. While there may be an ongoing debate on the accurate classification of students' inaccurate science conceptions, it seems there is agreement among the authors that such misconceptions exist and interfere with learning.

Another way of describing beliefs that students bring to the learning situation has been construed as a 'world view' (Proper, Windeen & Ivany 1988). Researchers who hold this notion describe a world view as a set of beliefs, held consciously or unconsciously, about the basic nature of reality and how one comes to know about it. In a cross-cultural study involving five countries, that is, Botswana,Indonesia, Japan, Nigeria and Phillippines, researchers working in collaboration found that the subjects hold identical world view presuppositions irrespective of their cultural background (Ogunniyi, Jegede, Ogawa, Yandila & Oladele 1995). The study confirms that world views are not bound to specific

cultures, but are universal. In a South African study involving student teachers, Lawrenz & Gray (1995) investigated the relationships among world views, student characteristics and scientific concepts. These researchers classified misconceptions into those that involve factual misunderstanding and those that were based on alternative world views.

The alternative world view in the study appears to mean inaccurate science perceptions which are based on beliefs which are particularly influenced by one's culture. One of the ideas noted by Lawrenz & Gray's study was that student teachers had different perceptions of what *long* means in an item that required them to give an example of a long distance. Several studies show that students do not come to the classroom *tabula rasa*. They bring conceptions consistent with the world views of the communities from which they come (Proper et al. 1988, Ogunniyi et al. 1995, Lawrenz & Gray 1995). Some of these conceptions are in conflict with the scientific conceptions taught in science classrooms.

In the research, the researcher used alternative conceptions or frameworks and misconceptions interchangeably. Some researchers have used all these terms to refer to inaccurate understanding of science concepts (Hand & Treagust 1987, Westbrook & Marek 1991, Lawson et. al. 1993, Sequera et al. 1993, & Smith et. al. 1993). In all cases alternative conceptions or misconceptions will refer to students' conceptions which are not consistent with the scientific world view. The discovery of the students' misconceptions is crucial for determining successful interventions that would lead to a

conceptual understanding of genetics in particular. Effective assessment tools should lead to the understanding of learners' problems by instructors and should be followed by adoption of constructivist teaching strategies that will encourage changes in conceptions. When teachers do not discover students' misconceptions and deal with them, they seem to reinforce such misconceptions because these misconceptions are not challenged.

2.13 BLOOMS' TAXONOMY OF EDUCATIONAL OBJECTIVES

The term taxonomy originally referred to the science of the classification laws of biology. However, in education the term "taxonomy" is closely associated with the name of Benjamin Bloom (Landsheere 1990). Blooms taxonomy of educational objectives consisted of six cognitive levels that were arranged in a hierarchial order from the simple to complex objectives requiring a higher level of thinking. Bloom's taxonomy consisted of the following objectives :

- 1. Knowledge, which includes recall or recognition of specific elements in a subject area.
- 2. Comprehension, which refers to an ability to translate or put information in different words or symbols.
- 3. Application, a higher order level of thinking where the learner must be able to use and apply previous knowledge to new information to solve problems.

4. Analysis : A learner who has mastered this level of thinking is able to breakdown for instance, communication into its constituent elements or parts such that the relations between the ideas expressed are made explicit.

5.

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- Synthesis: This process refers to the ability of putting together elements and parts so as to form a whole. It involves arranging and combining things in such a way as to form a pattern and structure not clearly there before. For instance, a learner can design a new instrument for carrying out a particular experiment.
 - Evaluation: An evaluation is defined as the making of judgements about the value of ideas, works, solutions, methods, material and so on For instance, the study evaluated the subjects ability to solve a simple genetics problem.

2.13.1 IMPACT OF BLOOM'S TAXONOMY OF EDUCATIONAL OBJECTIVES ON THIS RESEARCH

The research used ideas from Bloom's taxonomy to classify the questions used for the subjects. It was important to make sure that the questions did not only test rote learning. The taxonomy was therefore used to ensure that the test was balanced by including questions that demanded different levels of thinking. Bloom's taxonomy has improved our understanding of the different levels in which our minds can operate in thinking. It has therefore helped teachers to move away from testing recall only. Teachers who have been exposed to Bloom's taxonomy try to balance their tests by including as many of the six levels of Bloom's taxonomy as possible. Avenant (1986) states that a

teacher whose objectives go no further than the first level ie. Knowledge, merely pumps his pupils with facts which he expects them to memorise and regurgitate during tests or examinations. Balanced objectives would include a variety of cognitive skills learners are supposed to master. Objectives therefore specify the direction the programme will take and helps the instructor formulate a relevant evaluation strategy.

According to Cook and Welbesser (1972) an instructional objective stated in behavioural terms tells the learner what he will be able to do after completing the instruction. In essence a change should occur after successful instruction. If the learners's behaviour changes as he learns, it is wise to develop educational objectives in terms of what is expected for the learner to be able to do at the end of the instructional process. The aim of the teaching/ learning process would then be designed to evaluate the learner to master the desired competencies. Competence is a demonstration of knowledge, skills and attitudes required to perform a'given task or act (Walkin, 1991) states that one cannot talk about a demonstration of competence without mentioning standards. Standards specify distinct performance goals which are expected from a learner. When a learner has mastered a skill he/she will be able to perform consistently and reliably and will regularly maintain at the standard specified an effective and efficient output.

Instructional objectives written in behavioural terms usually state criteria for acceptable performance. The objectives inform the learner of the minimal standard of performance each individual must meet in order to demonstrate acceptable competence (Cook and Walbesser 1991).

The researcher used Bloom's taxonomy in developing the theoretical test on understanding of genetics by subjects. The subjects were therefore required to show their competence in handling genetics questions at different levels of Bloom's taxonomy of educational objectives. The research decided to employ criterion referenced measures because Popham (1990) suggested that if measurement devices are required to ascertain an education objective attainment, evaluators should employ criterion referenced rather than norm- referenced measures.

2.13.2 LIMITATIONS OF TAXONOMIES OF EDUCATIONAL OBJECTIVES

Popham (1990) encourages educational evaluators to employ the taxonomies of educational objectives but warns that they should be used only as gross heuristics, not fine grained analytic tools. In other words, the use of taxonomies of educational objectives does not guarantee a perfect evaluation tool. Although Bloom's taxonomy is used widely in educational circles the classification presents problems because the levels change according to the context in which they are used. For instance a student who solves an application problem in genetics may have been working at a knowledge level if he had memorised the solution of this problem without much understanding.

In this chapter, factors that affect the learning of African students have been discussed, as well as the conceptual frameworks that formed the basis of the research. It was suggested that learning for conceptual understanding is affetced by many factors like prior knowledge, one's culture which includes language, the teacher's style of teaching and the different contexts in which learning takes place. It was stressed that real learning only occurs where students gain conceptual understanding of phenomena discussed. Student teachers at tertiary institutions, as well as qualified practising teachers, were said to have shown poor understanding of science. Evidence was also presented that increased science course work or greater specialization is no guarantee that an individual does not harbour misconceptions. Indeed many student teachers leave tertiary institutions without their misconceptions having been discovered and those who become teachers inevitably pass them on to their pupils.

The presence of misconceptions or alternative frameworks in students was said to exacerbate the need for the development of diagnostic tools. These tools make instructors aware of the nature of misconceptions so that misconceptions could be addressed using appropriate interventions. It was also pointed out that students hold misconceptions which are based on an alternative world views. This world view was described as a set of beliefs which learners bring to the learning situation (Proper et al., 1988). Culture was said to play an important role in the formation of concepts and ideas and as a means of viewing

the world. It was also advocated that these world views should be the starting points in constructivist teaching classrooms, if students are to learn science conceptually. Another source of difficulty was the fact that students learn in a foreign language. This results in many students not understanding science. At initial level science needs to be taught in the learner's language and then gradually in the second language which smoothly accelerates the notion of conceptual transfer.

Finally, the social constructivist paradigm was discussed. Learning in this paradigm was viewed as something that is done by an individual, but which is socially mediated. It was noted that the constructivist model emphasizes students' active participation, which enables instructors to be aware of misconceptions. If instructors are aware of misconceptions, they will have a better chance of anticipating student difficulties and designing presentations that avoid reinforcing or perpetuating such misunderstandings. Many different theories of learning were discussed for instance theories by Skinner, Piaget, Bruner, Ausubel etc. None of the theories were viewed as complete answers to our problems of understanding the process of learning. Learning is a very complex activity but awareness of the different theories helps contribute to our understanding of the differnt factors that affect learning and to be aware of what can be done to facilitate learning. Having provided a broad survey of learning theories the researcher concluded that the theoretical framework underpinning the study are theories of socio-cultural constructivism and problem-solving. Problem-solving is a daily activity and learners should develop skills to tackle their problems in an a logical and systematic manner.

CHAPTER 3

GENETICS IN THE SCHOOL CURRICULUM

3.1 INTRODUCTION

The treatment of social issues in the biology syllabus is crucial because it reveals the true nature of the sciences as a form of human activity. Science is frequently taught as though it is divorced from reality. Genetics is a biological topic that impacts on the life of all human beings. It does not only help people understand genetic defects in their communities, but also provides important technology for providing adequate supplies of food. Besides, with increasing civil liberties in South Africa, all citizens need to understand all aspects of science that might impact on their lives. The Genome Project is one example which appears to have potential for ethical, religious and legal impacts once the technic of mapping individuals' genes has been accomplished. These impacts are already often debated in the media and citizens need to be able to read these articles with understanding.

This idea of including biosocial issues in the curriculum was well supported by Lavoie (1993) who cited the National Research Council suggestion that biology has received increased attention in recent years with the rise of nationally significant biosocial issues of an environmental, ecological and medical nature. A plea for the inclusion of bio-social issues in the South African school curriculum was also strongly advocated in the Magi's study. Magi (1993) investigated the extent to which the biology teachers and student teachers were aware or understand biology related problems that affect African

communities in Kwa-Zulu Natal north -coastal region. Findings of this study suggested that there was a discrepancy between what was taught at school and the needs of the African community. The study also found that the biology which was taught in African schools did not seem to address the biosocial issues that affected life of the people in the north-coastal region of Natal.

3.2 GENETICS IN THE SOUTH AFRICAN SCHOOL SYLLABUS

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The grade 11 and 12 syllabus in use in South African schools is common for all schools. It is quite explicit in what it requires students to be taught and what skills need to be developed. The syllabus shows that students are expected to master three basic areas of genetics as discussed below.

The first part of the syllabus deals with cell division and genetics. In this topic the learners are expected to understand the processes of mitosis and meiosis. These two processes, particularly meiosis, are crucial to the understanding of genetics. Use of the Punnet Square is also impossible if one does not understand meiosis. This section of the syllabus also includes understanding of the roles of the nucleic acid as well as the structure of DNA. Furthermore learners study the replication of DNA followed by the mechanism of protein synthesis. Students tend to find these areas of genetics difficult to grasp because they are abstract concepts.

The second part of the syllabus requires the learners to understand genetic terminology and mechanisms involved in the transmission of inheritance. Genetic

terminology has been reported as one source of problems to students. The number of specific terms to learn causes confusion to most learners (Pearson and Hughes 1988). Pearson and Hughes suggested standardizing the number of genetic terms to be used at undergraduate level. As examples of genetic transmission, only monohybrid and dihybrid crosses are done. Learners are also introduced to gene mutation, natural selection and the practical application of genetics in plant and animal breeding.

3. The third section of the syllabus encourages teachers to introduce practical activities which might include making models of the various structures involved in genetics, for which a variety of easily obtainable materials is suggested. However, in overcrowded classrooms, particularly in rural areas, not much practical work can be done. In really impoverished areas it can also be very difficult even to lay one's hands on empty cereal boxes to use in class. Although practicals are supposed to occur in poor schools they seldom actually take place.

3.3 OUTCOMES-BASED EDUCATION

In 1998 the South African education began to undergo a revolutionary change when outcomes-based education (OBE) was introduced, starting with grade 1. William Spady has been the father and the driving force behind OBE. He lectured extensively in Canberra Sydney, Melborne and Brisbane where foundations for OBE were established. Outcomesbased education is said to prepare students for life after school. The crucial question for educators in this system of education is what competencies students must have if they are

to compete successfully in life after graduating. The present system of education in South Africa focuses on book knowledge and not on pupils' ability to apply knowledge and principles learned in real life situations. There has therefore been an outcry from industry and other employers about school leavers' deficiencies in skills required in the employment sector as well as general survival skills within communities. Learners lack skills such as functional literacy in reading with understanding, numeracy and ability to solve simple practical problems. The shift to OBE has therefore been the government's initiative in response to the social and economic needs of the country. The African National Congress led government hopes effective delivery of OBE will assist in developing skills that will enable learners to function in a scientifically and technologically literate society. Wallace (1985) suggests that the type of education which equips learners with a range of skills should enable them to use their education to enhance their quality of life.

Spady (1993) confirms that, "in outcomes-based education the intended learning results are the start-up points in defining the system". The justification for outcomes- based education is that it describes an outcome as a culminating demonstration of learning which occurs at the end of learning. It therefore focuses on those skills that should be developed, particularly those relevant to survival in the world. The rapid changes in the world demand that people be life-long learners if they are to survive and function effectively in the rapidly changing world. Memorisation of information such as what happens in many impoverished South African schools does not prepare students for life. Things that were memorised are soon forgotten as students leave school. Ability to be a life-long learner is therefore a more valuable tool of survival in a changing world. The precise meaning of 'outcomes-based' as described by Kudlass (1990) is that everything done in teaching will be done directly around the final intended learning demonstration. The outcome must, however, be defined clearly and be understood by both the instructor and learner.

Some South African schools have adopted and implemented OBE and reported that for them it is the future of schooling. According to Robinson (1999) one school in Durban reports how teaching in the school has moved from a rigid textbook-based and teachercentred syllabus towards one that is learner-centred, allowing for knowledge integration in real life situations. In another school, also in Kwa-Zulu Natal, Robinson (1999), has adopted OBE in all classes in their school not only in grades 1 and 7 as was suggested by the government. One of the teacher's comments in the school was that learners in OBE combined creativity with research and logic to reach an understanding of both themselves and their environment. It is therefore encouraging to see that teachers are experimenting with OBE and finding out what works and what does not work. No form of education, even OBE will address all the ills of the South African system but there is light at the end of the tunnel if teachers start shifting from a teacher-centred to a learner-centred model which recognises that there is life after school.

3.3.1 FORMS OF OUTCOMES-BASED EDUCATION

According to Spady (1993) there are three forms of outcomes-based education. The first is referred to as traditional outcomes-based education and uses the existing curriculum as its starting point. As a result the structure of the curriculum remains intact but differs from traditional education by its focus on outcomes. However, it remains content-dominated and not geared to life skills. The main characteristic of traditional outcomes-based education is that the school and classroom are the only contexts where the outcome can be demonstrated. The potential for an all- round education is therefore limited.

The second form is transitional outcomes-based education which uses the subject matter or content as a vehicle to develop higher order competencies in learners. Examples of higher order cognitive competencies developed are critical thinking and problem- solving. Other essential skills such as communication are also emphasized. South African science education researchers like Sanders (1996) have called for development of these skills among learners.

The third form of OBE is transformational outcomes-based education which Spady (1993) describes as future oriented. Its aim is to equip all students with knowledge, competence and orientations needed for them to successfully meet the challenges and opportunities of the world after school. It is therefore concerned with developing the students' ability and capacity to adapt to a fast changing technological world. Transformational OBE addresses the concerns of both educators and communities that the present South African education system is not producing learners that are well- prepared to face the world.

Spady and Marshall (1993) suggested that outcomes-based education is founded on three basic premises, that:

1. all students can learn and succeed

2. success breeds success

3. schools control the conditions of success.

The present system of education in South Africa has been based on meeting the needs of either brilliant or average students. The differences among students were not entertained, so everyone was required to master specific content at the same time. Those who could not cope were left behind and classified as slow learners. The new approach, outcomes-based education, will require instructors to be flexible when it comes to how long a student takes to learn an outcome. However, student outcomes will have to be obtained at a high level. This flexibility of teachers in allowing learners to attain competencies at their own pace is one example of positive control of the conditions of success by the school. This would be a major shift away from the negative control of forcing everyone to work at the same pace without consideration of the specific circumstances of each learner. The main aim of transformal outcomes-based education as summarised by Spady and Marshall (1993) is to produce a curriculum which ensures, among other things, the following:

- 1. high expectations for all to succeed
- 2. expanded opportunities and support for learning success.

The success of transformational outcomes-based education would be indicated by learners being equipped with the knowledge, competence and orientations needed for success after school.

Traditional methods of teaching are teacher-dominated, with students being passive and not active participants. This mode of learning does not promote problem- solving skills and critical thinking in students. What this type of learning does is to provide learners with knowledge which is not usable in the world of work. This is in direct contrast with transformational outcomes-based education which aims at providing learners with skills and competencies enabling them to become life-long learners and citizens who are able to adapt in a changing world. The introduction of OBE will therefore cause a major shift in the style of teaching. Teachers will cease to play a dominating role and will thus become facilitators of learning. Implications are that teachers need to be confident with their subject matter to be able to provide worthwhile learning experiences for their learners and that learners will construct their own understanding of phenomena.

One of the aims of this study is to highlight the impact of rote learning on the understanding of concepts by learners. It is hoped that this study will demonstrate that continuing education into higher levels does not improve conceptual understanding of the subject if it is taught through passive methods of teaching that do not activate vigorous cognitive engagement with the subject learned.

3.3.3 ASSESSMENT IN OUTCOMES-BASED EDUCATION

Another area in which important changes will take place in OBE is assessment and evaluation strategies. Present assessment methods test mainly knowledge (Isaacs 1993),

particularly in biology. Each student's individual performance is compared with a norm in a typical norm- referenced style of assessment. Typical assessments occur at the end of the term or year (summative) and their main aim is to arrive at a summary description of the student's achievements at the end of the course. However, in OBE curriculum implementation and assessment are integrated. The 'assessment curriculum,' as Broadfoot (1985:6) calls it, provides a feedback system which lays emphasis on:

- 1. assessing mastery of learning objectives
- 2. assessing a comprehensive range of factors that affect learning
- 3. diagnosis of strengths and weakness
- 4. collaboration between pupils and teachers.

The type of assessment described above is continuous, and because its key function is to support learning and teaching, it is generally termed 'formative'.

The focus of assessment in OBE is on outcomes. Broadfoot (1987) suggests that these outcomes could be general skills such as intellectual, scientific and social skills. Practical skills and social attributes such as personal qualities, attitudes and experience would be assessed as well. These are qualities which are important in the world of work although one must concede that they are not easy to assess. In the traditional style of assessment learners walked out of school with a report which described their personalities such as in such vague terms as 'satisfactory conduct'. The OBE students will get profiles which describe them more holistically. Law (1987) states that dissatisfaction with the traditional report is its incapacity to convey what is known about the student with sufficient

completeness, clarity and relevance for the purposes for which they are necessary.

Another important feature of OBE assessment will be the test items which will be criterion- referenced. Criterion-referenced tests examine students' mastery of specific skills, based on objectives derived from the curriculum (Helmke and Schraden 1995). In anticipation of using criterion-referenced tests in future, the researcher also adopted criterion- referenced tests for this research. The researcher's aim was to use an objective standard that would give a profile of strengths and weaknesses of students with respect to identified criteria. The revelation of students' difficulties could then be followed by suitable intervention strategies.

3.3.4 CRITICISM OF OUTCOMES-BASED EDUCATION IN SOUTH AFRICA

Criticisms that have been levelled at the introduction of OBE centre around the under preparation of teachers who will implement OBE. Mullholland (*Sunday Times*, 8 June 1997) expressed concern that the "new education system will produce confident illiterates". He has a perception that the automatic progression from one grade to another without the learners failing as in the traditional system, will breed a generation of young people who will be illiterate. Another concern was that tasks have to be performed within a certain time frame while OBE delivery strategy recognises learner differences in their pace of learning. However, it must be remembered that whether there is a time frame or not some learners will always be cognitively faster in processing information than others. Teachers will have to be sensitive to the needs of all the children and see to it that slower learners also succeed. Further criticism came from Jansen (1997), a prominent science educationist in KwaZulu-Natal who wrote a much debated paper entitled, 'Why OBE Would Fail'. The gist of the paper was that without proper in-service training, implementation of OBE would be doomed. The training of teachers will indeed be crucial to the success of the new programme. However, the researcher's view is that South Africans are fortunate that they will be able to learn from the faults of other countries such as Australia and Canada which adopted OBE as an approach years ago. OBE can therefore be adapted to local conditions, avoiding the pitfalls experienced in other countries. Kudlass (1994) writing on the advantages of OBE confirms that it can promote educational success if appropriately implemented and delivered. Proper and effective training of teachers will be crucial in the delivery of OBE, particularly in poor resourced black schools.

3.4 PROBLEM SOLVING AND CRITICAL THINKING

This research on the understanding of concepts and processes in genetics has come at an opportune time when the education system is shifting from rote learning to problem solving and critical thinking. These two skills are important for survival in a scientific and technological society that is rapidly changing. Wallace (1985) puts this aptly when he declares, "more must be done to enable young people to live with competence and confidence in the world which will exist at the end of the twentieth century". Genetics in a school or university unit in the curriculum offers a lot of opportunity for developing problem-solving skills, hence it has generated a lot of interest throughout the world of research. This research also emphasizes assessing whether subjects could solve basic genetic problems competently.

Among some of the main goals of teaching genetics to learners is to help learners to be competent in solving genetic problems. However, the learners do not often know how to begin solving a problem once they have read it. Learners flounder when trying to translate genetic symbols into meaningful statements. One must remember that a problem is a situation, quantitative or otherwise that confronts an individual, requires resolution and for which the individual sees no apparent or obvious means or path of obtaining a solution (Krulik and Rudnick 1995). Problem solving refers to people's efforts to achieve a goal for which they do not have an automatic solution. There are a variety of problems students have to deal with, for instance solutions to questions given by teachers solutions for personal problems like career goals, sex life and progress in academic work.

It is therefore useful to have logical ways of dealing with problems. Schunk (1991) page 190 suggests that regardless of content area and complexity, all problems have certain things in common. The common characteristics of problems are stated as being the following :

- Problems have an initial state which refers to the present status or level of knowledge of the problem solver.
- 2. Problems have a goal which the problem solver desires to attain.
- 3. Most problems require breaking the goal into a series of sub-goals that when mastered result in goal attainment.
- 4. Problems require performing operations on the initial state ie. the original problem and the sub-goals, where operations are activities that maybe behavioural or cognitive that lead toward the solutions of the problem.
A lot has been written about problem solving ability and its usefulness in addressing day today problems. Problem solving in the research was focused on solving basic genetic problems of the high school level. The subjects were supposed to have previously acquired knowledge, and skills to solve genetics problems particularly those at the level in which they would be expected to teach when they graduate. The plan to solve most basic genetic problems can be represented by a series of steps referred to as heuristic plans or heuristics in general. There are also general problem plans that can be followed in solving any general problem. For instance a general problem solving plan formulated by Bransford and Stein (1984) is known as I DEAL and has the following elements :

\mathbf{I} and \mathbf{I} and \mathbf{I} = \mathbf{I} and \mathbf{I}	Identify the	problem
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D = Define and represent the problem in your own words or in appropriate symbols.

E = Explore possible strategies to solve it.

A = Act on selected strategies.

L = Look back and evaluate the effect of your activities toward solving the problem.

Schunk (1991), Bransford and Stein (1984) view problem solving as a process that is sequential involving a number of logical steps. It seems therefore that learners that have had opportunities of problem solving in their academic work should develop better proficiency in problem solving than their counterparts who have not had these opportunities. An academic environment which is dominated by rote learning is unlikely to produce learners who are competent problem solvers. Writing about potential relationships between conceptual and procedural knowledge, Hiebert and Lefevre (1990) say that if conceptual and procedural knowledge are not clearly understood, students may have a good intuitive feel of mathematics but not be able to solve problems. Procedural knowledge refers to knowing how to go about a task (Biggs 1992). Hiebert and Lefevre (1990) describe conceptual knowledge as characterized by rich relationships. In other words conceptual knowledge cannot exist in isolation, it is linked to other information in a coherent and meaningful way.

In contrast with conceptual knowledge, learning that has occurred by rote consists of discrete pieces of information which do not form networks with other pieces of information. Therefore conceptual knowledge of genetics should form a meaningful link to procedural knowledge of genetics to lead to a more sound knowledge base and hopefully more efficient problem solving ability. Subjects can for instance memorise genetic heuristics without linking the heuristics to other areas of genetics. This kind of memorization of heuristics may not lead to effective problem solving. The important idea of this discussion is that learning should emphasise meaning and development of relationships between new and old information. Information must not be memorised without being understood if it is to be useful in future.

Commenting on general heuristics, Andre (1986) noted that heuristics are very useful when one is working with unfamiliar content. Such heuristics were said to be less efficient if one is working with familiar material and one can use different creative methods of solving problems in familiar situations. According to Schunk (1991), general heuristics can help subjects become systematic problem solvers. For many students, knowing a general

heuristic for problem solving would give them a general logical approach to problem solving.

One of the famous educational theorists, Thorndike, experimented with cats where the problem for each cat was how to escape from the cage (Sprinthall and Sprinthall 1990). Thorndike studied the behaviour of cats in specially designed puzzle boxes. He was interested in finding out how long it would take the cats to solve the problem by getting out of the puzzle box. Thorndike is said to have conceived problem solving as trial and error (Schunk 1991). Some students and ordinary people still use trial and error in solving problems, but solving problems by trial and error is not very effective. An individual wastes a lot of time using ineffective strategies until by chance he comes across what works. The use of heuristics for problem solving, for instance ,in genetics has the advantage of giving the subjects rules that facilitate arriving to a solution of a problem.

3.5 SOLVING PROBLEMS IN GENETICS

Krulik and Rudnick (1995) suggest that evaluating problem solving and reasoning is assessing a process and written instruments are difficult to use. Among techniques that can be used to asses problem solving and reasoning abilities are that learners are observed while in action of problem-solving and the use of tests which require a solution and a correct answer. Krulik and Rudnick (1995) suggest that partial credit should be given when students suggest the proper direction toward solving a problem, even if they do not get the correct answer. The message given to the student for crediting partial efforts of problem solving, is that trying to solve a problem is good. In real life one has to try to solve one's problems a step at a time, and partial success may give some relief and indicate future success. The research used structured objective and practical questions to study the subjects' understanding and problem solving ability in genetics.

There are domain specific heuristics that are used in solving genetics problems. The following flow chart adapted from Toole and Toole (1995) indicated the different steps students should go through in solving genetic problems. The different steps are arranged linearly as follows:

....

Figure: 1

FLOW DIAGRAM OF GENETICS HEURISTICS adapted from Toole and Toole (1995)

Choose a single letter to represent each characteristic l Choose the first letter of one of the contrasting features where more than one character is considered. It will be easy to identify which letter refers to which character Į Let the upper case letter represent the dominant feature and the lower case letter the recessive one. Never use two different letters where one character is dominant. Always state clearly what feature each symbol represent. Two different letters indicate incomplete dominance. Ţ Represent the parents with the appropriate pairs of letters. Label them clearly as parents and state their phenotypes. State the gametes produced by each parent. Label them clearly, and encircle them. Indicate that meiosis has occurred. Ţ . Use the Punnet square, to show the results of the random crossing of the gametes. Label male and female gametes although they may not affect the results. T State the phenotype of each different genotype and indicate the number of each type. The upper case (dominant) letter is always put first when working out the genotype. ٠٣ If chance predictions are involved, expand the binomial (a+b) to the proper n power. Substitute the fractions given by the Punnet Square in steps and solve.

According to the flow chart presented here, there are eight linear steps that should be followed in solving genetic problems. Toole and Toole (1995) warn that if short cuts are taken by students, mistakes usually occur. Short cut methods can only be taken once students are proficient in using long methods ie when they have moved from novice to expert level.

The heuristics of genetics problem solving is made up of two distinct parts in the same way as is true of mathematics procedural knowledge (Hiebert and Lefevre 1990). One part is composed of the formal genetics language, that is, genetic symbols which learners must understand to be able to use them appropriately. The second part consists of the rules that apply to a systematic solving of genetic problems. Learners therefore need to understand both the rules governing genetic problem solving as well as the symbols used in genetics. Hiebert and Lefevre (1990) argue that symbols enhance concepts because as a formal language system they provide a powerful tool for dealing with complex ideas. In genetics if symbols are not used correctly they do not convey a correct message. For instance the symbols Tt generally represent a heterozygous tall individual with a dominant (T) and recessive(t) gene.

It must, however, be emphasised that heuristics such as the example presented for solving problems in genetics, do not guarantee a solution but minimise the amount of time used in trying to reach a solution. Matlin (1983) suggests that people can improve their problem solving performance by training. Training can include teaching heuristics and providing appropriate skills for students with strategies to solve problems.

3.6

PROBLEMS SOLVING BY EXPERTS

Some experiments have been carried out which compare problem solving by novices and experts. Novices tend to look immediately for a formula that they can use. Schunk (1991) states that experts, rather than generate formulas, initially draw diagrams to clarify the relations among problem aspects. The problem is put in a simple form first and experts do fewer operations on the problem than novices. The following are some of the differences as described by Schunk, in problem -solving between novices and experts. Experts have the following attributes:

Posses more declarative knowledge;

Have better hierarchial organization of knowledge;

Recognise problem formats more easily;

Monitor their performances more carefully and

Understand better the value of strategy use.

It therefore appears that a sound knowledge of the subject and opportunities to practice problem solving in one's domain would enhance problem solving skills. Frequent opportunities for students to solve problems in genetic should gradually increase the students skills to the expert level. Authoritarian teachers are not likely to promote critical thinking since their style of teaching emphasises rote learning, with the teacher being the centre of activity and students being passive listeners. In the research problem solving in genetics is first one way of stimulating the development of critical thinking. The development of critical thinking is important in problem solving. Critical thinking is defined by Ennis (1991) as reasonably reflective thinking that is focused on dealing what to believe or do. Critical thinking requires active involvement of the individual in the reflective act and goes beyond the mechanical recitation of information that is seen in many classrooms. The need for critical thinking was also echoed by Lang (1997) in an article where the author suggests that employees must be taught how to think. The author suggested that companies have created a critical thinking crisis in their organizations by reinforcing behaviours that are not conducive to critical thinking. According to Lang (1997) thinking is a core business skill and he suggests that quality thinking must occur and be shared in the whole company. Critical thinking across the company i.e. involving all the employees, would improve the quality of service rendered by the company. These few examples on critical thinking show that this skill is a necessary ingredient not only to be developed in the classroom but throughout life to ensure a better quality of life.

Instructors can, promote critical thinking by creating environments where learners can dare to be critical thinkers. One has to be daring to think critically and creatively because innovative ideas can be ridiculed by both teachers and fellow students. Teachers who encourage critical thinking should allow learners to express their ideas without reservations

Problem-solving skills are one of the key goals of science education. Fisher (1993) states that the ability of the child to apply thought to the solution of problems provides the key to success in adult life. This research will aim to highlight the fact that teachers who have not learned to solve problems successfully themselves, will not be able to teach problem-

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solving and thinking skills effectively. Problem-solving activities stimulate the development of desired qualities such as thinking and reasoning. They also provide instructors with opportunities to observe how learners tackle problems, and how they communicate and learn. All this feedback can be used to enhance learning.

Critical thinking enhances problem- solving. Chiras (1992) defines critical thinking as a process by which one subjects research findings and theories to scrutiny, looking for inconsistencies in logic, alternative interpretations and subtle but pervasive biases that may have led to erroneous conclusions. What Chiras says is incongruent with the culture emphasised in the homes of the subjects of the research. In African communities viewing things critically is not encouraged particularly if they have been said or written by adults. Students therefore tend to look at books as the absolute sources of wisdom and would never think there is a need to put books through critical analysis. Probes used in this research served the purpose of monitoring whether student teachers had, among other things, developed adequate problem solving and analytical skills in genetics. Fisher (1993) links thinking skills to creative thinking, critical thinking and problem-solving. Many researchers, for example, (Fisher 1993, Chiras 1992 and Rossouw 1994) have stated that creating opportunities for critical thinking and teaching pupils thinking techniques will encourage pupils to use them later in life. It is even hoped that such individuals will be able to deal more competently with problems they encounter in their daily lives. Rossouw (1994) highlights three reasons behind the need to teach thinking skills:

- 1. Sound thinking can reduce errors.
- 2. Considered actions are better than impulsive actions.
- 3. The abundance of information demands sound thinking.

Because students do not get adequate opportunities to practise problem- solving, they tend to make mistakes which show that they are not trained to think critically about responses they give to examination questions.

3.7 GENETICS IN BIOLOGICAL EDUCATION

The aim of the grade 11 and 12 genetics syllabus is to introduce students to basic genetics. It serves both a foundation for further university work as well as providing functional knowledge for understanding matters involving genetics in the community. Matters involving genetics demand clear understanding of highly scientific concepts. For instance such understanding will enable students to recognise that genetics can play a crucial role in proving paternity in disputed cases. It is only after students have mastered relevant scientific concepts that they can apply their understanding to solving such problems with understanding. Only then can they be said to be genetically literate. This literacy is particularly important for those who will have to pass their knowledge on to learners. If student teachers lack an authoritative grasp of the subject matter they cannot be effective teachers.

It has been said that one of the highest goals of science education concerns is improving students' ability to think critically, reason logically and ultimately solve problems (Lavoie, 1993). Indeed, a lot of researchers have recently focused their attention on the ability of students to apply their knowledge to solving genetic problems. There seems to be an interest in the understanding of genetics not only to facilitate the passing of examinations but also because of its impact on society. Genetics also affords educators plenty of opportunities to teach both critical thinking and problem- solving skills. It also affords them opportunities to monitor whether students are developing sound problem- solving strategies or not. This was one of the reasons the researcher chose to research students' understanding of genetics, particularly because most of the current research is being carried out in the in the United States, Britain, Australia and other countries, with very little being done in Africa. Many researchers (Stewart 1982, Browning and Lehman 1988, Smith 1988, Lawrence and Whackling 1990, and Kindfield 1994) have found that students at different levels of education, in different countries have difficulties in solving genetic problems. Some inventories of these difficulties have been documented. However, it would be unwise to apply these results in the South African situation without considering the mismatch that might be due to differences of culture and language. The researcher therefore decided to investigate problem-solving challenges that might be displayed by students in Africa where the mismatch between the scientific culture and local culture is more pronounced than in more developed countries.

A survey in the county of Surrey in Britain showed that 'A' level students (equivalent to the first year of university in the South African education system) had misconceptions about the terms *gene* and *allele* (Pashyley 1994). Some of the students believed that genes and alleles are the same. Teachworth (1994) found that some students had difficulty stating the relationship between alleles and chromosomes. The problems which students have as described here by various researchers, seem to be caused by the highly specialized language of genetics which has to be used with precision. The students had problems making fine distinctions between different genetic terms in spite of the fact that the language of instruction was their mother tongue. It was the researcher's concern to find out how student teachers for whom English is a second language would fare in similar tests.

There is a lot of literature which offers suggestions on how students can be helped to overcome their misconceptions about genetics. However, the researcher was struck by Smith (1988) and Meyers (1993), who suggest that instruction should include sufficient opportunities for students to think aloud as they solve problems, describing what they are doing and why. This constructivist strategy has the advantage of providing students with opportunities to attend to procedures and thought processes they are using. Students have a tendency to write the first thing that comes to mind whether it is reasonable or not. However, careful questioning forces students to think and reflect on what they are saying or doing. It is a model the researcher saw as reasonable for this research because one of its implications is that teachers will not remain oblivious to the students' understanding of concepts and will therefore be able to help them more effectively.

The issue of specialized language of genetics which is reported as a problem in English speaking countries will be crucial in this study. The student teachers involved in this study will not only be challenged by specialized genetics terms but by a foreign language in which they are not completely competent and fluent. In an effort to gather information about the students' conceptual understanding of genetics, it will be crucial to make a clear distinction between purely linguistic difficulties and non-understanding of concepts.

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The choice of a research method for this study was based on the nature of the problem investigated, that is, the researcher's beliefs about how people learn and how they interpret phenomena around them. It is important to remember that the aim of this research study is to assess the understanding of basic genetics by student teachers and to find out how well they can apply their knowledge in solving basic genetic problems. Kelly (1988) made an important observation when she said that the social implications of science were generally neglected in school science. This is equally true of tertiary science. Science is presented in a decontexualised manner with learners being unable to apply new knowledge in their daily lives. One of the crucial contexts in which science is taught is culture. However, Bajah (1981) warned that science and culture are often discussed separately, as if they are mutually exclusive. He emphasized that no matter what new knowledge is brought to a people, their heritage and culture remain as their reference points or contexts through which the new learning is mediated. If science is to be taught effectively teachers must help students to understand how their cultural beliefs affect their learning of science concepts. When students work in groups as in cooperative learning, it helps them discuss their beliefs in a non threatening environment. It is during these times that learner can talk freely with their peers about conflicts between their beliefs and the scientific facts they learn. The resulting cognitive conflicts lead to evaluation of incoming information and hopefully to better understanding of issues.

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Quantitative research on the other hand operates in a context free domain, avoiding any factors that may bring biases into the picture. However, Roth (1993) argues that even quantitative science research projects are marked by situational logic and context dependent reasoning. He further suggests that scientific facts constructed by natural science research are dependent upon the micro social conditions of the laboratory as well as on the politics of scientific research . Politics of scientific research are seen when decisions have to be made about choosing priorities for research . Sometimes the decisions of the kind of research to be promoted are ethically questionable and void of objective reasoning because scientists are after all human.

It was therefore clear to the researcher that to get a holistic picture of the student teachers' understanding of genetics, an inclusion of a paradigm that would take cognizance of social factors that affect learning would be necessary. A phenomenographic approach was therefore adopted to supplement quantitative methods, since according to Smith and Sendelboach (1982) such an approach is not confined to the collecting of particular kinds of data determined in advance. Phenomenography is a research method suitable for mapping qualitatively different ways in which people experience, conceptualize, perceive and understand various aspects of phenomena in the world around them (Sherman and Webb 1990). Just as this study was concerned to discover students' errors in describing concepts in genetics, phenomenography is also interested in discovering mistaken conceptions of reality. The phenomenographic approach has therefore had the effect of producing a wealth of detailed information about a much smaller number of people and cases. The wealth of information gathered by quantitative methods provides deeper insights which sometimes cannot be revealed by quantitative

means only. The wealth of information gathered can be used to improve professional practice. Yin (1984) describes qualitative research as research which assumes that there are multiple realities and that the world is not an objective thing but a function of personal interactions and perceptions. The analysis of qualitative data gives the researcher an opportunity to view a complex issue from the perspective of a wide and rich environment. Although the dominant paradigm will be quantitative, it does not mean that one cannot integrate qualitative methods where such an act would enhance the research product. Statistical data was therefore also used where appropriate.

Merriam (1988) described the qualitative case study as a particularly suitable method for dealing with critical problems of practice and extending the knowledge base of various aspects of education. This research is a case study in which the research outcomes will hopefully be used to improve professional practice at the University of Zululand. The research was carried out by a practitioner who wanted to evaluate the skills students teachers take away from their teacher training. It would be useless to encourage student teachers to teach such things as critical thinking and problem solving if they do not have the expertise themselves. It is also hoped that other practitioners might gain some insight into problems that student teachers still have in dealing with a biological topics like genetics just before they graduate .

3.9 ETHICAL CONSIDERATIONS

Burgess (1989) declares that trust is the basis for exchange of information. He further suggests that if the researcher is inviting the subject to enter into a relationship which is

honest and open, the researcher too, owes the subject a similar level of openness and honesty. The researcher was prepared to reciprocate in this way as this would also afford the opportunity to get to know the individual students better.

The student teachers who constituted the research subjects were informed by the researcher that research on their understanding of genetics would be carried out. They were also given background information on how genetics as a biology topic seems to present a lot of problems to students not only in South Africa but all over the world. The methodology that was to be used was explained and they were told that this would also help them assess their own competency in solving simple genetic problems. They would also discover their own misconceptions about genetics which the researcher promised would be addressed in individual and group discussions. It was also explained that taking part in the experiment would be advantageous in that they would gain first hand learning in how to carry out classroom-based research, a skill they would need not only for their postgraduate studies but also as a tool to improve their own professional practice.

Once the basic outline of the aims of the research and the research protocol were given to students, they were allowed to ask questions and voice their concerns. It was therefore through mutual discussion and motivation that the whole class decided to take part. The student teachers were also told that the successful execution of the research study would require them to go through the whole research protocol. In this chapter a brief discussion of the South African grade 11 genetics syllabus was presented. An overview of the important topics covered was given. Secondly, outcomebased education, the new education model South Africa has adopted, was discussed. It was stressed that OBE is based on learning outcomes which are demonstrations of the learning the student has accomplished. Three types of OBE were presented, that is, traditional, transitional and transformational OBE. It was explained that the teaching strategies of OBE will move from a teacher-centred to a learner-centred model. Assessment will shift from norm- referenced to criterion-referenced tests. The basic aim of OBE was described as ensuring that all children are successful in their schooling and become able to adapt to the working world because they have developed sufficient life skills at school. Thirdly, the importance of developing problem-solving skills, critical thinking and creative skills was discussed. These were said to be desirable skills if learners are to be able to adjust to a scientific and technological world.

Finally, some research findings on the difficulties students encounter in solving basic genetics problems were discussed. It was suggested that a constructivist model of instruction would be useful both to discover and to address the students' difficulties.

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CHAPTER FOUR

RESEARCH DESIGN

4.1 INTRODUCTION

Having surveyed the literature on the significance of genetics as a school subject and how it can be used to enhance problem-solving skills, this chapter focuses on the research design of the study. The aim of this research study was to investigate student teachers' understanding of genetics, particularly their ability to apply their knowledge to solving simple genetics problems. Genetics has been described as one of the most difficult topics in biology. This is why students develop many alternative conceptions or misconceptions (Moll and Allen 1987, Browning and Lehman 1988, Kindfield 1994, Moletsane and Sanders 1995). Students tend to memorise the various concepts in genetics and can sometimes plug in correct formulas and solve simple straightforward genetic problems. This sometimes erroneously gives the impression that they can solve problems when they cannot.

When it comes to the application of the various aspects of genetics, and to solving real conceptual problems, difficulties arise. For students who will later become teachers these difficulties are crucial because they indicate that they cannot teach genetics effectively in their classrooms. Present literature on misconceptions or alternative conceptions about genetics in South Africa have dealt mainly with high school students and to a lesser extent with some first year students at the undergraduate level. Not much has been done to

investigate whether or not student teachers hold the same misconceptions as their prospective students. McNamara (1990) expresses disappointment regarding the lack of availability of literature that investigates teachers' thought processes. This research study is an attempt to remedy this situation.

4.2 **SUBJECTS**

The subjects of this case study were twenty five student teachers enrolled for the Bachelor of Pedagogics (Science) degree at the University of Zululand. All respondents were in their professional year of study. They had already completed eight university courses with four at the first year level and four at the second year level. Two of the courses at the second year level constituted their chosen methods of teaching subjects. All the subjects had biology as one of the teaching method subjects. Among the second choices of methods of teaching subjects for the experimental group were agriculture, Home Economics, Geography, and Physical Science, and were numerically distributed as follows:

NUMBER OF STUDENTS	SECOND METHOD OF TEACHING	
19	agriculture	
2	home economics	
3	physical science	
	geography	

TABLE 1: STUDENT TEACHERS' SECOND METHOD OF TEACHING

The subjects consisted of eleven females and fourteen males, their age groups ranged from 21 to 30 years of age with most subjects between the ages 21 to 25 years.

Genetics as a subject is studied in grade 11 and 12 in the matric biology syllabus of South Africa (see appendix 2). Of the 25 subjects that participated in the research, twenty three did genetics in standard ten in their schools. Two of the subjects reported that they first encountered genetics as a topic at the university level. The two subjects that did not do genetics at high school said their teachers skipped genetics. The two subjects said they thought their teachers might have had problems with teaching genetics. All the subjects except two students had done genetics in more than one course during their training in the faculty of science at the university of Zululand.

Only the two home economics subjects had done one science course, Biology 215, which is a first semester course specifically designed for biology teachers, and which also offered genetics. Biology 215 and 225 is a second year course that is done by all potential biology student teachers. It is a course that was specifically designed to cater for the needs of students who want to teach biology when they graduate. Students who majored in agriculture, physical science and geography, besides biology, had two or three chances of studying genetics at the university level. Courses that also offered genetics, which some subjects had done were Zoology 125, and Plant Science. This background of the various courses students have taken which offered genetics was given to indicate that subjects had been offered various opportunities to study genetics in their courses.

The tool used to collect the background information on the subjects appears in appendix 18. One, however, did not know whether learning genetics for understanding had been emphasised or not during the lectures and whether students had acquired the necessary conceptual understanding. The tests given during the research were to find out if students had understood their courses in genetics and acquired the necessary skills to solve genetics problems.

Males formed 56% of the subjects while 44% were females. There were therefore more males than women in this group. The higher proportions of male students to female students is not surprising since more males seem to dominate the science field. Some explanations are that women are not highly motivated to take science courses because science has been portrayed by both male and some female teachers as a male subject (Bryne 1993). Female students are sometimes given the impression by some instructors that they will not cope with science studies and this perception becomes a self fulfilling prophecy.

4.3 STRATEGIES FOR DEVELOPING RESEARCH INSTRUMENTS FOR TESTING UNDERSTANDING OF CONCEPTS

The tools to be developed had to be used to assess the student teachers' knowledge of genetics as well as their ability to apply it to new situations. They would be required to show their understanding of the various aspects of genetics. It was therefore essential to adopt the criteria proposed by Sanders and Mokuku (1994: 488) and summarised by them as follows:

Student teachers who understand genetics concepts would:

- know and be able to recognise the name and definition of a concept
- be able to define the concept in their own words

be able to recognise instances (not previously encountered) of the concept be able to distinguish between and classify and know instances of the concept (not previously encountered)

be able to apply the concept in new situations.

The researcher also took into consideration what Hein (1991) suggests as characteristics of research on conceptual understanding. Mentioned among these were the notion that the nature of the instrument must be such that the student is actively involved in the task. This approach differs from previous types of probes which were mainly multiple choice type questions. Opportunities for interaction between the student and the investigation are important so that students' responses can be clarified. A third factor mentioned was the need for in-depth probing in which the concept is tested not only in one probe but in other contexts as well. The investigation might not reach an accurate perspective of the students' understanding with one probe. As a result of the above strategies the researcher chose to collect data in three different ways : from written responses to probes, from transcripts of interviews and from practical work. The purpose of collecting data in this fashion was to maximise the possibility of getting a true picture of the respondents' progress towards mastering the concepts of genetics.

4.4 THE DEVELOPMENT OF THE DIAGNOSTIC TEST

The development of the diagnostic instrument began with a study of the grade 11 South African biology syllabuses on genetics (appendix 2). Grade 11 biology is one of the South African Senior Certificate subjects whose syllabus is prescribed by the Education Department and is examinable at the end of grade 12. Using the grade eleven syllabus was considered appropriate since the respondents were following a Senior Secondary Teachers' Diploma course which prepares them to teach genetics at grades 11 and 12.

4.5 **RESEARCH INSTRUMENTS**

The first step in the research was to develop a pilot Criterion Referenced Test (CRT) which consisted of six probes. These probes were a mixture of objective and structured questions that tested cognitive skills. The questions also had criteria which indicated what skills the subjects were supposed to demonstrate. All the questions were classified according to Bloom's taxonomy of cognitive objectives. The questions were not arranged in a hierarchical order because some questions included a range of cognitive levels of thinking, for instance, question (6), see appendix 4. The pilot test items (appendix 4) made the following demands on the candidates.

TABLE 2 : CRITERIA AND COGNITVE LEVELS ACCORDING TO BLOOM'S TAXONOMY

ItemNo	Description of Criteria	Bloom's Taxonomy Level
1.	Identify correct genetic terminology	Recall
2.	Identifying relationships of sub-cellular entities in a cell and arrange them in a logical sequence.	Comprehension
3.	Demonstrate understanding of genetic symbols and conventions and illustrate the mitotic process.	Understanding, Application and Synthesis
4	Formulate a valid conclusion about a mitotic event	Evaluation
5	Calculate the number of chromosomes at each stage of mitosis and meiosis in man.	Application

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6	а.	Demonstrate appropriate use of genetics symbols and a Punnet	Comprehension, Analysis,
	5 - S.	Square.	Application, Synthesis and
	b.	Demonstrate ability to solve a genetic problem by calculating	Evaluation.
		genetic rations.	
ter e est	С.	Demonstrate understanding of Mendel's Second Law by applying	
		it to the problem.	

4.6 **THE PILOT STUDY**

The pilot Criterion Referenced Test was graded according to the mark scheme which appears in appendix 5. The results of the pilot phase were used to modify the nature of probes used in the actual research. The pilot phase had to take into consideration issues of validity. Zeller (1990) describes a test as valid if it measures what it is supposed to measure. The author further suggests that there is agreement on the importance of valid measurement to the success of scientific endeavours. The research sought to develop an instrument to measure the understanding of genetics concepts by the subjects. As a process of establishing validity of the test, the researcher selected indicators that would reveal whether subjects understood genetics concepts or not. Secondly, the researcher administered a pilot study in which the chosen indicators task one to six (appendix 4) were written by 32 subjects, a class of 1996 student teachers. It must also be indicated that a pre-pilot class had also gone through a pre-pilot test in 1995 in an effort to establish the validity of the test instruments.

The instrument used during the initial trialing period (pre-pilot study) appears in appendix 6 and shows that if it is compared to the pilot test a few changes were effected in probes 3 and 6. Probe 3 in the pre-pilot study had proved to be unreliable as subjects could guess

the correct answer without being able to justify their choice of the answer. Probe 6 had proved too easy and did not discriminate among the good and poor students. Appendix 7 shows the mark scheme that was used to grade the pre-pilot phase test.

4.6.1 RESULTS OF THE PILOT THEORY TEST

Scores obtained from the subjects who wrote the pilot test were used to analyse the suitability of the questions in testing the criteria assigned to each probe. Scores from the written pilot test are presented below.

FIGURE 2 : THE PILOT-TEST SCORES OF THE SUBJECTS' KNOWLEDGE OF GENETICS TERMS.



Figure 2 shows the test score profiles of probe 2, which consisted of eight items of objective type questions which tested subjects mastery of genetic terms. Pre-test score averages for items A, B, C, and H were above 50% while for items E and F the average

scores were 40%. Item D which required the subjects to identify the term used to refer to, "a straight section of a chromosome forming part of a DNA molecule "was poorly done with an average score which was below 20%. Many student teachers in the pilot test reported that whether item D was a valid definition of a gene or not, they still found it too technical and confusing. Item D was therefore replaced, the replacement appears in appendix 4.

No subject in the pilot test had a correct response for item G where the average score was 0%. Many subjects on being interviewed about what they found so difficult about item D agreed that they had not applied their minds properly to item D. Students who had agriculture as their major in particular said the term "hybrid" comes in regularly in their study of genetics. For these reasons item D was not changed. The post-test scores were included to show the kind of improvement that occurred after students had been given a chance to discuss in groups some of the problems they had experienced in the pre-test. The pilot subjects had been very disturbed that the test looked easy and yet they had found it so challenging. Many of the subjects wanted to discuss their responses and find their mistakes. The post-test had come about as a way of finding out if the revision that was conducted in groups individually and with the instructor, had been beneficial. It was also a strategy of finding out which items persisted to give subjects problems even at the post-test stage. The results of the post-test also gave more feedback that could be used in validating the instrument.

The figure below shows scores on questions 1-6 in the pilot pre-test and alongside the pilot-post-test score. The post- test scores of the pilot phase were included to show

that some improvement occurred in all the questions after group discussions of difficult items. Discussion of the pre-pilot test by the subjects in groups also helped the researcher to really find out what the subjects' difficulties were in the test. There were cases of subjects who said, I was just careless with, for instance, counting the number of chromatids in probe 5. Some said they did not interpret the questions correctly". One very bright subject expressed her frustration by saying," we have done all these concepts in genetics I can't understand why I got such a low score". Many subjects said the questions were framed in a tricky way making them unfamiliar to them. A lot more candidates complained about not being able to interpret probe 3 because they are not familiar with symbols in genetics.

FIGURE 3: THE PRE- AND POST- TEST PROFILE FOR SCORES OF THE WHOLE CLASS RELATING TO THE SUBJECTS' KNOWLEDGE, UNDERSTANDING AND PROBLEM-SOLVING IN GENETICS.



Figure 3 compares pre-test with post-test scores for the whole class with respect to the subjects' knowledge, understanding and problem-solving in genetics. Probes 1 and 2 had percentage mean scores just above 40 % while probes 3 and 4 had mean scores below 20% at pre-test stage. Probes 5 and 6 had mean scores that were just above 30%. Bude (1993) states that probes or questions should be selected for their content validity (testing what they are supposed to test) and low scores should be secondary consideration. However, probe 3 had to be revised since the main aim of this probe was to test understanding of mitosis, and this probe was not doing that successfully. The main problem with probe 3 was that the pilot phase subjects failed to interpret genetic symbols AaBbCc said to be representing genes found in the nucleus of the cell. The pilot subjects were therefore unable to determine the number of chromosomes they had to deal with. The number of chromosomes one is dealing with is very crucial in mitosis. If the subjects could not determine the number of chromosomes the cell had, this would have made it impossible for them to answer the question correctly. The validity of probe 3 was therefore threatened by the subjects lack of competence in using genetic symbols. Commenting on the difficulties encountered in dealing with probe 3 one of the pilot stage subjects said: "To me it is not easy to answer this probe because I have no clear understanding of when and how mitosis work in genetics. In fact the whole chapter of genetics is a problem to me since I started hearing about it". To the researcher the use of the phrase "hearing about genetics" was significant because it implied the transmission style that had been prevalent in the genetics lessons attended by the subject.

Another comment about probe 3 by one of the pilot subjects was," I could not answer this question because I haven't been exposed to this type of crossing where we have to

consider the location of gene pairs". The post- test also indicated persistence of the problem of understanding genetic symbols as indicated by a mean score of 30.63%. The revised version of probe 3 appears in appendix 8 which shows the final research tool. The revised probe 3 presents mitosis in diagrams which tend to facilitate understanding in pupils who are second language speakers. The pilot probe 4 which also had a very low mean score of 9.38% was revised by substituting a question which tested on a wider scope the understanding of the process of meiosis with diagrams.

The pilot-test probe 4 was an objective question which made it easy for subjects to guess the answer. However, the pilot-test results showed that the subjects were not even guessing correctly as reflected by the low scores in both the pilot pre- and post-test scores. Understanding the process of meiosis has been said to be crucial to the ability of respondents to solve genetics problems. There was therefore a need to include a probe that would successfully test the subjects' understanding of meiosis without the loophole of a possibility to guess the answer. Probes 5 and 6 whose mean scores were 32.18% and 35.88% were not revised as shown in appendix 6. In the pilot stage of the research probes 5 and 6 had proved reliable in exposing those who understood mitosis and meiosis and those who could use their understanding of these two processes to solve a problems in genetics.

The testing of the validity and reliability of a research tool is a vigorous process. The researcher has already pointed out that even before the pilot test was done pre-pilot investigations had taken place in 1995 with a group of ten student teachers. The preliminary instrument used then appears in appendix 6. The results of that preliminary

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test led to changing probe 6. In the preliminary piloting stage probe 6 proved to be too easy for all the subjects and did not discriminate well among the candidates. It was one of those questions in which subjects rely heavily on the memorization and rote application of an algorithm without sufficient understanding of the meiotic basis for the steps involved in the solution. The item 6 was therefore replaced by the item 6 found in both the pilot and the research instrument (appendix 4 and 8).

According to Patton (1990) qualitative inquiry depends at every stage on the skills, training, insight and capabilities of the researcher. It was therefore the researcher's concern to involve colleagues who are specialists in genetics and others who are experts in the teaching of biology in general, to scrutinize the subjects' responses. It was done so that these colleagues would verify that the misconceptions reflected were indeed found in the subjects' answers. The strategy of soliciting comments from colleagues is referred to as "peer debriefing" and is a good test for validity (Guba and Lincoln, 1996). It is important to solicit criticism from colleagues as a way of trying to minimise human factors that could otherwise bias the research findings, had no other independent specialist been involved.

The second pilot instrument was a practical task as shown in appendix 10. The task required the subjects to represent a pair of homologous heterozygous chromosomes at the metaphase stage I of meiosis. For the practical question (the second tool) the following criteria and levels of Bloom's taxonomy of cognitive objectives were stated.

4.6.2 THE PRACTICAL TEST CRITERIA AND COGNITIVE LEVELS ACCORDING TO

BLOOM'S TAXONOMY

CRITERIA		COGNITIVE LEVELS
a.	Interpretation of the problem by representing a model	Understanding
	of a pair of heterozygous chromosomes at meiotic	
	metaphase	
b.	Accurate representation of arrows showing	Comprehension evaluation
	movement of chromosomes in the next stage of	
	meiosis.	
С.	Naming the next stage of meiosis after metaphase	Recall
d.	Appropriate use of genetic symbols to represent a	Application and
	heterozygous pair of homologous chromosomes	Comprehension

It must be noted that there were overlaps in the material that was tested. For instance, there was a theoretical test of the subjects' understanding of meiosis represented by probe 4 and some parts of probes 5 (appendix 8) and there was also a practical question on meiosis (appendix 10). Meiosis is crucial in the subjects' ability to solve genetic problems. If one does not understand meiosis one cannot solve problems in genetics (Stewart 1982 and Kindfield 1991). Also, Bless and Higson-Smith (1995) state that sometimes one has to ask the same question in different ways in order to check that the subject is not responding arbitrarily.

The second instrument involved a short practical test was adapted from Brown (1992:150) to suit local conditions and materials. In the study Brown wanted to find out

whether Advanced-Level students understood meiosis. Although the study was done in Britain with students who were first language speakers of English, the level was appropriate for the subjects since Advanced-Level is equivalent to the first year level at the universities of South Africa. All the subjects had completed their second year at the university of Zululand and all had completed genetics at a second year course level. There was also the researcher's curiosity to find out how second language speakers would fair in doing a similar task. But of course, more importantly, was that the task seemed relevant to the kind of study the researcher was conducting.

The subjects at the pilot stage were given the practical question (appendix 10) and were allowed 30 minutes to work on it. Each subject was given 2 bars of different coloured plasticine, beads and a transparent tape to hold his or her model in position. Appendix 11 shows the mark scheme that was used to grade the practical pilot test. Appendix 9 shows the misconceptions that were found by Brown(1992) when this researcher worked among English Advanced-Level students. The practical work seemed to make a clean cut manifestation of those who understood meiosis and those who did not. Those who did not understand meiosis showed erroneous models indicating confusion about a heterozygous homologous pair of chromosomes. The practical test was not altered after the pilot stage since it seemed a reliable tool to test the understanding of meiosis. Besides the use of the practical tool with the pilot group, the practical test had been used with a pre-pilot group of student teachers and had been seen to work well. The pre- pilot group was the exploration stage and an initial effort to find out how the instrument would work. Consistent results revealing student misconceptions made the researcher decide that the practical instrument was both valid and reliable. It became the final research tool without alteration and it appears in appendix 10.

4.7 KNOWLEDGE AND UNDERSTANDING OF GENETICS HEURISTICS

The instruments for research were the practical and the theoretical test. However, there were additional tasks the subjects of the research did which did not require elaborate instruments. For instance the subjects were requested to write down the steps they followed in solving problems in genetics. The simple instructions for this task appear in appendix 12. The aim of the activity was to find out if there was any correlation between the subjects knowledge of genetics heuristics and their ability to solve a genetics problem like probe 6.

4.8 A GENETIC FINGERPRINTING QUESTIONNAIRE

The last instrument was a simple questionnaire which required the subjects to express their opinion regarding the rape crisis in South Africa particularly with reference to teachers. The questionnaire also sought to find out if the subjects were aware of the genetics fingerprinting technique which has proved very successful in bringing rapists to court. The researcher decided to include this social aspect of genetics in order to balance the picture of the subjects' understanding of genetics. Students ought to demonstrate their ability to handle theoretical questions related to their learning fields, but in particular, students should also demonstrate that they are informed citizens prepared to deal responsibly with science related issues in society. Ost and Yager (1993) support this view by stating that good science programmes must produce citizens who have the skills of critical thinking, who can make reasoned judgements and who understand that the society of the future will

be increasingly technological in function and driven by science. The questionnaire was deliberately context based (see appendix 13) because peoples views on issues are usually context based (Wood-Robinson, Lewis, Leach and Driver, 1997). An example of how people form their views based on context is illustrated by the issue of abortion. Some people are against abortion but if abortion is advocated on the basis of rape then they radically change their views. The context for the questionnaire was rape and genetic fingerprinting because the two issues will inevitably have to be addressed by anyone who intends to enter the teaching field, particularly at this point and time when there is so much sexual violence against women. Teachers may also have to explain to students what technology is available to assist in the apprehension of rape perpetrators.

4.9 ADMINISTRATION OF THE RESEARCH INSTRUMENTS

All the research instruments were administered on the same day. Instruments involved were the practical and theory tests, and the subjects' knowledge of genetics heuristics.

4.9.1 THE PRACTICAL TEST

Subjects were given the practical test appendix 10 to work on individually. Each person was given 2 different coloured plasticine bars, beads and cellotape to hold one's model in position. These simple items were all the subjects needed to complete their model. The subjects were given half an hour which had been proved adequate time to produce the model during the pilot phase. The mark scheme that was used to grade the practical appears in appendix 11.

The theoretical test consisting of six probes was written in the afternoon for an hour and a half. Each individual wrote the test and like in the practical test, there was no collaboration. Subjects were requested to answer all questions or explain why they could not answer the question if there was such a case. The subjects normally prepare for content tests privately. Past experience had shown student teachers performing very poorly when tested on content even if meant for a grade 12 level test. The researcher therefore allowed time during the workshop where subjects were helped to revise mitosis and meiosis in a practical way in groups. They were given a worksheet with instructions which they discussed and filled in (see appendix 3). The worksheet came from a teacher In-service package that was used in Swaziland in a programme called the "Science Improvement Programme "(Peek and Mokgokong 1986). The worksheet involved practical work and the activity engaged subjects for an hour which was followed by discussion and opportunity to ask questions. The subjects were fully engaged during this revision time and seemed to debate a lot among themselves. One such results of debate and negotiation of meaning by subjects is shown in appendix 20.

4.9.3 SUBJECTS' KNOWLEDGE OF GENETICS HEURISTICS

The second revision activity were simple genetic problems (appendix 14) that were supposed to help subjects revise genetics heuristics for problem solving. Before the subjects solved the problems, however, they were asked to form informal collaborative pairs and to write steps in sequence (heuristic) on how they go about solving a genetic problem. The heuristics exercise was meant to find out how much subjects remembered or understood of these heuristics. The sequence followed would be a good indication of whether subjects understood the process of solving problems in genetics. Once the pair of subjects had written their plans for solving a genetics problem, these were collected and the subjects solved the genetics problems. However, one pair of the subjects wanted to solve genetic problems and then write the heuristics later. For the latter subjects it was difficult to write the heuristics by mentally reviewing the steps they go through when solving genetic problems. What followed was that some subjects needed a concrete problem from which they worked their heuristics. The genetic problems were given to the subjects in the anticipation that it would jolt their memories on what they had learned previously in genetics. The results which were steps of how to solve genetics problems written by a pair of individuals were graded using the mark scheme which appears in appendix 15. It must, however, be acknowledged that the heuristics appearing in appendix 15 was an abridged version for novice problem-solvers in genetics, which if followed, would help the subject arrive at the solution of the problem in probe 6 (Peek and Mokgokong, 1986). The heuristics genetics appearing in the literature review includes more details and one would not have expected the subjects to remember all those details.

Appendix 12 shows instructions of what the subjects were required to do in collaboration. The subjects were not helped in writing down steps they used in solving genetic problems because the aim was to find out how much they knew about genetics heuristic and using it to solve problems. However, once all the pairs of the subjects had finished solving genetic problems, the solutions were discussed by the subjects themselves and subsequently showing them on the blackboard.
The subjects were given as much time as they needed to complete the questions (appendix 13) which solicited their opinions on the rape of school children and which also asked them about their awareness of technology in genetics. All subjects had finished their responses within half an hour. The subjects responses were not graded but an inventory of the categories of the subjects responses was made.

4.11 INTERVIEWS

After the models of the metaphase stage 1 of meiosis made by the subjects in the practical test were graded, using the mark scheme appearing in appendix 11, it became clear that six students who had erroneous models had to be called to explain their models. The criteria for the choice of 6 subjects was based on the number of misconceptions they had in general in their models. In other words the responses of these subjects were a rich source of misconceptions. Calling these subjects for a face to face interview was therefore a way of confirming whether the misconceptions represented by the subjects' models really existed or not. Models of the subjects' appear in appendix 16.

The questions asked depended on the subject's model, since the models were different. For instance, some subjects were asked why chromatids were represented in different colours. Other subjects were asked why their models had 2 pairs of homologous chromosomes instead of a pair as required by the question. In some cases the questions referred to the arrows showing the movement of chromosomes at anaphase. The researcher had to verify that the directions of movement at anaphase the subjects had drawn was what they really meant. The subjects had also to confirm that the arrows they had drawn represented the direction they thought chromosomes would move at anaphase. The type of interviews used was therefore a non-scheduled structured interview. Bless and Higson - Smith (1995) describe non-scheduled structured interviews as the type that is frequently used if there is need for more specific and detailed information from the subjects. This type of interview is called non-scheduled interview in the sense that the interviewer is free to formulate other questions if judged appropriate for the given situation.

4.12 DATA COLLECTION

Data were collected in different ways. First, data was collected through a collaborative pair where subjects wrote down the steps (heuristics) they use when solving genetic problems. The use of a pair was to encourage the collaborative pair to remember as much as possible what they knew. Two heads are surely better than one head. The second type of data was collected when subjects did a practical test on meiosis. The third type of data was collected when subjects wrote a diagnostic test with six items. The fourth method of collecting data was a mini questionnaire which sought to elicit subjects opinions on rape in schools. The questionnaire also sought to find out how well informed subjects were about genetic fingerprinting. The last method of collecting data was a non-scheduled interview for some subjects who showed a lot of misconceptions. The subjects were called to to explain some of their practical hands- on test models to confirm that their presentations depicted their understanding of meiosis.

In the choice of collecting data the researcher was aware that some students are stimulated by verbal communications (linguistic activity) while others prefer doing things with their hands (kinesthetic activity). The researcher was also aware that other subjects favour collaborative work this is particularly true of African students as collaboration is emphasized in their culture. It was important, however, that all students as individuals be able to communicate effectively by presenting their ideas in the written form. Nunan and Lamb (1992) argue that one of the major challenges to the effective management of learning is to cater for different learning styles. This explains why it was important for the researcher to cater for as many learning styles as was possible.

Different ways of gathering data are useful in showing that the researcher's findings are "grounded" in what was discovered and also assist in ensuring that the results are valid and reliable. The term "grounded theory" was used by Corbin and Strauss (1990) and Glasser and Strauss (1967) to indicate that results obtained in the study describe phenomena that were verified through systematic data collection and analysis. The research therefore used the three methods of data collection in an attempt to reduce bias and to increase the validity and reliability of the information gathered (Anderson, Herr and Nihlen 1994). Another advantage of more than one source of data is to compensate for the limitation of each method (Mouton and Marais 1990). The researcher believes that a more balanced view of the understanding of genetics was gained by using different methods of collecting data.

One realises soon after beginning to collect data that qualitative methods produce a lot of detailed information. It is therefore very important to know what to do with the information gathered in order to organise it into a logical document which will be easy to read and understand. First, the researcher graded the subjects tests and criteria for performance was applied that rated the performance according to whether it was excellent, very good, medium or very low. Statistical analysis was applied to show if there was any significant difference between the achievement of male and female subjects. Statistical analysis was also applied to show if there was any correlation between knowing genetics heuristics and solving genetic problems. The same (method) analysis was also applied to show if the correlations between any two related factors were significant. The application of statistics helped the researcher to gain a clear focus on the achievement of the sub-groups in the sample. Also, the categories developed facilitated interpretation of what was happening in terms of subjects' understanding of concepts and their ability to solve problems.

Further analysis involved taking extracts from students work in the form of models made during practical work and written statements. The samples of written work and models of the practical work products were actual exhibits of what the subjects could or could not do. Tyler (1990) states that since an evaluation is focused on what the subjects have learned or not, one should avoid the use of abstract numbers in reporting whenever what students have learnt can be reported more concretely. The next kind of analysis therefore involved developing an inventory of the categories of misconceptions revealed in the students written work, practical and non-scheduled interviews. These categories were also reconciled with diagrams the students had made during the interviews as well as with what they had written in the tests. The practical test was also graded and the results were used as additional information to reinforce some of the categories developed. The information was therefore used for the purpose of presenting as much evidence as was possible to support the findings. Evidence to support the various categories of misconceptions discovered was supported by verbatim quotations. These have been stated by Patton (1990) as essential ingredients of qualitative inquiry.

The main thrust of the analysis of all the instruments lay in identifying misconceptions students had and whether these were corroborated by data from all the instruments. This was followed by interpretation which involved explaining the meaning of data, particularly with reference to apparent sources of misconceptions. This approach was used by Vakalisa (1995) in an analysis of qualitative data from an in-service research study.

4.14 **CONCLUSION**

This chapter outlined the steps taken by the researcher in doing a pilot test to get a feel for what would happen in the large- scale test. This was followed by a description of the research sample and the research protocol that was followed. An emphasis was placed on the fact that theories or hypotheses that emerge from this research will all be derived from data collected, that is, they will be a product of "grounded theory". The researcher also explained that qualitative analysis would be balanced by quantitative analysis of descriptive and inferential statistics. Finally a brief description was given of how the results would be analysed and interpreted, so that they would make sense to all interested parties.

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CHAPTER 5

PRESENTATION OF RESULTS

5.1 **INTRODUCTION**

In a booklet released by the National Department of Education (1997) entitled *Curriculum* 2005, Professor Sibusiso Bhengu, Minister of Education, stated that the new curriculum would effect a shift from content-based to outcomes-based education. He further said that the new curriculum guided by the vision of producing 'a thinking, competent future citizen' will aim at equipping all learners with the knowledge, competencies and orientations needed for success after they leave school. This indeed would constitute a major shift away from what has been happening up to now particularly in African schools. It will also be a major challenge to the training of teachers who come from a system of 'parrot' learning, but who should now be trained to teach thinking skills and problem solving. A major assumption underpinning this study is that the data obtained would contribute towards achieving the aims of curriculum 2005 in terms of the thinking problem-solving skills of future biology teachers.

The research sought to investigate whether student teachers at the University of Zululand understood genetic concepts they had learnt during the training. Student teachers were also tested whether they could apply their knowledge to solve problems in genetics. For a balanced view of the understanding of genetic, the researcher also sought to find out if the subjects understood the role of genetics fingerprinting technology in the conviction of rapists and other law offenders. Genetic fingerprinting is a topical issue in South Africa since Vernon (1999) of the 'Sunday Times' reported the intention of the justice department in South Africa to use DNA testing to solve crime. Vernon also wrote about a success case in Britain of how police traced a child rapist by making the entire male population of a small town supply them with DNA samples. The issue of rape and genetic fingerprinting brought in a social issue which challenged student teachers' awareness of the application of technology in genetics in their communities. When the criterion referenced test were designed the researcher had to describe criteria that were

tested and also lay standards that would indicate mastery of the concepts and skills tested. The calendar (1999) of the university of Zululand prescribes some standards that students have to achieve to be rated as having successfully mastered their work. Lewin (1997) states that successful performance against a criterion is judged to indicate a question of knowledge and skills aquired. The following table 2 shows standards that were adapted from the calendar of the university of Zululand which the researcher used to determine the level of proficiency of the subjects in genetics theory and practical tests.

TABLE 3 :THE STANDARDS USED TO RATE THE SUBJECTS PERFORMANCE ONTHE THEORY AND PRACTICAL TESTS

OUTSTANDING	CREDIT	PASS	FAIL
75-100	74-65	64-50	49-0
A	B	С	D

In this standard mastery is indicated by categories A and B. Category C is accepted as a pass but it does not indicate mastery of the concepts while category D indicates nonmastery of the concepts or skills tested. One must, however, add that it is often very difficult to come up with sufficient precision to unambiguously decide whether or not criteria have been achieved at the required level. There is for instance difficulties of deciding on borderline cases for instance 74%, 64% and 65% and 49% and 50%. Besides the problems mentioned, the standards seemed usable for the purpose of the research.

5.2 PRESENTATION OF RESULTS AND DISCUSSION

The results were presented in the order not particularly the same as they were taken in the research protocol. The first results to be presented and discussed are the theoretical test, followed by the subjects heuristics for solving genetic problems. The next results presented and discussed were the practical results. Finally the results of the questionnaire on the subjects' opinions on the rape crisis and genetic fingerprinting will be presented and discussed.

5.2.1 THE THEORY SCORES

Scores obtained from the written test which consisted of six probes, will be presented. The six probes were organised in such a way that the first probe dealt with knowledge of genetic terms. These included eight sub-sections for probing the items labelled A to H. Probes two to six dealt with higher cognitive level material testing various kinds of cognitive operations. Some of these were interpreting information, analysis, synthesis, evaluation and application of knowledge to solve genetic problems. The first step in the presentation of results was to present a table which showed the overall standards attained by the subjects in probes 1-6. The table gave a picture of what levels of a achievement or standards prevailed in the class of 1998 who are referred to as subjects.

TABLE : 4THE STANDARDS OF MASTERY OF GENETICS TERMINOLOGYAND UNDERSTANDING OF GENETICS BY SUBJECTS (PROBES1-6).

CATEGORIES	OUTSTANDING	CREDIT	PASS	FAIL
Criteria	75-100	74-65	64-50	49-0
No of subjects	: • 1	1	7	16

The performance of the subjects in probes 1-6 shown by table 2 indicated a very poor performance with 16 of the subjects falling on the failing grades. Therefore about 64% of the subjects had done very poorly on most of the skills tested. Only 36% of the subjects achieved an acceptable passing grade. Table 2 indicates that most of the subjects had extreme difficulty understanding concepts in genetics, inspite of the fact that most candidates studied genetics at the high school level and some even had further 2 or 3 courses that offered genetics at university level. It seems that mere repetition of a course does not lead to mastery of concepts. What is desirable is to help subjects derive meaning from what they learn. Further analysis of the theory question was done to show the mastery of the theory concepts and skills in genetics tested by each probe.

The table 3 shows mastery level of the subjects for skills tested by probes one to six.

TABLE : 5	THE SUBJECTS' MASTERY OF CONCEPTS AN	D SKILLS TESTED
	BY INDIVIDUAL PROBES	

ACHIEVEMENT SCORES	PROBE 1	PROBE 2	PROBE 3	PROBE 4	PROBE 5	PROBE 6
100-75	4 (second end)	11	13	1	2	2
74-65	0	0	3	2	0	6
64-50	11	2	1	3	10	3
49-0	10	12	8	-19	13	14

Table 3 shows an analysis of how subjects fared on the various probes when classified according to mastery level. According to table 3 a reasonable number of subjects (17) representing 68% the subjects had a passing grade in probe 3 a question that tested understanding of mitosis. For probe two about half the number of subjects 13 displayed some mastery of the structure of the cell while the other half (12) displayed difficulties of conceptual understanding of certain entities found in the cell. Probe 2 seemed to have been an appropriate question in diagnosing whether subjects could demonstrate through diagrams the relationships of the sub cellular molecules, that is, genes, bases nucleus and chromosomes to the cell. Subjects had to show an understanding of the building blocks of genes and chromosomes. One aspect of showing understanding was the ability to arrange these molecules in an ascending or descending hierarchical order. Probe two (2) exposed some misconceptions that subjects had. The main misconceptions identified are discussed below:

1. Some subjects' diagrams represented chromosomes as floating in the cytoplasm with an intact nucleus somewhere in a corner.

Other subjects had difficulty in arranging the four entities, that is, human cell, base chromosome and a gene in either ascending or descending order.

2.

Probe 3 therefore indicated subjects' difficulty with understanding basic molecular genetics which includes the building blocks of DNA. Below are two examples of how some subjects arranged the four biological molecules.

A human cell		A base
A base	OR	a human chromosome
A chromosome	, ,	a gene
A gene		A human cell.

The examples did not reflect a particular order and seemed to be random arrangements. There was also confusion about what constituted the building blocks of genetic material and also of the sizes of the different molecules with reference to one another. Confusion of molecular sizes was confirmed by a subject who said "a gene is small but not smaller than a human cell". The subject went on to say that "a human cell is the smallest structure since it is the building block of a living organism". That was an example of a failure to appreciate that building blocks operate at different molecular levels such as sub-cellular, cellular, tissue and organ level.

Probes that contained meiosis were poorly answered. For instance in probe four, 19 subjects failed, and the failure rate indicated 76% of the subjects. Only six subjects indicated some competence in dealing with probes testing the understanding of meiosis. The understanding of meiosis has been cited as being very important in the understanding of genetics (Stewart 1982 and Kindfield 1990). Poor performance by the subjects in most of the probes may therefore be attributed partly to their not understanding of meiosis.

Probe five was also poorly done by subjects. It consisted of two (2) items on mitosis and another two items on meiosis. Subjects indicated that probe five was phrased in a way they had not encountered before. The subjects suggested that the questions they had encountered in mitosis had merely asked them to give an illustrated account of mitosis or meiosis. In most cases the subjects merely repeated a version of mitosis or meiosis memorised from the text book. The aim of this probe was therefore to test for subjects' ability to apply their knowledge of cell division in situations where they were required to compute the number of chromosomes in the various stages of mitosis or meiosis. The subjects had never met such a question before. Judging from the low 12 or 48% subject pass rate, it seems the subjects had difficulty using the knowledge of the fact that chromosomes replicate during cellular division. Biggs and More (1993) discuss reasons why students fail to use strategies they have learnt. One suggestion is that sometimes students use low level routines which are surface strategies which are easily forgotten; at times students have inadequate knowledge of what is required.

5.2.2 Further discussion and analysis of probe 4

Appendix 17 shows four different erroneous interpretations of the meiotic stages C and D. All the subjects' answers show that they were not aware that the cell had 6 chromosomes, that is, 3 pairs of homologous chromosomes. Cell C was supposed to show the results of the separation of the homologous pairs of chromosomes. Cell D was supposed to show the products after the separation of the sister chromatids. The answer given by subject 1 does not show that the chromatids had separated. The answers of subjects 3, 4 and 5 do show that the sister chromatids had separated at stage D of meiosis but their calculation of the number of chromosomes had been incorrect. The calculation of the number of chromosomes in stage A could have been a problem for the subjects. The real problem seems to have been the understanding of homologous chromosomes. Subject one also just guessed the number of chromosomes as can be seen in the response to question number 4(1). The cells undergoing meiosis are also indicated as being found all over the body and not only in the sex cells. The subjects therefore showed a lot of conceptual problems with the understanding of meiosis.

5.2.3 Further discussion and analysis of probe 5

Table 4 below shows a pattern of responses to probe five relating to number of chromosomes in human cells undergoing different stages of mitosis or meiosis. The responses were divided into three or four groups according to their degree of accuracy.

1. Answers correct or the 'keys'.

- 2. Answers incorrect but referred to numbers of chromosomes that could be found in an human somatic or sex cell and
- 3. Wild guessing referring to a number of chromosomes not likely to be found in human beings.

5.2.1.4 TABLE 6 : THE SUBJECTS' RESPONSES TO PROBE 5 RELATING TO THE UNDERSTANDING OF MITOSIS AND MEIOSIS

ITEMS	CELL DIVISION STAGE	RESPONSES	PERCENTAGE OF SUBJECTS
			GIVING THE RESPONSE
5(i)	Metaphase of mitosis	92 chromosomes (key)	0%
		46 chromosomes	60%
•		23 chromosomes	32%
araan ahaan ahaan Araan ahaan Araan ahaan		Wild guessing	8%
5(ii)	Metaphase of meiosis	92 chromosomes (key)	8%
	an a	46 chromosomes	36%
		23 chromosomes	24%
		Wild guessing	32%
5(iii)	Telophase of mitosis	46 chromosomes (key)	68%
		23 chromosomes	4%
		wild guessing	28%
5(iv)	Telophase II of meiosis	23 chromosomes (key)	64%
	n an	46 chromosomes	12%
		Wild guessing	24%

The pattern of responses in table 4 shows that very few students were able to apply their

The pattern of responses in table 4 shows that very few students were able to apply their knowledge of mitosis and meiosis to work out the number of chromosomes at the metaphase stages for both types of cell division. The question had requested subjects to count chromatids as chromosomes. This section required some processing of information for instance, like remembering that prior to mitosis and meiosis there is a duplication of chromosomes. At this metaphase stage each chromosome consists of two identical chromatids. The lack of understanding and inability to interpret events in both metaphase phases is reflected in the very low percentages of subjects who obtained correct answers. For mitosis more of the subjects obtained correct answers whereas for meiosis only 8% of the subjects obtained correct answers. The confusion of subjects was also indicated by subjects who guessed widely by mentioning numbers of chromosomes that are not even found in any human being, cell whether it be a somatic or sex cell. The numbers referred to 2, 4, or 8 chromosomes which are numbers usually used in undergraduate biology courses to illustrate meiosis or mitosis.

A very high percentage of subjects seemed to have memorised or understood the products expected after mitosis and meiosis at telophase stage. This was indicated by the higher average scores of 68% for telophase products of meiosis. Six students who were called to explain why they could get correct answers for 5 (iii) and 5(iv) explained that they had memorised the products of mitosis which they said had always had normal (diploid) number of chromosomes while that of meiosis always result in half the number of chromosomes, i.e (haploid). The answers to the latter questions had therefore been arrived at by memorization. It therefore transpired that getting the correct answer did not necessarily mean understanding conceptually what really goes on in mitosis and meiosis. Schunk (1991) writing on information processing stated that rote memorization is an inefficient mode of learning in real life. People learn and retain things better through understanding, that is, comprehending the principle underlying the task performance.

Probe 5 was a typical application question in that subjects were required to deal with 46 chromosomes, whereas illustrations of mitosis and meiosis in all the books they have ever used only use 2 to 8 chromosomes for the sake of simplicity. The probe therefore seemed

relevant to testing if subjects could use their knowledge to interpret a different situation they had not encountered before. The subjects failed dismally when it came to interpreting events of mitosis and meiosis at metaphase stages. The more difficult mental operations need practise to the level where subjects can manipulate, mentally, any number of chromosomes. Again, this probe emphasizes the need for subjects to understand concepts in genetics and not only memorize concepts by rote since information memorized without meaning seems not accessible during problem solving. Subjects in the research by their own admission seem to have stuck to the content where 4 or 8 chromosomes are generally used to illustrate the processes of mitosis and meiosis in undergraduate textbooks.

Two of the criteria for judging understanding of concepts were stated in chapter 4 as first, being able to recognise instances (not previously encountered) of the concept. Secondly, it was to be able to apply the concept in new situations. These were two cognitive demands made by probe 5 on subjects. Subjects were not able to apply their knowledge to solve the problems in probe five it is therefore hard to believe the subjects had mastered the concepts involved in meiosis.

Probe six dealt with problem solving in genetics. Achievement scores by different subjects indicates that 14 of the subjects failed. More than 50% of the subjects could not solve a simple genetic problem. Only 11 subjects representing 44% could solve a problem and judging by the competence levels shown in table 3 most of the subjects attained partial credit. The low achievement by the subjects in genetic problem solving was not surprising. A look at probes four and five which dealt with different aspects of meiosis shows very low scores. The understanding of meiosis is crucial in the ability to solve genetic problems. It therefore did appear that subjects were not able to solve the simple genetic problems because they did not understand meiosis.

TABLE 7 :ACOMPARISONOFTHERELATIONSHIPBETWEENKNOWLEDGEOFGENETICHEURISTICSANDABILITYTOSOLVEGENETICPROBLEMSAMONGSUBJECTS

ACHIEVEMENT SCORES	GENETIC HEURISTICS	PROBLEM-SOLVING SUCCESS RATES
75 - 100	14	1
65 - 74	0	5
50 - 64	4	2
0 - 49	4	14

The results in table 5 show that many subjects, that is, 9 pairs out of the 11 pairs that wrote genetic heuristics did very well. Only two pairs seemed to have had no clue on what steps one follows when solving a genetic problem. Table 5 also shows that the problem solving abilities of subjects were poor. Only 8 subjects representing 36% of those who did both parts of the test had passing scores. Fourteen of the subjects showed lack of proficiency in solving problems in genetics inspite of the fact that an equal number of subjects had displayed procedural knowledge for solving problems in genetics.

The researcher was interested in finding out if there was any correlation between achievement scores in knowing genetics heuristics and solving genetics problems. The Pearson product moment correlation co-efficient was calculated using Elzey (1987) micro computer programme. The value of the Peason correlation (r) was found to be 0.263 at, P=0.05. The value of a perfect correlation is 1.0, therefore the obtained correlation meant very low correlation. According to Elzey (1987) if one wants to make statements regarding the meaning of correlation, then one had to compute the coefficient of determination, which was obtained by squaring the correlation coefficient (r²). In this case $(r^2) = (.263)^2 = 0.069$ indicated that 6.92% of the variance of genetics heuristics scores was accounted for by the variance of the problem-solving scores.

The relationship between the two variables was too small since only about 7% of the variance in the knowledge of heuristics was associated with the variance in the ability to solve genetic problems.

Testing of the significance of the correlation coefficient had to be done because statisticians are never happy with just calculating the Pearson product moment as a method of determining the degree of the relationship between two variables. Elzeys (1987) computer programme was used to calculate the correlation coefficient t-value. The application of the programme produced a t- ratio of 1.219 at P=0,05. The obtained value of 1.219 was a smaller item than the table t-value of 2.086 and therefore there was no significant positive correlation between knowing genetic heuristics and the subjects ability to solve genetic problems.

5.3 INTERPRETATION OF RESULTS

One would have expected that the knowledge of genetic heuristics would facilitate problem solving by the subjects. But when one viewed table 4 it was apparent that a high number of subjects knew the heuristics but only 8 subjects could solve the problem up to acceptable pass levels. Fourteen subjects had very low or failure grade achievement, indicating that the subjects had difficulty in genetic problem solving. Further, testing for correlation of scores between the knowledge of genetic heuristics and problem solving ability was found positive but weak. On testing for the significance of the correlation between knowing heuristics and solving problems in genetics, it was not statistically significant. Throughout the research the importance of learning with meaning was stressed. It appeared the subjects in the research memorised genetic heuristics without really understanding how to apply them to solving new problems in genetics. Thus the procedural knowledge was there but perhaps, because there had been no conceptual understanding of genetic concepts the procedural knowledge was not very useful to subjects.

TABLE 8:THERELATIONSHIPBETWEENCONCEPTUALUNDERSTANDING OF MEIOSIS AND THE ABILITY TO SOLVEGENETICS PROBLEMS BY THE SUBJECTS

ACHIEVEMENT CRITERIA	75-100	64 - 74	64 -50	49 - 0
Understanding of meiosis by subjects	1	2	3	19
Problem-solving by subjects	2	6	3	14

Table 6 shows a comparison between subjects' knowledge and understanding of meiosis to the subjects ability to solve a genetic problem. As many as 19 of the 25 subjects did not understand meiosis and an equally high number of 14 subjects also failed to solve the genetic problem. The results showed that there might be a relationship between understanding the process of meiosis and the ability to solve a genetic problem. The researcher therefore applied the correlation coefficient to find out if there was any relationship between the two variables. Elzey's (1987) microcomputer programme was used and a value of r = 0.590 was obtained which indicated a positive correlation between understanding of meiosis and an ability to solve genetics problems. The coefficient of determination (r^2) was 0.348. This value meant that 35% of the meiotic process scores were associated with the variance in the ability of subjects to solve problems in genetics. Computation of the t - value for the coefficient of determination was 3.259 at P= 0.05. The critical table t-value was 2.086. There was therefore a significant correlation between understanding meiosis and the ability to solve genetics problems.

In a study by Stewart (1982) based on the difficulties experienced by high school students when learning basic Mendelian genetics, the author examined the knowledge and problem solving abilities of the students as they worked through types of simple genetic problems. The main findings of the research was that meaningful problem-solving in genetics was based on the understanding of the role of meiosis in genetic inheritance.

The understanding of meiosis is critical in the successful solution of genetic problems. One of the steps that one should remember in solving a genetic problem is the formation of gametes which involve the process of meiosis. The use of the Punnet square also uses the principle of meiosis, therefore a student who does not understand meiosis properly is not likely to solve genetics problem accurately.

5.3.1 FURTHER ANALYSIS OF THE THEORY TEST ACHIEVEMENT SCORES

Graphs present data in a style that facilitates reading fast vast amounts of information (Taylor - Fitz-Gibbon, 1987). The achievement scores of subjects were therefore also presented in histograms. Histograms display at a glance a clear picture of the class mean scores in the various probes. Histograms were also found as a suitable way of presenting differences between the male and female achievement scores. Different histograms showing subjects learning in genetics will be discussed below:

FIGURE 3 : THE SUBJECTS' MASTERY OF GENETIC CONCEPTS (1-6) RELATING TO KNOWLEDGE AND UNDERSTANDING OF GENETICS



Figure 3 presents a histogram showing a different way of displaying the results. The histogram shows at a glance that the subjects performed reasonably well in probe 3 with a mean score of 67.55%. Probe three was followed by mean scores of 49.50% and 50% for probes 1 and 2 respectively. Very poorly done at a mean score below 40% were probes 4 and 5, both of which dealt with mitosis and meiosis. Probe six also with a mean score below 40% dealt with solving a genetics problem showed that many subjects had problems with solving a genetics problem inspite of the fact that many of the candidates know genetics heuristics. Writing on the "Theory and application of a Cognitive-Network Model of prediction Problem Solving in Biology", Lavoie (1993) states that once we have knowledge of students' information processing skills we can develop teaching strategies that facilitate more effective cognitive networks. Lavoie (1993) like Hiebert and Lefevre (1990) suggest that to be useful in problem solving, procedural and declarative (content) knowledge should be connected in ways most conducive to solving problems, achieving conceptual understanding and facilitating subsequent learning. For the subjects in the research it seems procedural knowledge existed in isolation from content or declarative knowledge. There were no rich networks between the two forms of knowledge, the networks are important for developing understanding and laying a foundation for subsequent learning.

FIGURE 5: THE SCORES REPRESENTING SUBJECTS' KNOWLEDGE OF GENETICS TERMS



Figure 4 shows the test score profiles of probe one which tested the subjects' mastery of terms in genetics. The-test score averages for items A, B, C and H were above 60% which indicated a reasonable understanding of these terms by subjects. Unlike items A,B,C and H which were straight forward recall items, D, E, F and G required analysis and a deeper understanding of genetics. Item D for instance referred to mutation, while E referred to a haploid state. Item F referred to a heterozygote while G was a hybrid. The average scores for all these items was below 45%. For a subject who does not understand meiosis very well it would not be easy to remember terms like the haploid number which refers to the reduction of chromosomes in meiosis. Language problems cropped up now and then, for instance, the grammatically correct answer to probe F should have been a heterozygote but all the 28% candidates who got this item correct wrote heterozygous which is a descriptive word and not a noun.

5.3.2 DISCUSSION OF SUBJECTS' KNOWLEDGE OF GENETIC TERMS.

The non-mastery of genetic terms requiring higher order thinking before finding an appropriate term, indicates the importance of learning with meaning as opposed to rote learning. Schunk (1990) describing conditions for successful encoding, which is a process of integrating new information into the information processing system for storage in long-term memory, stresses the importance of meaningful learning. When concepts are memorised by rote and do not have rich connection in the mind with other concepts they become useless because they cannot be retrieved from memory when they are needed. It was interesting to note that subjects scored very high marks in the genetic terms they remembered. One can also speculate that these probes consisted of simpler aspects of genetics which subjects understood while the other four items D, E, F and G consisted of items of higher order thinking which subjects had not mastered.

FIGURE 6: COMPARING MALE AND FEMALE SUBJECTS' ACHIEVEMENT SCORES RELATING TO KNOWLEDGE AND UNDERSTANDING OF GENETICS (PROBES 1-6)



Figure 4 shows the performance of male subjects compared to that of female subjects. A glance at figure 4 shows that both male and female subjects did equally well on probe three. Both male and female subjects showed some reasonable understanding of the process of mitosis. While male subjects managed to get a mean score of 50% for probes one and two, female subjects' mean scores were below 50%. Probe 4, 5 and 6 tested higher order cognitive skills. Although male subjects got slightly higher means scores then females, all the subjects did poorly with mean scores below 40%. Therefore competence of the subjects in the skills tested for by probes 4, 5 and 6 was very low. From probes 4 to six the mean scores declined rapidly, showing how difficult it was for subjects to apply their knowledge to those higher order questions.

During informal discussions subjects conceded that the lecture method is the dominant teaching style at the University of Zululand. However, subjects also had a 3 hour practical period per week. Lectures are mainly based on a transmission style of teaching. Another very important factor is that lecturers offering the Biology course taken by the subjects were not qualified teachers, in terms of possessing a teaching diploma. Johnson, Johnson and Smith (1991) writing on increasing college faculty instructional productivity state that for lecturing to be successful and to overcome the obstacles to effective lecturing,

students must become cognitively active. The authors suggested the use of informal cooperative learning groups for discussions between lectures.

The advantage of using cooperative learning groups is that the lecturer gets a chance to listen to the groups discussing concepts. The discussions give the instructor direction and insight into how well students understand the concepts being taught. In a way cooperative learning groups ensure that misconceptions and gaps in understanding are identified and corrected and learning is personalised. Results of the research indicate that some of the subjects may not have been through this learning process during their training.

5.3.3 FURTHER ANALYSIS OF THE DIFFERENCES BETWEEN MALE AND FEMALE SUBJECTS' ACHIEVEMENT SCORES

The researcher sought to find out if the differences between male and female achievement scores were significant. A t-test was applied using Elzy's (1987) microcomputer programme. There were 11 females and 14 male subjects. The statistics for the two groups of subjects were as follows:

TABLE 9: FEMALE AND MALE ACHIEVEMENT SCORES IN THE THEORY TEST

		
	FEMALE	MALE
Ν	11	14
Mean	39.22	45.48
Standard deviation	18,22	17.76
Variance	332.06	315.40
Standard error of main	5.48	4.75

Statistics was applied to find the t-value for the subjects at P=0.05. The obtained calculated value t = 0.862 was below the obtained table t-value of 2.069. Therefore the researcher could not reject the null hypothesis that there were no significant differences

between the male and female scores. In fact the mean scores in both cases were low being below 50 although the male scores were slightly higher than those of females.

Biology has been said to be a popular option for the girls perhaps because it deals with biosocial issues which enhance the learning of female subjects (Dean 1978 and Attar 1990). The achievement of the females in the study was not very different from that of the male subjects. Female subjects, however, still need encouragement to venture into more technological fields which are still dominated by men. Harding (1980) contends that the underachievement of women in the sciences related careers at all levels, but especially in the more technological fields, has its roots in the school where few girls obtained the relevant qualifications to get into specialised careers.

5.4 SUBJECTS' CONCEPTIONS OF GENETICS HEURISTICS FOR PROBLEM-SOLVING

Students' actual specimens of work gives a better insight into the kinds of meaning subjects attach to concepts. It was for this reason that where possible, the researcher presented some of the subjects written work.

Instructions for subjects for the activity was that they should work in pairs and write down steps that they followed when solving genetic problems. Most pairs discussed in a mixture of their mother tongues depending on whether the two individuals spoke the same language or not. Below are some examples of the genetic heuristics given by some cooperative pairs of subjects :

SPECIMEN 1

d.

a. Describe clearly the phenotypes and genotypes of the parents

b. Then write down the gametes

c. Then do the crossing

Write down the phenotype and the genotypes of the F_1 generation. Also write ratios.

SPECIMEN 2

a. Identify the different types of parents e.g. TT x tt

- b. Look for gametes
- c. Find the F1 generation.
- d. Use a Punnel (sic) square
- e. Look for genotype and phenotype ratios.

SPECIMEN 3

- a. First make sure that you understand the problem, analyse it.
- b. You have to be able to identify the parents
- c. You have to be able to identify the gametes of the parents
- d. "Procede" by crossing male and female gametes to get the offspring
- e. From the offspring make the genotype and phenotype ratios.

SPECIMEN 4

- a. First identify the problem
- b. Know the letters whether homo/heterozygous
- c. You use the known genes to trace the unknown genes.

5.4.1 Discussion of the subjects genetic heuristics

The subjects had to decide for themselves what steps they had to include and in what sequence. Some steps were written in a reasonable sequence for instance specimen 1. The specimen therefore indicated that subjects probably understood their heuristics. Other specimens, for instance, specimen 2 contained all the elements of genetics heuristics but the sequence had not been evaluated properly by the pair of subjects. For instance the use of the Punnet square called the "Punnel square" came after F_1 generation. The

cooperative pair probably used another method of crossing. The third specimen brought a crucial factor in the solution of a problem that is the analysis of a problem to make sure one understood it. Specimen 4 was an example of those subjects that did not quite understand or remember the sequence they had to follow in solving genetic problems. One interesting aspect of specimen 4 was a distinct notice of two handwritings which indicated the extent of the cooperative spirit.

5.5 ERRONEOUS MEIOTIC METAPHASE 1 MODELS MADE BY SUBJECTS IN THE PRACTICAL TEST

Writing on guidelines in reporting the results of an educational evaluation, Tyler (1990) suggests that the report should indicate what of the expected learning has not taken place. The author also states that in reporting, whenever what students have learnt can be reported more concretely this must be done instead of relying on numbers only. Below the research will be discussing some erroneous models made by different subjects during the practical work. The erroneous models appear in appendix 16. The first model in appendix 12 shows erroneous orientation of chromosomes of a meiotic stage 1. The model also shows non identical chromatids with one chromatid carrying a dominant gene while the other one carries a recessive gene. The subject, however, seemed to have been aware of loci of genes though alleles were placed inaccurately in the model. The information on the subject's explanations of heterozygous and homologous chromosomes revealed misconceptions about these two concepts. The use of different colours for the chromatids also indicated some confusion about the concepts homologous and heterozygous chromosomes.

Model 3 shows a different type of misconception where allele A is labelled as the whole chromosome and allele 'B' label for the other chromosome. The use of two different capital letters for heterozygous is not the conventional way of representing alleles. Letters A and B would under genetics convention represent codominant genes.

•

The second model in appendix 16 shows what should have been a pair of homologous chromosomes. An erroneous model arose from the subject's experience that chromosomes are always shown as consisting of two chromatids in books. Below is a transcript of the conversation the researcher had with the subject during the non-scheduled interview.

•	How many pairs of homologous chromosomes were you supposed
	to show?
•	One pair
•	Does your model show one pair of homologous chromosomes?
•	Yes
•	Why are there tetrads, that is, four chromatids of each colour?
:	Because you see, chromosomes appear like this diagram whenever
	you see them in books.

Representation of a chromosome by a subject. When the duplication of chromosomes occur during the interphase stage, you get four chromatids.

The discussion with the subject who made model two was illustration of how one can know bits of information and fail to relate them meaningfully. The misconception in model two was related to the subject's misunderstanding of the cell cycle. By the time the cell starts dividing meiotically it has already undergone duplication of chromosomes during the interphase stage. Chromosomes are also visible during meiosis or mitosis because besides duplication, they also shorten and thicken. The subject also had problems with using genetics symbols accurately and placing alleles in loci.

Model 4 shows a homologous pair of chromosomes. The 2 alleles, that is, the dominant allele A and the recessive allele are placed on sister chromatids. This misconception was also found in Brown's (1991) study as shown in appendix 19. While in Brown's case the alleles were placed in loci in the chromosomes in the research the alleles were placed outside the chromosomes.

Model 5 was similar to model four except that the subject who produced this model did not follow instructions. Alleles B and b were used instead of A and a. The alleles were also not placed in specific loci.

Model 6 shows a pair of homologous chromosomes with alleles A and a outside the chromatids. The sister chromatids also bear different alleles an almost similar situation as was observed by Brown (1991) in misconception type 2 shown in appendix 19.

Misconceptions discovered by Brown (1991) in a similar study with 'A' Level students are shown in appendix 19. It seems British students only had problems with the accurate placing of alleles A and a, on the sister chromatids. In the research subjects did not only have problems with placing the alleles on the sister chromatids, they also seem to have had problems with the concept locus of a gene. The alleles in all models except the first one were placed outside the sister chromatids.

Some of the subjects in the research had problems with making models of a pair of homologous chromosomes. Models 1 and 2 show this difficulty, comparatively speaking the subjects for whom English was a second language exhibited more misconceptions them was shown in Brown's (1991) study where the subjects were first language speakers of English. One cannot say conclusively that the subjects' difficulties in producing an accurate model was caused by poor language skills. Other factors that may have contributed to poor performance by subjects may be the way genetics was taught, for instance, by lecture method.

5.5.1 DISCUSSION OF THE PRACTICAL TEST RESULTS

Hofstein and Lunetta (1982) describe practical work as contrived learning experiences in which students interact with materials to observe phenomena. There are many reasons that one can put forward as possible purposes of practical work. For the research some of the aims were to discover if subjects could follow instructions, use their knowledge to produce an accurate model of a pair of chromosomes at meiotic phase 1. Results showed that subjects had a lot of difficulties with the understanding of the concepts alleles, heterozygous and homologous chromosomes. Some subjects had difficulty using genetic symbols accurately. Because of all these difficulties in the conceptual understanding of concepts that are crucial in the understanding of meiosis, at least 52% of the subjects showed very poor understanding of meiosis in the practical. The practical work needed a thorough understanding of genetics concepts before one could produce an accurate model.

Johnstone (1987) stated that there was, among some educational circles, some misunderstanding between Piaget's, Concrete Thinking Level and Practical activities. Some people believed that because practical work involved the handling of concrete objects it was making students to work at concrete level. However, one hopes that the research showed that the subjects had to work at higher cognitive levels in order to translate the instructions into accurate models. Those subjects who were lacking in the accurate conceptions of, for instance, alleles, homologous and heterozygous chromosomes could not produce accurate models.

Poor performance by some subjects, just above half of the subjects, perhaps gives one a warning of how important it is that practical work should promote accurate understanding of concepts. Practical work needs to challenge students' existing concepts so that inaccurate conceptions are revised. Knott and Matunga (1995) discussing possible purposes of laboratory classes state that much laboratory work has become a ritual in which students follow routine instructions and are not required to think. Such kinds of practical do not challenge students thinking and also do little to help students to discover

their shortcomings. Modern ways of describing practical work is that it should be both hands-on and minds-on. This means that while it develops manipulative skills it should develop thinking skills as well.

5.5.2 FURTHER ANALYSIS OF THE PRACTICAL TEST RESULTS

The practical test was written by both male and female subjects and the researcher was interested in knowing if achievement by the two groups were similar or not. The researcher therefore applied a t-test to evaluate whether there were significant differences between the male and female subjects scores in practical work.

The subjects consisted of two unequal groups, that is, eleven female subjects and fourteen male subjects and so an independent t-test was applied (Taylor Fitz-Gibbon, 1987). The statistics for these two groups of subjects were as follows:

TABLE 10: FEMALE ANDMALE ACHIEVEMENT SCORES I N THE PRACTICAL TEST PRACTICAL TEST PRACTICAL TEST PRACTICAL TEST PRACTICAL TEST

	FEMALES	MALES
Ν	11	14
Mean	7.00	8.14
Standard deviation	3.13	2.70
Variance	9.8	7.29
Standard error of mean	0.813	0.72

There was a larger variance estimate for the female subjects than for the males. For calculating the t-value the researcher used Elyzey's microcomputer programme (1987). The table t - value of 2.064 exceeded the calculated t - value of 0.959. The researcher therefore could not reject the null hypothesis that there was no significant difference in achievement scores between the male and female subjects in the practical test.

5.5.3 DISCUSSION OF THE MALE AND FEMALE SUBJECTS ACHIEVEMENT IN THE PRACTICAL TEST

Many authors have discussed the fact that women seem to underperform in science related tasks (Watts 1994, Bryne 1993 and Ifelluni 1997). The research, however, found that there were no significant differences between the male and female achievement scores in practical work. It seems from these results that the learning conditions at the university of Zuhuland does not affect the performance of female subjects in a negative way. There are methods of teaching that have been said to be good for enhancing learning for females. The learning of females is said to be enhanced by linking science to social issues and practical problems (Deem 1978, Harding 1980, Sullins, Hernandez, Fuller and Tashiro 1995). The practical work may have been one method of assessment that enabled female students to display their knowledge in a better way than they did in theory.

5.6 SUBJECTS' OPINIONS ON THE RAPE OF SCHOOL GIRLS BY TEACHERS

The subject of rape of school children and toddlers in South Africa is an emotional one. Many people believe there is a rape crisis in South Africa. In the local radio broadcasting in the Zulu language it was announced that in February 1999 there were 12 rapes every minute in South Africa. Amupadhu of the *Mail Guardian* of the twelfth to the eighteenth February 1999, reported of a policeman that had raped his three year old daughter repeatedly. The sexual abuse of children is therefore exercised by people of all walks of life including law enforcement officers like the policemen. Bennett (1995) stated that sexual harassment and sexual violence constituted one of the most serious problems for women, staff and students on South African campuses. In the Drum magazine of April 1998 there was an article about how some teachers see young girls as 'fringe benefits' and objects to satisfy their sexual desires.

The aim in seeking the subjects opinions on rape was to get their reactions toward a social problem they should be prepared to face when they start teaching. Below are some of the subjects responses to the first question which asked subjects how they felt about

teachers who rape school girls. The responses were selected in such a way that they represented different opinions of subjects on the matter. The responses were also not ranked according to any particular order.

SUBJECT A : "Teachers who rape school children should be expelled from the teaching profession".

SUBJECT B: "Teachers who rape school children should be suspended"

SUBJECT C: "It becomes a 'wound' to me when teachers rape school girls".

- SUBJECT D: "Teachers are 'seduced' by the school girls who do not sit in a proper manner".
- SUBJECT E: "...... after banning them (teachers) from school their private parts need to be cut off from them to stop the raping process".

SUBJECT F : "It is a terrible situation to find male teachers harassing female students because it destroys their future".

SUBJECT H: "Teachers who rape school girls must be forced to marry these girls".

SUBJECT I: "It is unprofessional for teachers to rape school girls. Rape is a criminal offence which violates human rights. The government must cancel the teaching post and the teacher must be taken to gaol".

As can be seen from the subjects' expressed opinions, many think that the raping of children is outrageous. Many of the subjects suggested that drastic measures be taken against rapists of school children. Below is a breakdown of the kinds of punishments that subjects thought were suitable as a penalty for raping school children.

TABLE 11: VIEWS OF SUBJECTS ON HOW RAPISTS SHOULD BE PUNISHED

TYPE OF PUNISHMENT	PERCENTAGE OF SUBJECTS SUPPORTING THE KIND OF PUNISHMENT
1. Expulsion or suspension from teaching	40%
2. Castrate the teacher	4%
3. Arrest and send the teacher to gaol	26%
4. Serious unspecified steps should be taken against the teacher	14%
 The teacher should be expelled from the school and community 	4%
6. The rapist must be forced to marry the victim	4%
 Rape is the victims fault-no punishment was suggested 	8%

5.6.1 DISCUSSION OF THE RESULTS REGARDING SUBJECTS' OPINIONS ON RAPE

Most of the subjects were strongly against the raping of school girls by teachers. Many subjects (40%) thought such teachers should be expelled from the teaching profession. Some subjects thought that misbehaving teachers should not only be expelled from school but from the community as well. There were also very severe forms of punishment suggested by subjects for instance, castration for perpetrators of rape. Another controversial opinion was that the rapists must be forced to marry the victims. The last suggestion could be very traumatic for the victim if carried out.

There were instances where it was apparent that language deficiencies interfered with the subjects expression of ideas clearly and effectively. For instance, the statement from subject C is a direct translation form Zulu to English. A person not familiar with the Zulu language might have difficulty understanding what the subject meant. Subject G also had difficulty in expressing his/her opinion because of poor proficiency of the language. Hall,

There were instances where it was apparent that language deficiencies interfered with the subjects expression of ideas clearly and effectively. For instance, the statement from subject C is a direct translation form Zulu to English. A person not familiar with the Zulu language might have difficulty understanding what the subject meant. Subject G also had difficulty in expressing his/her opinion because of poor proficiency of the language. Hall, (1995) suggests that some students whose first language is not English will need support to extend their speaking and writing repertoires and to practice new words and phrases in a relevant context. Subjects need to acquire sufficient linguistic competence in order that they can express their ideas fluently.

Another interesting aspect of the subjects' responses was a realization by some subjects that rape violates the victims human rights. For instance one subject said, "It is unprofessional for teachers to rape school girls. Rape is a criminal offence which violates human rights". Subject G also referred to the violation of the children's rights to live a happy life. Human rights for all is a new concept in South Africa introduced during South Africa's first universal election in 1994. It was heartening for the researcher to realise that student teachers are aware of human rights and realised that they are applicable to other people and not themselves only. Writing about child abuse, sexual harassment and violence, Wolpe, Quinlan and Martinez (1997:93) state that "Fcr girls, the impact of child abuse is to learn that male violence is the condition against which their rights and freedom are negotiated. Their early learning is that submission is a survival skill. In this context, education about human rights has little meaning". Therefore, many challenges lie ahead to actually bring a viable human rights culture to all sectors of South African communities.

Among the subjects responses was another familiar element where girls are alleged by rapists to have asked for it. Subject D for instance suggested that teachers are seduced by the school girls who do not sit in a proper manner. According to Wolpe et al., (1997) the rape crisis is exacerbated by the fact that teachers frequently treat sexual harassment lightly because "the girl asked for it". This view that girls ask for rape was supported by another subject who said "School girls have a tendency of offering seduction to teachers so that teachers get fascinated by them. Another way of wearing must be established".

The subject's view was that school children may be inviting rape by what they wear. The emphasis on the rape of girls does not mean boys are not subjected to sexual abuse. The perception is that more girls than boys are subjected to sexual violence.

The second question on sexual harassment of school girls was what subjects would say to a girl who had just been raped and had come to them for advice. Most of the subjects said they would send the victim to a doctor, a social worker, the guidance teacher or to a police station. Other subjects had the following to say :

- SUBJECT J: "First I would treat her trauma by giving her counselling and making her feel acceptable even after the rape".
- SUBJECT K: "I can tell the victim that this is not the end of the world. There is still life ahead. She must not lose hope and must concentrate on her learning as before".

SUBJECT L : "I would refer the student to rape crisis help line".

SUBJECT M : "I would take the student to the doctor and then to a social worker. I won't say a lot to her except showing sympathy and understanding".

Some subjects like J to M realised the traumatic experience a rape subject is likely to go through. The immediate impulse of these subjects was that they would seek to comfort and reassure the victims before referring them to appropriate service providers. The stigma attached to rape was illustrated by comments from subject J and L which went as follows "making her feel acceptable even after the rape" and "I can tell the victim that this is not the end of the world". Perhaps the stigma attached to rape is due to the fact that some men believe that girls invite rape by the way they dress. There is a need for education that will recognise and uphold other people's dignity. The sexual harassment that school girls are subjected to is likely to affect their self-esteem as well as their class performance. Writing about curriculum and sexuality, Wolpe et al., (1997) noted that there had been ongoing reference to the dysfunctional effects of various forms of violence on the level of attainment of girls and young women. The authors suggested that punitive measures against rapists cannot eradicate forms of violence. They advocated that the issue of sexuality be placed fully on the agenda and that learners and educators understanding and awareness can be changed through education.

Inspite of the high rate of sexual violence in South African schools, sex education is still not promoted throughout South Africa. Bennet (1995) stated that from evidence accumulated in South Africa it was clear that girls in secondary schools experience high levels of sexual harassment and sexual assault from peers and male teachers. The amount of sexual harassment experienced by students not only females but males as well, requires the inclusion of sex education in the curriculum. The American Association of University Women Educational Foundation AAUW (1992) discussed the "Evaded Curriculum" which referred to matters central to the lives of teachers and students but which were only touched upon briefly or not all at in the classrooms. These crucial matters are topics like sex education, sexually transmitted diseases, eating disorders, drugs and other issues for which knowledge is critical for survival. It is interesting to note that in South Africa these topics are referred to as the "silenced curriculum" while in America the AAUW refers to them as "evaded curriculum".

5.7 SUBJECTS' KNOWLEDGE AND UNDERSTANDING OF GENETIC TECHNOLOGY

The third question in the instrument on sexual harassment and violence in South Africa asked the subjects to identify technology used in identifying rapists. None of the subjects mentioned genetic fingerprinting but 77% of the subjects referred to a gene, DNA or semen test. The rest of the subjects referred to fingerprinting which is a different technique from genetic fingerprinting and to the use of police identikits. The following are some of the answers given by the subjects.
SUBJECT N : "A DNA test can be used where the sperms of a male can be examined, the criminal can be traced by using the findings".

SUBJECT O: "The excellent kind of technology to identify a rapist is to get a fingerprint".

One of the subjects wrote about the kind of technology she/he thought might be available in future. Below is what the subject said:

SUBJECT P: "Something as a shield (unoxhaka) should be put in the female genital organs which can trap the male organ. This should only be taken out by the professional doctor. This can make conviction of rapists easy. A doctor would know if a person comes with that thing in his genitals that he had been raping and the doctor should call the police. This thing (the shield) should not be fatal but should take ± 2 months to heal". For the doctor, reporting the patient would involve critical ethical issues relating to doctor-patient confidentiality.

Subject P sounded exasperated by sexual violence and so she advocated the radical measure to protect women against sexual abuse. Subject P showed difficulty in expressing her ideas in English. For instance she referred to a shield which she translates into 'unoxhaka' in Zulu, but that is not a correct translation because the word refers to a snare in English. The quality of some of the subjects' presentations were affected by the lack of competence and fluency in English.

Subject O confused genetic fingerprinting with ordinary fingerprinting. The fingerprints subject O referred to were those which are a pattern of ridges and furrows which constitute fingerprints. Fingerprints are also used for identification purposes since they not only persist unchanged throughout our lives, but are also unique to each of us except identical twins.

The last question subjects were asked in the sexual harassment tool was to give their general understanding of how genetic finger printing works. Sixty eight percent of the subjects had a basic idea of how genetic fingerprinting works. Below are some examples of what subjects indicated as their general understanding of genetics fingerprinting technology.

SUBJECT Q : "My general view about this technique is that the blood of a rapist is identified, where the DNA will show the blood type of the rapist. This can be successful only if the suspect is known because he can be forced to go to the test and if the raped girl got pregnant, the blood test of the new born be examined".

SUBJECT R: "The technology involves analysing the semen from the suspect and compare with the sperms from the female". Both subjects Q and R had a general view of what genetic engineering means. Subject Q was, however, confused about the blood typing technique which was equated to genetic fingerprinting. The subjects were not expected to remember the precise protocol of fingerprinting. Toole and Toole (1999) described steps that are followed when a genetic fingerprinting procedure is done. The procedure involves the following steps:

1. The DNA is separated from the sample

2. Restriction endonucleases are used to cut the DNA into sections.

3. The DNA fragments are separated in agoras gel using electrophoresis

4. The fragments are transferred to a nitrocellulose membrane.

 Radio active DNA probes are used to bind to specific portions of the fragments known as the core sequences.

6. The portions of the fragments of the DNA not bound to the radio active probes are washed off.

- The maining DNA still attached to the nylon membrane is placed next to a short of X ray film.
- The radio active probes on this DNA expose the film revealing a pattern of light and dark bands when it is developed. The pattern makes up the genetic fingerprint.

The actual process of genetic fingerprinting is a complicated process which demands the understanding of molecular biology. Subjects were found to be generally informed about genetic fingerprinting although they did not understand the fine details. Vernon (1999) wrote in the 14 January issue of *Sunday Times* that South African Police had taken a cue from Britain and the United States of America by starting to take hair and blood samples from possible suspects and convicts so that their DNA can be used as a way of linking them to crimes. Genetic literacy is therefore a good thing because it would enable the subjects to participate in debates on genetic matters affecting their communities in an informed way.

5.8 CONCLUSION

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It this chapter, the results of the study were analysed and discussed. The results indicated that although subjects showed a better understanding of the miotic process, scores relating to the understanding of meiosis were very low. Low scores in the understanding of meiosis affected the subjects ability to solve genetic problems. The study found out that there was a significant correlation between the subjects' understanding of meiosis and their ability to solve genetic problems.

The study did not show any significant correlation between the subjects' knowledge of genetic heuristics and the application of heuristics to successfully solve a genetic problem. Subjects showed a high level of competency in writing their plans to solve genetic problems but the procedural knowledge did not translate into a successful solution of genetics problems.

The subjects showed very low competencies as a group in all the probes that tested high order cognitive abilities. According to the subjects some questions were structured in pattern they were not familiar with. The subjects indicated a preference for essay type questions during discussion of their difficulties with certain probes in the test.

There was no significant difference between male and female achievement scores. It seemed that the questions did not favour unduly either of the sexes.

On the subject of rape, a significant high proportion of subjects rejected outrightly the sexual abuse of children. Only two of the subjects felt rape was the victim's fault and brought on herself either by poor dress code or poor sitting. Those subjects who rejected the sexual abuse of school girls advocated very serious punishments for the perpetrators.

A high proportion of the subjects (77%) were aware of the use of the genetic fingerprinting technology to convict rapists. An equally high proportion (66%) of the subjects were generally aware of how the genetic fingerprinting technology works. The study therefore showed that there was a high level of awareness of the application of genetic knowledge in the subjects communities in order to solve crime.

CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

6.1 INTRODUCTION

The study investigated student teachers knowledge and understanding of genetic concepts. The researcher explored the nature of difficulties students have in solving genetics problems as well whether there were alternative frameworks or misconceptions or not. In pursuance of the study a diagnostic tool was developed to test the student teachers' conceptions of basic genetics. Obtaining valid data about the subjects conceptions of genetics would depend on the availability of a suitable diagnostic test. In addition the researcher investigated student teachers' opinions on the rape of school girls by male teachers. Secondly the researcher sought to find out the level of awareness by student teachers of the technology available to assist in the apprehension of rapists. The last investigation became desirable because South Africa has experienced a wave of sexual abuse of toddlers, school children and women in general. It was therefore necessary to engage students in thinking about this social problem and the role they can play as future teachers to address it.

The study was organised as follows:

In chapter one the relevant hypotheses, questions, aims of the study and definitions of terms were presented. Chapter two dealt with the theoretical framework of the study while chapter three dealt with the status of the teaching of genetics in South Africa and other countries. Chapter four dealt with the research design and included the development of the research instruments, their test and validation and procedures for the analysis of data. Chapter five dealt with the analysis and interpretation of results. Chapter six reviews the study and provides the summary of the findings. It also draws conclusions, examines the implications of the research.

6.2 STATEMENT OF THE PROBLEM AND AIMS OF THE STUDY

Teachers have to be confident and sure of their subject content if they are to teach effectively. By identifying student teachers' difficulties as well as misconceptions, the researcher hoped she would be better informed about how to prepare student teachers. Some topics in biology have been identified as difficult for students because of their abstract nature. One of such topics is genetics. To teach genetics effectively it is expected that the teacher is well knowledgeable of the concepts involved apart from knowledge of the content itself.

The research comes at a time when instructors are encouraged to study their own classrooms to facilitate changes and to introduce ideas that will enhance learning. The crucial question that emerges is whether students in many black schools, where the failure rates are the highest, are taught for conceptual understanding of the discipline or mere rote learning. Grade twelve examinations results have been very poor for two consecutive years, that is, 1997 and 1998. The nation at large, notably the African population, is grappling with the problem of students who seem not to be able to master concepts in their various subjects. These problems in education call for new strategies that will start addressing learning problems in order to enhance the development of conceptual understanding of what students learn at every level.

The study had three main aims:

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- 1. To examine the quality of the content knowledge and the conceptual understanding of genetics held by student teachers.
- 2. To determine if student teachers have misconceptions of some genetic concepts.
- 3. To develop a diagnostic tool for monitoring the development of genetics concepts and problem-solving skills among student teachers.
 - To examine student teachers' level of awareness of genetic fingerprinting technology and their opinions on the rape of school girls by male teachers.

6.3 LITERATURE AND THEORETICAL ISSUES

A summary of the most pertinent issues that emerged from the research are presented below. They are, however, not presented in the order of importance.

The first issue concerned the understanding of genetics by subjects. Biology instructors seemed to be in agreement that genetics as a topic contains concepts that are abstract and very difficult to learn (Longden 1982, Martius and Walker 1992, Moletsane and Sanders, 1995). Besides understanding concepts, student teachers also have to understand the precise technical genetic terminology. It is therefore necessary for teachers to make good diagnostic tests which they can use to monitor proper development of concepts. Students should also be encouraged to describe their answers qualitatively so that instructors can gauge the quality of their understanding.

The second issue covered the nature of learning. Science educators agree that learning by rote does not lead to the ability to apply that knowledge in new situations to solve problems (Smith, Blakeslee and Anderson, 1993). Meaningful learning was emphasized because it leads to conceptual understanding of the subject matter. Hiebert and Lefevre (1990) describe conceptual knowledge as characterized by rich relationships. New knowledge is linked and integrated to prior knowledge. The important idea in the emphasis of meaningful learning and the development of rich links between prior and new information was that it leads to better encoded information that is accessible for solving problems.

A lot was said about problem-solving and its usefulness in addressing day to day problems and not only genetic problems. Although the research sought to investigate the student teachers' ability to solve simple genetic problems, it was also noted that learning problemsolving skills in one domain could help subjects develop logical problem-solving skills for their real life-problems (Rossouw 1994). Matlin (1983) suggested that people can improve their problem solving performance by training. Training could include teaching heuristic methods and providing appropriate opportunities for students to solve problems. One of the other issues regarded as impacting on the education of African student teachers was language. Students who learn biology in a foreign language exhibit difficulty in putting their ideas on paper clearly and succinctly. Biology also has its own unique terminology, consisting of long words that are difficult both to spell and verbalise. The struggle to learn biology in English is therefore a very tough one for students for whom English is a second language. Driver (1989) highlighted the difficulties of language by stating that science has its own language and sub-culture to which students must be introduced and helped to assimilate.

Science concepts were described as complex and it was noted that a considerable number of subjects had developed erroneous ideas about genetics as they progressed through their learning. These erroneous ideas were termed misconceptions. Different biology authors have confirmed that genetics as a topic gave students difficulties. Also, they do not seem to have developed the necessary problem-solving skills needed in conceptualising genetics. The principle of learning and teaching for understanding and problem-solving has been highlighted by a number of authors. For example, Meyer (1992) states that testing for problem-solving abilities has become a central issue in education. It was also suggested that problem-solving can be taught and that like any other skill, practice makes perfect.

The role of culture in learning was highlighted. Learners bring to the classroom their own world views which may affect the learning of biology, particularly if traditional beliefs clash with biology. Scientific knowledge as in biology education is defined in precise terms, while indigenous cultural knowledge is characterised by multiple meanings which are not defined but negotiated socially. The last item was the importance of looking at gender issues, particularly in terms of equal access to science education by both males and females. The need for constructing tests and using testing techniques that accurately reflect the abilities of both girls and boys wa highlighted.

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6.4 SUMMARY OF FINDINGS

The following is a summary of the findings of this study.

The overall performance of the subjects on probes one to six was very poor indicating a lack of competency in the areas of genetics tested for by these probes. Only 36% of the subjects showed an acceptable proficiency level in the knowledge and skills tested for by the theory test.

Subjects gave a better performance in probes that tested for knowledge as in probe one. Knowledge of the meiotic process in probe 3 was demonstrated to a sufficiently high standard by subjects. The subjects showed extreme difficulty in displaying competency in knowledge and understanding of probes 2,4,5 and 6 which dealt with higher order questions. The probes tested knowledge, understanding and problem-solving skills of subjects.

The subjects displayed a very high proficiency level in the knowledge of heuristics for solving genetic problems. However, the knowledge of genetics heuristics did not translate into abilities to solve genetic problems by the subjects. There was a very low positive correlation between knowing heuristics and the ability to solve genetic problems. No significant positive correlation between knowing genetics heuristics genetics and the subjects' ability to solve genetic problems was found.

There was a significant positive correlation between the subject's knowledge and understanding of meiosis and an ability to find a solution of a genetic problem. The understanding of meioses was found to be critical in the successful solution of genetics problems.

There were no significant differences between male and female subjects' achievement scores with respect to the selected concepts tested for in the theory and practical.

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Both the theory and practical tests revealed that subjects had misconceptions with reference to understanding certain aspects of genetics topics.

- The majority of the subjects condemned outrightly, the sexual harassment of school girls. Various forms of punishment were advocated for teachers who rape school children.
- Subjects who discussed their genetics heuristics in English finally gave a more coherent and logical presentation than those who first discussed these in Zulu followed by a translation. Those subjects who translated their responses tended to give a direct translation which did not always accurately convey what they meant.

The subjects involved in the study viewed rape as:

- i. violating human rights of another person
- ii. a traumatic experience for the victim,
- iii. an act that has stigma attached to it for the victim
- A high percentage of subjects (77%) were found to be aware of genetic fingerprinting technology. An equally high percentage (66%) was aware of how genetic fingerprinting works. The study therefore showed that there was a high level of awareness of the application of genetic knowledge by the subjects.

6.5 **CONCLUSIONS**

Some of the conclusions that were drawn from the study include the following:

The number of courses in genetics as a subject taken at university level does not necessarily have an impact on the quality of understanding shown by the subject. Misconceptions and difficulties in solving genetic problems existed in all candidates irrespective of the number of genetics courses they had taken. Language was found to be one factor that impacted negatively on the understanding of genetic concepts by the subjects in this study. Instances of poor interpretation of simple instructions in the practical test and grammatically incorrect sentences suggested problems of communication and the inability to understand and express ideas correctly. The language difficulties subjects exhibited seem to support Ogunniyi's (1997) contention that the language of examinations in Science, among other subjects, is well above the linguistic competence of learners who use English as a second language. The subjects of this research had to contend with two foreign languages, that is, English as a medium of instruction and the unique and specific language of science. The researcher therefore highlighted the need to address the problems associated with the use of English as a second language, and also to think of innovative ways of teaching biology to them so that students understand it.

The subjects in the research showed better competence on probes that tested lower cognitive abilities like knowledge. However, probes which required the subjects to engage in higher cognitive levels of thinking, presented them with difficulties. Some of the difficulties of higher cognitive thinking manifested themselves in a failure to apply previous knowledge in solving basic genetic problems, such as calculation of phenotypes and genotypes, explaining phenomena and applying data from the problem to Mendel's Law of Segregation. Failure to solve problems and to apply knowledge by some subjects suggested that the subjects may have been subjected to rote learning in their studies. Some of the subjects indicated that the kind of probes used in this research was a new experience for them. The subjects' comments probably alluded to a culture of rote learning instead of conceptualization. The subjects' achievement scores did not seem to be affected by the subject's sex. Achievement in both the theory and practical were not significantly different.

Mastery of procedural knowledge (heuristics) does not automatically translate into an ability to solve genetics problems. The reasons for this situation could be related to the fact that genetics has a lot of abstract concepts that a student must understand before he/she tackles a problem. Hiebert and Lefevre (1990) contend that heuristics that are memorised cannot be activated during problem solving. Brown (1990) identified two

Mastery of procedural knowledge (heuristics) does not automatically translate into an ability to solve genetics problems. The reasons for this situation could be related to the fact that genetics has a lot of abstract concepts that a student must understand before he/she tackles a problem. Hiebert and Lefevre (1990) contend that heuristics that are memorised cannot be activated during problem solving. Brown (1990) identified two knowledge requirements for problem-solving, the first one is procedural knowledge which informs decisions to employ certain steps and reject others in solving a problem. The second one is conceptual knowledge of the topic, for instance, genetics. Deficient conceptual knowledge will obviously show in flawed procedural sequence.

Cooperative groups seemed to have produced higher standard of competence level compared to the tasks where subjects were working individually. One is tempted to say that cooperative learning has a positive effect of helping learners remember what they have learned. Miller (1987) states that during cooperative learning, learners facilitate each other's learning, help each other to remember the task rules and goals better than would have been possible when working alone.

While the majority of subjects condemn teachers who rape school girls, there were a few individuals who thought girls invite rape by their style of dressing or the way they sit in class. Therefore there is still a need to educate men in particular about human rights with reference to women.

During the registration period subjects had been asked to fill in their registration form appendix (12) whether they liked genetics or not and why. All the subjects gave an intrinsic reason for liking genetics. None of the subjects referred to the usefulness of genetics technology. These responses initially gave the impression that subjects were not aware of the use of genetic engineering for therapeutic purposes and for solving crime. The results of the research, however, indicated that the subjects were aware of the genetic fingerprinting technology.

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The use of diagnostic tools by lecturers is to be encouraged because it exposes students misconceptions and opens opportunities for more focussed teaching also, by marking students work against criteria, students can become better informed about how well they have performed and therefore better at evaluating their own work and progress.

There is need to discuss sexuality in schools, particularly because of the sexual violence noted by both teachers and the public to female students. It seems the time has come that the "evaded curriculum" be put in the fore, because students need to know their rights as far as sexuality and gender issues are concerned. There is also a need for formal education on human rights so that the culture of respect of the next person is upheld.

The method of Biology lecturers in the Faculty of Education at the University of Zululand cannot assume that student teachers who follow the Teachers' Diploma Programme after two years in the Faculty of Science are competent in all the content they have learned. There is a need to help student teachers to master concepts that have already been identified as giving both student teachers and practising teachers difficulty.

Teaching and learning for the subjects in the research took place through a language which was not their first language. This not only placed the subjects at a disadvantage but may have also led to linguistic difficulties which contributed to poor learning of concepts hence the discovery of misconceptions among the subjects. However, misconceptions are not only found in students who are taught in their second language; they are universal. One can imagine, however, that if one is not proficient in the language in which one is taught, one is likely to develop misconceptions arising from poor interpretation of the foreign language. Poor language facility also meant that even if the student knew the answer, the quality of presentation was limited by poor mastery of the language. The tertiary institutions which have a population of students for whom English is a second language need support services to facilitate mastery of the English language by such students. This study has important implications in the training of student teachers. First, there is a need to make them aware of the existence of misconceptions or alternative frameworks among students. Didactics methods instructors need to train student teachers in how to develop diagnostic tests, because without them, it is impossible to diagnose learning difficulties. Secondly, there is a need for a shift from rote learning to problem-based teaching and learning, which will equip students with thinking and problem-solving skills for survival in a technological world. Thirdly, there is a need to use teaching strategies that stimulate both males and females to learn science equally, by using co-operative methods of learning and by making sure that the books and examples used in classes are not gender-biased to the disadvantage of any of the students.

Some of the subjects in this study did not seem to recognise hybridization, which one would have expected to be a familiar concept to agriculture students. Nineteen of the twenty five students had agriculture as their second major. The researcher had hoped that this concept would be familiar in the sense that African families have practised methods of improving their live stock and hunting dogs in particular. That the subjects had a problem linking genetics terminology to their everyday lives suggests that science is learned in a cultural vacuum in their institutions. There is a need to develop materials that relate to the African experience and to draw examples from for the subjects' cultures where possible. Writing on why females do not feature prominently in science (Bryne 1993) contends that they have a negative attitude to science because of its impersonal and abstract nature and the lack of relationship to real human problems.

Other researchers (Ogunniyi 1998, Sifuna 1992, Lubben, Campbell and Dlamini 1996) have called for the development of curricula with greater relevance to Africa. This could be done in terms of comparing technology appropriate to Africa and by comparing the African and the scientific world views. In medical circles, for instance, there is now a realisation that some of the herbs used by herbalists have scientific basis. There is therefore a definite call for education across all levels that is relevant to the needs of Africa. The idea of contexualizing science curricula has therefore arisen from the need to link science to everyday life or to experiences that students have had or are likely to master problem-solving skills.

6.7 **RECOMMENDATIONS**

On the basis of the findings of this study, the following recommendations on the teaching and learning of genetics at tertiary levels and high schools are proposed:

Practical work in genetics should emphasize learning of concepts and development of thinking skills. It should not be a ritual in which students follow routine instruction and are not required to think. Practical work must be structured in such a way that it offers challenges and problems that students are supposed to solve during the practical activity.

Cooperative learning groups should be encouraged because they seem to produce better results than when students are working alone. A pair or more of students working towards a common goal possess a larger repertoire of cognitive and social problem-solving skills than one person. Negotiation of meaning during group work facilitates the development of language skills. Cooperative learning groups encourage peers to exchange views in order to refine thinking and deepen understanding. Negotiation of meaning during group work facilitates the development of language skills. Students for whom English is a second language should be encouraged to communicate in English, so as to get practice in speaking and writing in this language.

Lecturers at tertiary level as well as teachers in schools should ensure that questions that are used to test students are varied and test both low and higher cognitive level questions. Questions should not only indicate that they can be answered from using a memorised preplanned answer. Examinations should demand from students to exhibit qualities like critical thinking from tasks that require students to use logic and reasoning.

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REFERENCES

Abagi, O. & Wamahiu, S. (1995) Household Based Factors and School Participation of Girls: Lessons From the Existing Surveys. Nairobi: Academy Science Publishers.

Abruscato, A. (1982) Teaching Children Science. New Jersey : Prentice Hall.

- Addo, C. B. (1997) Teacher Attitudes Manifestation of Traditional African Beliefs.
 pp 23-27. Southern African Association for Research in Mathematics and Science
 Education Proceedings. Ed. Martie Sanders. University of the Witwatersrand, Fifth
 Annual Meeting, January 22-26 1997.
- Adey, P. and Shayer, M. (1994) Really Raising Standards: Cognitive Intervention and Academic Achievement. London and New York: Routledge.

Allen, A. (1996) 'Science and technology ailing, report bemoans'. The Star, 2nd October.

Amapadhu, G. (1999) A Policeman Rapes his 3 year Old Daughter: The Mail Guardian,
14th-18th February.

Anderson, J. R. (1990) Cognitive Psychology and its Implications (3rd ed.) New York: Freeman.

- Anderson, G.L., Herr, K. & Nihlen, A.S. (1994). Studying Your Own School. An Education's Guide to Qualitative Practitioner Research. California : Crown Press Inc. A Sage Publication.
- Andre, T. (1986) Problem Solving and Education. In physe G. D. and Andre, T. (eds.)
 Cognitive classroom learning : Understanding, thinking and problem solving (pp. 169-204). Orlando : Academic Press.

Anstey, G. (1997) 'Teachers send pupils on the road to nowhere'. The Star, 20th July.

- Arnaudin, M.W. & Mintzes, J.J. (1985). Students' Alternative Conception of the Human Circulatory System: A Cross age Study. Science Education, 69 pp. 721-733.
- Ausubel, D. P. (1968) Educational Psychology : A cognitive view. New York : Holt, Rinehart and Winston.
- Ausubel, D. P. (1979) The Facilitation of Meaningful Verbal Learning in the Classroom. Educational Psychology, 12, 162-178.
- Attar, D. (1990). Wasting Girls' Time. The History and Politics of Home Economics. Berkshire : Virago Press Limited.
- Avenant, P. J. (1986) Guidelines for successful teaching. Durban : Butterworth Publishers.

- Bajah, S. T. (1981). An Overview of Science Teaching and Learning Problems in Africa.
 A paper presented at the sixth intensive workshop on curriculum development in the Science. Curriculum Development Centre, Maseru, Lesotho, September 7-19 1981.
- Barber, S. (1996). Our Students finish Bottom of the Class in Maths and Science. Shock report on South African Schools. Own Correspondent. 24th November.
- Barnard, J. (1993). Pupils' Understanding of Mathematics. In Southern African
 Association for Research in Mathematic and Science Education Proceeding. Rhodes
 University, First Annual Meeting, January 28-31 993. (Ed) V.J. Reddy pp. 58-64.
- Beyer, B. & Charlton, R.R. (1986). Teaching Thinking Skills in Biology. The American Biology Teacher, 48 (4), pp. 207-212.

Becket, B. S. (1995) Biology : A Modern Introduction. London : Oxford University Press.

- Bickard, M.H. (1995). World-mirroring Versus World-Making: There's Gotta be a Better
 Way. Constructivism in Education. Edited by Leslie P. Steffe and Jerry Gale. Hillsdale,
 NJ: Lawrence Erlbaum.
- Biggs G. B. (1992) Modes of learning, forms of knowing, and ways of schooling. In A.
 Dematriqui M.Shayer and A. Efkildes. Neo-Piagetian Theories of Cognitive
 Development. Implications and applications for education. London: Routledge.

Biggs, J. B. & More P.J. (1993) Process of learning 3rd Ed. Sydney Prentice Hall.

- Bless, C. and Higson Smith, C. (1995) Fundamentals of Social Research Methods. An African Perspective. Cape Town : Juta and Company Ltd.
- Bloom, B.S. (1956) Taxonomy of Educational Objectives. Cognitive Doman. London : Longmans.
- Bogdan, R.C. and Biklein, S. K. (1982). Qualitative Research for Education : An Introduction to Theory and Methods. Boston : Massachusetts: Allyn and Bacon Inc.
- Borasi, R. (1996) Reconceiving Mathematics Instruction. New York : Alex Publishing Corporation.

Bransford, J. D. & Stein, B.S. (1984) The Ideal Problem Solver. New York : W.H. Freeman.

Brenner, S. (1990). 'The Human Genome : The Nature of the Enterprise'. pp. 6-17 In Human Genetic Information: Science Law and Ethics. Chichester: London Wiley Interscience Publications. Ciba Foundation Symposium 149.

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Broadfoot, P. (1987). Introducing Profiling. A Practical Manual. London : Macmillan Education.

- Brown, R. (1994) A Level Students : Their Problems with Gene an Allele. Journal of Biological Education, 1994, 28 (2).
- Brown, C.R. (1990). Some Misconceptions in Meiosis Shown by Students Responding to an Advanced Level Practical Examination in Biology. Journal of Biological Education, 24 (3), pp.182-186.
- Browning, M. E. and Lehman, J. D. (1988). Identification of Student Misconceptions in Genetics. Problem Solving via Computer Programs: Journal of Research in Science Teaching, 25 (9), pp. 747-761.

Bulter, I. (1992). *Questioning Practical English in Venda* Matlhasedi Vol. No.1 Education and Development Forum for and from the Rural Periphery.

Bruner, J.S. (1961) The Act of Discovery. Harvard Educational Review, 31, 21-32.

- Bruner, J. S. (1966) Toward a Theory of Instruction Cambridge: Massachisetss. The Belknap Press of Harvard University Press.
- Burgess, R.G. (1989). Grey Areas: Ethical Dilemmas in Educational Ethnography. In The Ethics of Educational Research. Ed. R. G. Burgess. pp. 60-76. London: The Falmer Press.

Byrne, M. (1993). Women and Science: The Snark Syndrome. London: The Falmer Press.

- Catsambis, S. (1995). Gender, Race, Ethnicity and Science Education in the Middle Grades. Journal of Research in Science Teaching, 32 (3), pp. 243-257.
- Chick, J. K. (1972) Language Policy in Education. In McGregor, R. And McGregor, A. (Eds) Education alternatives Cape Town : Juta and Company Ltd.
- Chiras, D. D. (1992). Teaching Critical Thinking Skills in the Biology and Environmental Science Classrooms. American Biology Teacher, 54 (8), pp. 464-469.
- Clough, M. P. and Wood-Robinson, C. (1985). Children's Understanding of Inheritance. Journal of Biological Education, 1985 19 (4).
- Clough, M. P. and Clark, R. L. (1994). The Constructivist Model Forces Students to be Actively Engaged in Learning. The Science Teacher, October, pp. 46-47.

Cohen, L. and Manion, L. (1994). Research Methods in Education. London: Routledge.

Cole, N.S. (1990) Conceptions of Educational Achievement. Educational Research. 19(3) pp 2-7.

Cooke, A. (1997) 'Many Mathematics Science Teachers Unqualified'. The Star 16th July.

Cooke, J.M. and Walbsser, H.H. (1972) Constuctive Behavioural Objectes Book 1. College Park. Maryland : Maryland Book Exhange. Corbin, J. & Strauss, A. (1990). Basics of Qualitative Research: Grounded Theory Procedure and Techniques. Newbury Park: Sage.

Curriculum 2005. (1997) Lifelong Learning for the 21st Century. Issued by the National Department of Education.

Deem, R. (1978). Women and School. London: Routledge and Kegan Paul.

- Dekker, E. I. and Lemmer, E. M. (1993). Critical Issues in Modern Education. Johannesburg: Heinemann.
- De Landsheere (1990) Taxonomies of Educational Objective. In Walberg, H.J. and Haertel, G. D. (eds.) International Encyclopaedia of Educational Evaluation. Oxford : Pergamon Press.
- Denzin, N. K. (1978). Sociological Methods. A Source Book. New York: McGraw-Hill Book Company.
- Deutch, C. E. (1995) Teaching the Principals that Govern the Structure and Function of Biomolecules. In the American Biology Teacher, 57 (2).
- Dorit, R. L., Walker, W. F. Jr. and Barnes, R. D. (1991): Zoology. International Edition. Toronto: Sanders College Publishing.

Driver, R. (1989). The Construction of Scientific Knowledge in School Classrooms. In Millar

R. (ed). Doing Science! Images of Science in Science Education. Lewes: Falmer Press.

- Driver, R. (1989). The Construction of Scientific Knowledge in School Classrooms. In Millar, R. (Ed) 1989 Doing Science: Images of Science in Science Education. Lewes: Falmer Press.
- Duschl, R.A., and Gitomer (1991). Epistemological Perspectives on Conceptual Change. Implications for Education Practice. Journal of Research in Science Teaching, 28 (9), pp.839-858.
- Eisemon, T. O. (1990) Examinations Policies to Strengthen Primary Schooling in African Countries. International Journal of Educational Development. Vol 10 No. 1. pp. 69-82.
- Elzey, F. F. (1987) Introductory Statistics : A Microcomputer Approach. Monterey, CA: Brooks/Cole Publishing Company.
- Ennis, R. 998) Critical Thinking : A Streamlined Conception. In Lang C. (ed) Teaching Philosophy, 14, 5-224.
- Entwistle, N. J. and Treagust, D. F. (1994). Teachers' Thought About Changing to Constructivist Teaching/Learning Approaches within Junior Secondary Science Classroom. Journal of Education for Teaching, 20 (1).

- Faw, H.W. and Waller, T.G. (1976) Mathemagenic Behaviours and Efficiency in Learning from Prose Materials: Review Critique and Recommendations. Review of Educational Research, 46, 691-720.
- Ferguson Hessler, M. G. M., and T. de Jong (1993). Does Physics Instruction Foster
 University Students Cognitive Processes? A Descriptive Study of Teacher Activities.
 Journal of Research in Science Teaching, 30 (7), pp. 681-696.
- Fisher, K.M. (1985). A Misconception in Biology Amino Acids and Translation. Journal of Research in Science Teaching, 22, pp. 62-63

Fisher, R. (1995). Teaching Children to Think. Cheltenham: Stanley Thornes Publishers Ltd.

Fisher, R. (1995) Teaching Children to Learn. London: Stanley Thornes Publishers Ltd.

÷ 4.

Fitz-Gibbon, C.T. (1996). Monitoring Education Indicators, Quality and Effectiveness. London: Cassell.

Flavell, J. (1963) The Developmental Psychology of Jean Piaget. Princeton. NJ: Van Nostrand.

Frederick, R. and Larkin, J.H. (1991). Cognition in Scientific and Everybody Domains.
Comparison and Learning Implications. Journal of Research in Science Education, 28 (9), pp. 733-760.

Gelmans, R. (1979) Preschool Thought. American Psychologist 34. pp 900-905.

- Ginsberg, H. and Opper, S. (1987) Piaget's Theory of Cognitive Development. Englewood Cliffs : Prentice Hall.
- Gitlin, A., Bringhurst, K., Burns, M., Cooley, V., Myers, B., Price, K., Russell, R. and Tiess, P.
 (1992). Teachers' Voices for School Change: An Introduction to Educative Research. London: Routledge.
- Glaser, B.G. and Strauss, A.L. (1967). The Discovery of Grounded Theory. Strategies for Qualitative Research. New York: Aldine Publishing Company.
- Gouws, E. (1997). Entrepreneurship Education : An Educational Perspective. South African Journal of Education, 17 (3).

162

- Gredler, E. (1997). Entrepreneurship education : An Educational Perspective. In South African Journal of Education 1997, 17 (3).
- Gredler, M.E. (1992). Learning and Instruction: Theory into Practice. 2nd ed. New York: Macmillan Publishing Company.

الي الم الم المراجع الم المنظم المراجع المراجع الم المراجع المراجع المراجع المراجع المراجع المراجع المراجع الم المسابقة إلى المراجع ال

Guba, E.G. and Lincoln, Y.S. (1996) What is a Constructivist Paradigm? In Anderson, D.S. and Biddle, B.J. (eds) knowledge for policy : improving education through research. London: Falmer Press. Gultig, J. (1995). A New Vision For Teacher Education. An address for the inaugural conference of KwaZulu Natal Organisation of Teacher Educators (KNOTE). Natal College Of Education, 28 March.

Hamilton, R. and Ghatala, E. (1994). Learning and Instruction. New York: McGraw-Hill Inc.

Harding, J. (1978). Sex Differences in Performance in Science Examinations. In: Deem R.(Ed) Schooling for Women's Work. London: Routledge and Kegan Paul.

Hayward, G. (1991). Applied Genetics. London: Thomas Nelson and Sons Limited.

Heigenhahn, B.R. and Olson, M.H. (1993) An Introduction to Theories of Learning. 4th ed. New Jersey. Prentice Hall International.

Hein, G. (1991). Assessment for Active Science. In Expanding Student Assessment. Ed. V. Perrone.

- Helmke, A. and Schrader, F.W. (1995). Diagnostic Prescriptive Teaching. International Encyclopaedia. Teaching and Teacher Education (Ed.) Anderson N.W. Cambridge:
 Pergamon Press.
- Henning, E. and Fourie, E. (1997). Community and School : Learning Beyond the Curriculum. South African Journal of Education, 17 (3) pp. 16-124.

Hermang, L.; Morris, L.L. and Taylor Fitz-Gibbon, C. (1987) Evaluation's Handbook. London.

- Hiebert, J. and Lefevre, P. (1986) Conceptual and Procedural Knowledge : The Case of Mathematics. Hillsdale, N.J. Lawrence Erlbaum Associates Inc. Publishers.
- Hilderbrand, C. E., Torney, D. C. and Wagner, R. P. (1994) What is the Genome Project?. In Coooper G.N. . The Human Genome Project : Deciphering the Blueprint of Heredity.
- Holt, D., Chips, B., and Wallace, D. (1992) Cooperative Learning in the Secondary School: Maximizing Language Acquisition, Academic Achievement and social Development.
 Washington, D.C. : National Clearinghouse for Billingual Education.
- Horn, I. (1997:215) Learning, Knowledge and Mental Frameworks : The Role of Constructivism in Education. J. Van Der Vyver (Ed). In Transforming Education.
 Southern African Experiences Volume 1. South Africa Frontline Graphics and Printing.
- Ifelluni, I.C.S. (1997). School and Home Factors as Correlates of Academic Achievement of Nigerian Female Teenagers In Mathematics. Kenya: Academic Science Publishers.
- Isaac, T. (1993). The Influence of the Senior Certificate Examination on Method of Teaching Biology at Standard Ten Level in Indian Secondary Schools, pp. 135-139.
 In Southern African Association for Research in Mathematics and Science Education Proceedings. First Annual Meeting, Rhodes University, January 28-31 1993. Ed. V. Reddy.

- Jansen, J. (1997). Why OBE will Fail. A paper presented at a workshop at the University of Zululand.
- Jegede, O. J. (1995) Collateral Learning and the Eco-cultural Paradigm in Science and Mathematics Education in Africa. Studies in Science Education 25 : 97-137.
- Johnstone, A. (1988) The Demands of Practical Work. Department of Chemistry. University of Glasgon, Glasgon, Scotland.
- Johnson, W. D.; Johnson, R.T. and Smith, K. A. (1991) Increasing Collage Faculty Instructional Productivity. Eric Higher Education Report No. 4. The George Washington University.
- Jones, R.N. and Richards G.K. (1991). Practical Genetics. Philadelphia: Open University Press.

Kagan, J. (1971) Change and Continuity in Infancy. New York : Wiley.

Kamwangumulu, N.M. (1996). The Language Clause in the New Constitution Implications for Mother Tongue Tuition. Bulletin. New for the Human Science, 3 (5).

Kaplan, G. (1992). Contemporary Western European Feminism. London: Allen and Uniwin.

Keller, E.F. (1997). Women Scientists and Feminist Critics of Science. Daedalus Journal of the American Academy of Arts and Science, 116, pp.77-91.

Kelly, G.A.(1955). The Psychology of Personal Constructs. New York : W.W. Norton and Co.

Kelly, A. (1988). Action Research: What is it and What Can it Do? In Issues in Education Research . Qualitative Method Ed. Burgest R.G. London: Falmer.

Kelly, G.A. (1995) The Psychology of Personal Constructs. New York : W.W. Norton and Co.

- Kimura, R. (1988). Religious Aspects of Human Genetic Information. National Research Council 1988 Committee on Mapping and Sequencing the Human Genome. Washington D.C.: National Academy Press.
- Kinderfield, C.H. (1994). Assessing Understanding of Biology Process. Elucidating Students Models of Meiosis. The American Biology Teacher, 56 (6), pp. 367-371.
- Knott, M. and Maatunga, P. (1995) Methods of Teaching and Learning. In Matira, B.
 Muwangi, A., and Schlette, R. (eds) Teach your Best : A Handbook for University
 Lecturers. Naurobi: German Foundation International Development.
- Krulik, S. and Rudnick, J.A. (1995) The New Source-book for Teaching Reasoning and Problem Solving in Elementary School. London : Allyn & Bacon.

- Kudlas, J.M. (1994). What You Should Know About Outcome-Based Education. The Science Teacher, 6 (5) pp. 32-35.
- Lavoie, D. R. (1993). The Development, Theory and Application of a Cognitive Network Model of Prediction Problem Solving in Biology. Journal of Research in Science Teaching, 30 (7) pp. 767-785.
- Law, B. (1988). Uses and Abuses of Profiling. London: Paul Chapman Publishing Limited.
- Lawrenz, F. and Gray, B. (1995). Investigation of World-view Theory in a South African Context. Journal of Research in Science Teaching, 32 (6), 555-568.
- Lawson, A.E., Baku, W.P.; DiDonato, L. and Verdi, M.P. (1993). The Role of Hypothetic -Deductive Reasoning and Physical Analogous of Molecular Interactions in Conceptual Change. Journal of Research in Science Teaching, 30 (9), pp.1073 - 1085.
- Lang, C. (1997) Teach Employees How to Think. In L. de Lange. Business Gutelligence. 25th November. pp. 45.
- Lemmer, E.M. (1993) Gender Issue in Education. In Dekker E.I. and Lemmer E.M. (Eds) Critical issues in Modern Education. Butterworth : Heinemann.
- Levin, T. L., Sabar, N. and Libman, Z. (1991). Attitudinal Patterns of Boys and Girls in Science. Journal of Research in Science Teaching, 28 (4) 315-328.

- Lewin, K. (1997) Theoretical and Practical Aspects of Item Construction for Primary Science Subjects. Bude, V. and Lewin, K. (eds) Vol 2. Assessment of Science and Agriculture in Primary Schools in Africa; 12 Country Cases Reviewed. Education, Science and Documentation Centre : Bonm.
- Longden, B. (1982). Genetics are there Inherent Learning Difficulties? Journal of Biological Education, 16 (2), pp. 135-140.
- Lubben, F., Campbell B., and Dlamini, B. (1996). Contexualizing Science Teaching in Swaziland: Some Student Reactions. International Journal of Science Education, 10 (1), pp.1-9.
- Mackenzie, L. (1992). On our Feet. Taking Steps to Challenge Women's Oppression. University of Western Cape: For the Centre for Adult and Continuing Education.

د. این استان میرود استان از میرود استا استان استان میرود استان از میرود استان میرود استان میرود استان میرود استان میرود استان میرود استان میرود استان

ي الاية المنتخذ المنتخذ المنتخذ المنتخ

- Macnab, W. and Hausell, M.H. and Johnstone, A. Y. (1993). Journal of Biological Education. 1993, 2 (27), pp. 135-139.
- Magi, N.V. (1993). Biosocial Issues as a Component of Biology Education. Unpublished Dissertation.

Makau, B. (1997). Measuring and Analyzing Gender Differences in Achievement in Primary and Secondary Education. Nairobi: Academy and Science Publishers.

- Makhubu, L.P. (1997) Africa's Research Priorities in Science and Technology. A key note address delivered at the workshop on the "Formation of Research Networks Among Women. Scientists in Southern Africa". Swaziland, January 27-29 1997.
- Mammen, K. J. (1996) Diagnostic Tools in the Classroom. Bulletin, News for the Human Sciences, 3 (5), pp. 10.
- Martius, T. and Walker, J. O. (1992). A Paper and Pencil Strategy for Teaching Mitosis and Meiosis. Diagnosing Learning Problems and Predicting Examination Performance. The American Biology Teacher, 54 (8).

Matlin, M. (1983) "Cognition". New York : CBS College Publishing Company.

- Mayer, R. E. (1979) Can Adance Organizers Influence Meaningful Learning? Review of Educational Research, 49, 371-383.
- McNamara, D. (1990) Research on Teacher's Thinking: Its Contribution to Educating Student Teachers to Think Critically. Journal of Education for Teaching, pp. 147-160.
- Merriam, S. B. (1988) Case Study Research in Education. A Qualitative Approach. London: Jossey-Bass Publishers.
- Meyer, D.K. (1993) Recognizing and Changing Students' Misconceptions. An Instructional Perspective in College Education Teaching, pp. 104-107.

Miller, M. (1987) Argumentation and Cognition. In Hickman, M. (ed) Social Changes and Functional Approach to Language and Thought pp. 225-249. San Diego : Academic.

Moletsane, G. and Sanders, M. (1995). Erroneous Ideas Held by First-Year University Students About Chromosomes and Related Concepts. Biology Proceedings of the 16th National Convention of the Federation of Natural Science and Mathematics Education Association of South Africa, pp. 45-58.

Moll, B. and Allen, R.D. (1987). Students Difficulties With Mendelian Genetics. The American Biology Teacher, 49 (40).

Moll, L. C., and Diaz, C. (1987) Change as the Goal of Education Research. Anthropology and Education Quarterly 18(4) : 370-371).

Monjan, V.S. and Gassner, M.S. (1979). Critical Issues in Competency Based Education. Toronto: Pergamon Press.

Mouton, J. and Marais, H.C. (1990). Basic Concepts in the Methodology of the Social Sciences. Pretoria: Human Research Council.

Mullholland, S. (1997). 'New education system will produce confident illiterates.' In The Sunday Times, 8th June.

Namuddu, K. (1997). Female Education In Mathematics and Science In Africa (FEMSA).

Nairobi: Academy of Science Publishers.

- Newell, A. and Simon, H.A. (1972) Human Problem Solving. Englewood Cliffs, NJ : Prentice Hall.
- Novak, J. D. (1988) Learning signs and the signs of learning. Studies in science education. 15,77-101.
- Nunan, D. and Lamb, C. (1996) The Self-Directed Teacher: Managing the Learning Process. Cambridge: Cambridge University Press.
- Odom, A. and Barron, L.H. (1995) Development of a Two-Tier Diagnostic Test Measuring College Biology Students' Understanding of Diffusion and Osmosis After a Course of Instruction. Journal of Research in Science Teaching, 32 (1), pp. 45-61.

Ogunniyi, M. B. (1997). Multiculturalism and Science Education Research in the New South Africa. In Proceedings for Southern African Association for Research in Mathematics and Science Education. University of Witwatersrand, Fifth Annual Meeting, 22-26 January 1997.

- Ogunniyi, M.B., Jegede, O.J. Ogawa, M., Yandile, D. and Oladele, F.K. (1995). Nature of World View Presuppositions Among Science Teachers in Botswana. Indonesia, Japan, Nigeria and the Philippines. Journal of Research in Science Teaching, 32 (8), pp. 817-831.
- Osborne, R.J. and Freyberg, P.F. (1985) Learning in Science. The Implications of Children's Science Auckland : Heinemann.
- Pashley, M. (1994). 'A' Level Students : Their Problems with Gene and Allele. Journal of Biological Education, pp. 120-126.
- Patton, M. Q. (1990). Qualitative Evaluation and Research Methods. 2nd Edition. California: Sage Publication Inc.
- Pearson, J. T. and Hughes W.J. (1988). Problems with the use of Terminology in Genetics Education: A Literature Review and Classification Scheme. Journal of Biological Education, 22 (3) pp. 178-182.
- Peek, N. and Mokgokon, M. (1986) Science Teacher Improvement Programme. Genetics workshop material.

Piaget, J. (1998) Success and Understanding. Cambridge, M.A. Harvard University Press.

Piaget, J. (1973) The Psychology of Intelligence Totown. N. J. : Little field and Adams.

- Popham, W. J. (1990) A Twenty-year Perspective on Educational Objectives. In Walberg,
 H.J. and Haertel, G.D. (eds) International Encyclopaedia of Educational Evaluation.
 Oxford ; Pergamon Press.
- Proper, H., Windeen, M.F., and Ivany, G. (1988). World View Projected by Science Teachers: A Study of Classroom Dialogue. Science Education, pp. 547-560.
- Radford, A. and Baumberg, S. (1987). A Glossary of Terms for Genetics. Journal of Biological Education, 21 (2).
- Radford, A. and Bird-Stewart, J.A. (1982). Teaching Genetics in School. Journal of Biological Education, 16 (3), pp.177-180.
- Ramorogo, G.J. (1998) Effects of examplary teaching and learning materials of student's performance in biology. A dissertation submitted to the school of mathematics and science education of the UniversIty of the Western Cape.
- Raynor, C. (1995). Soweto Pupils' Access to Museums. In the Southern African Association for Research in Mathematics and Science Education Newsletter.
- Reddy, V. (1995). The Promotion of Equity in Science and Technology Education. A Paper presented at the African Science and Technology Education Conference (ASTE) in the University of Durban-Westville.
Reinhard, B. (1997). How Does the Medium of Instruction Affect. The Learning of

Chemistry? Experiences in a Malawian Secondary School. Southern African Association for Research in Mathematics and Science Education Proceedings (Ed.) M. Sanders. University of the Witwatersrand, Fifth Annual Meeting, January 22-26 1997.pp. 54-57.

Rosser, S. (1990). Female Friendly Science. New York: Pergamon.

- Roth, W.M. (1993). Heisenberg Uncertainty Principle and Interpretive Research in Science Education. Journal of Research in Science Teaching, 30 (7), pp. 667-680.
- Russell, T. (1993). Constructivist Research and Curriculum Development in Primary Science Education. Practice and Potential. pp. 39-53. In Southern African Association for Research in Mathematics and Science Education Proceedings. First Annual Meeting, Rhodes University, January 28-31 1993. Ed. Vijay Reddy.
- Russell, E. and Raubenheimer, D. (1995) Camp to Classroom Lessons about Gender for Interactive Learning. In Proceedings of the fifth Annual Meeting of the Southern African Association for Research on Mathematics Science Education.
- Rutherford, M. (1997) Teacher-Talk a Classroom Investigation. Southern African Association for Research in Mathematics and Science Education Proceedings. (Ed.) M. Sanders. University of the Witwatersrand, Fifth Annual Meeting, January 22-

- Sanders, M. (1993). Erroneous Ideas About Respiration. The Teacher Factor. Journal of Research in Science Teaching, 30 (8), pp. 919-934.
- Sanders, M. and Mokuku, T. (1994). How Valid is Face Validity? In M. Glencross (Ed), Proceedings of the Second Annual Meeting of the Southern African Association for Research in Science and Mathematics Education. pp. 479-489.
- Schnotz, W. and Ballstaedt, S. P. (1995) Comprehension: Teaching and Assessing.
 International Encyclopaedia of Teaching and Teacher Education. 2nd ed. (Ed.) Anderson
 L.W. Cambridge: University Press.
- Schott, G. (1996) Culture, Religion and Child Bearing in a Multiracial Society. A handbook for health professionals. Butterworth : Alix Henley. Oxford.
- Schunk, D. H. (1991) Learning Theories: An Educational Perspective. New York : MacMillan Publishing Company.
- Sequera, M., Leite, L., & Duarte, M. (1993). Portuguese Science Teachers' Education, Attitudes, and Practices Relative to the Issue of Alternative Conceptions. Journal of Research in Science Teaching, 30 (8), pp. 845-846.

Setati, M. (1997) Teaching and Learning Mathematics in a Second Language. Southern

African Association for Research in Mathematics and Science Education Proceedings. (Ed) M. Sanders. University of the Witwatersrand, Fifth Annual Meeting, January 22-26 1997. pp. 73-78.

- Shan, S.J. and Bailey, P. (1991). Multiple Factors: Classroom Mathematics for Equality and Justice. London: Trentham Books Limited.
- Shari, E. and Gauvain, M. (1992) Social and Cultural Influences on Collaborative
 Interactions. In G. Butterworth and P. Light (eds) Social Cognition. Studies of the
 development of understanding (pp 155-180) Chicago : University of Chicago Press.
- Sherman, R. R. and Webb, R. B. (1990). Qualitative Research in Education : Focus and methods. London: The Falmer Press.
- Shymansky, J.A., Wordworth, G., Norman, O. Dunkhose, J., Mathews, C. & Tang-Lui, C. (1993). A Study of Changes in Middle School Teachers' Understanding of Selected Ideas in Science as a Function of an In-Service Program Focusing on Student Preconceptions.

17. State (19. State (19. State)

Journal of Research in Science Teaching, 30 (7), pp. 737 - 755.

1. 1 + 5.

Sifuna, D.N. (1992). Diversifying the secondary school : The African experience.

International Review of Education, 38 (1), pp. 5-18.

Sirestarajah, K. (1997). Transformation Science Education - Southern African Experiences. In Transforming Education Southern African Experiences. Volume (Ed) Van Der Vyver E. Johannesburg: Southern African Society for Education.

- Sloat, B. (1990). Perspective on Women and Science. LSA Magazine. University of Michigan, 13, pp.13-17.
- Smith, M.V. (1988). Successful and Unsuccessful Problem Solving in Classical Genetic Pedigrees. Journal of Research in Science Teaching, 25 (6) pp. 411-430.
- Smith, E.L. and Sendelboach, N.B. (1982). The Programme, the Plans and the Activity of the Classroom : The Demands of Activity Based Science. In Innovation in the Science Curriculum Classroom Knowledge and Curriculum Change. London: Ed. J. Olson.
- Smith, E.L., Blakeslee, T.D., and Anderson C.W., (1993). Teaching Strategies Associated with Conceptual Change Learning in Science. Journal of Research in Science Teaching, 30 (2), pp. 111-126. London: John Wiley & Sons Inc.

Solomon, J. 91993) The Social Construction of Children's Scientific Knowledge. In Black,

B.J. and Lucas, A.M. In Children's Informal Ideas in Science. London : Sage Publications.

- Spady, W.G. (1993). Educational Leadership. Report compiled from edited transcripts of Dr Spady's presentations conducted in Canberra, Sydney, Melbourne and Brisbane.
- Spady, W.G. and Marshall, K.J. (1993). Beyond Traditional Outcomes-Based Education. Report compiled from edited transcripts of Dr. Spady's presentations conducted in Canberra, Sydney, Melbourne and Brisbane.
- Sprinthall, A.; and Sprinthall, R.C. (1990) Educational Psychology : A developmental approach. 5th. Ed. New York : McGraw-Hill.
- Sullins, E.S., Hernandez, C., Fuller C. and Tashiro, J.A. (1995). Predicting Who Will Major in a Science Discipline: Expectancy-value Theory as Part of Ecological Model for Studying Academic Communities. Journal of Research in Science Teaching, 32 (1), pp.99-119.
- Sund, R. and Trowbridge, L. (1973) Teaching Science by Inquiry in the Secondary School, 2nd ed. Columbus Ohio: Charles Merril Publishing Company.
- Suzuki, D.T., Griffiths, A.J.F., Miller, J.H., and Lewontin, R.C. (1989). An Introduction to Genetic Analysis 4th Edition. New York: W.H. Freeman and Company.

Stewart, J.H. (1982). Difficulties Experienced by High School Students when Learning

Basic Mendelian Genetics. The American Biology Teacher, 44 (2), pp. 80-89.

Stenhouse, L. (1963) A Cultural Approach to the Sociology of the Curriculum. Pedagogism Forskoning. Scandinavian Journal of Educational Research 120-134.

Strauss, A. and Corbin, J. (1990) Basis of Qualitative Research. Grounded Theory Procedures and Techniques. London : Sage Publishing.

Tamin, P. And Goldning, E. (1974) Discovery Learning as viewed in Retrospect by Learners. Journal of College Science Teaching pp. 23-26.

Taylor Fitz-Gibbon, C. And Morris, L.L. (1987) How to Analyze Data. London : Sage Publishing.

Teachworth, M. (1994). The Science Teacher, 61 (7) pp. 5-58.

Tema, B. (1992). Recognising Alternative Concepts. Biology and the Rural Child. Matlhasedi,1(1). Education and Development Forum for and from the Rural Periphery.

The AAVW (1992) Report on how Short Change Girls Commissioned by the American Association of University Women Educational Foundation. Wesley College Centre for Research on Women. New York: Marlowe and Company. Tennyson, R.D. (1995). Concept Learning: Teaching and Assessing. In International Encyclopaedia. Teaching and Teacher Education. 2nd ed. Anderson, L.W. (Ed.) Cambridge: Pergamon.

Thorndike, E.L. (1927) The Law of Effect. American Journal of Psychology, 39, 212-222.

- Tolman, R.R. (1997). Difficulties in Genetics Problem Solving. American Biology Teacher. Vol. 39.
- Toole, G., and Toole, S. (1995) Understanding Biology for Advanced Level. 3rd edition. Cheltenham : Stanley Thornes (Publishers) Ltd.

Tucker, V. (1997) Diversity in the United States. Grand Valley State University. Sociology Department. Notes.

Tyler, R. (1990) Guidelines in Reporting the Results of an Educational Evaluation. In Walberg, H.J. and Haertel, G.D. Oxford : Pergamon Press.

Vakalisa, N.C.G. (1995). African Science Teachers Perceptions of how in Service Education Influences Classroom Teaching. A case study. Ohio: A Bell and Howell . Company.

Vernon, K. (1999) 'Pagad Challenges DNA Sampling as Unconstitutional'. In the Sunday Times 14th February. Vygotsky, L.S. (1986) Thought and language. Cambridge, MA. MIT Press.

Walker, R. (1989). Doing Research : A Handbook for Teachers. London: Routledge.

Walklin, L. (1991) The Assessment of Performance and Competence. Cheltenham : Stanley Thornes Publishers Ltd.

Wallace, R.G. (1985). Introducing Technical and Vocational Education. London. Macmillan Education LTD.

Waninga, T. (1992). The Challenges Facing Education in Papua New Guinea Today.
Building Bridges In Teacher Education. Proceedings of the 12th Annual International
Seminar for Teacher Education. The University of New England Armidale, New South
Wales, Australia April, 1992.

Wasanga, C.M. (1997). The Attitude Towards Science Among Primary and Secondary School Students. Kenya, Nairobi: Academy of Science of Publishers.

Walts, M. (1994) Constructivism, Re-Constructivism and Task-orientated Problem-solving. In
 Fensham, P, Gunstone, R. and White, R. The content of science : A Constructivist
 Approach to its Teaching and Learning. London : The Falmer Press.

Wessels, H.J. (1979) Biology : Summaries, Questions and Answers. Isando : South Africa:

McGraw-Hill Book Company.

Westbrook, SL., & Marek, E.A. (1991). A Cross-Age Study of Student Understanding of the Concept of Diffusion. Journal of Research in Science Teaching, 28 (8), pp. 649-666.

Whackling, M. & Lawrence, G. (1988). Expert and Novice Solutions of Genetic Pedigree Problems. Journal of Research in Science Teaching, 25 (7), pp. 531-546.

Wood - Robinson, C., Lewis, J., Leach, J. and Driver R. Young People's Knowledge and Understanding of Some Aspects of Basic Genetics and Gene Technologies, and their Attitudes to Pre-natal Screening for Cystic Fibrosis. Proceedings of the First Annual Meeting of the Southern African Association for Research in Mathematics and Science Education.

Woodward, H. (1992). The Importance of Being Individual: Profiles, Portfolios and Personal Journals For Individual Evaluation. Building Bridges In Teacher Education.
Proceedings of the 12th Annual International Seminar For Teacher Education. The University of New England Armidale, New South Wales, Australia, April, 1992. pp. 527-530.

Wolpe, A., Quinalan, O. and Martenez, L. (1987) Gender Equity in Education. Pretoria : Department of Education. South Africa. Yin, R.K. (1994). Case Study Research Design and Methods. In Applied Social Sage

Publications. Inc.

Young, B.L. (1980). Teaching Primary Science. 2nd ed. Hong Kong: Longman.

Youngson, R.M. (1994) The Guinnes Encyclopedia of Science. London : Guinness Publishing Ltd.

Zietsman, A. and Naidoo, S. (1997). Girls' Understanding of Concepts of Thermal Properties of Matter. Abridged Research Report Nº 22. Research Priorities for The Education Of Girls and Women In Africa. Nairobi: Academy of Science Publishers. Yin, R.K. (1994). Case Study Research Design and Methods. In Applied Social Sage

Publications. Inc.

Young, B.L. (1980). Teaching Primary Science. 2nd ed. Hong Kong: Longman.

Youngson, R.M. (1994) The Guinnes Encyclopedia of Science. London : Guinness Publishing Ltd.

Zietsman, A. and Naidoo, S. (1997). Girls' Understanding of Concepts of Thermal Properties of Matter. Abridged Research Report Nº 22. Research Priorities for The Education Of Girls and Women In Africa. Nairobi: Academy of Science Publishers.

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APPENDIX ONE

KWAZULU-NATAL NORTH COAST - MAP

APPENDIX 1: KWAZULU - NATAL NORTH COAST

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APPENDIX TWO

STANDARD NINE (GRADE ELEVEN)

SYLLABUS CONTENT

ELABORATION OF CONTENT TO PROVIDE GUIDELINES FOR THEORY AND THE RELEVANT PRACTICAL WORK.

1. CELL DIVISION AND GENETICS

1.1 THE ROLE OF THE NUCLEUS

1.1.1 Structure and functions

(a)

Revision of : functions of nucleus to control structure and metabolism of cell and to provide a mechanism, through cell division, for the transmission of hereditary characters.

(b) Structure of :

nuclear envelope with pores; nucleoplasm; chromosomes (chromatin network); nucleolus. Seat and manufacture of ribosomal RNA.

1.1.2 Nucleic acids: DNA, RNA

(a) Practical study of DNA-structure Prepare / build units (nucleotides) that make up a DNA-molecule (i.e. with paper, clay, wood, etc); build a DNA-molecule and explain. (diagrammatically). DNA structure: nucleotide composition, complementary nitrogenous bases linked by hydrogen bonds; successive nucleotides linked by sugar phosphate bonds; resulting molecule having double helix configuration; location of DNA molecules.

(b) Replication

Use DNA-model; explain replication - the mechanism by which a DNA molecule can make an exact copy of itself; occasional upset of this mechanism resulting in the formation of "new" DNA molecules (mutation).

(c) Role of protein synthesis

Introduction of RNA-structure, different types of RNA (i.e., m-RNA; t-RNA; r-RNA); functions of RNA; Nature of a protein as a specific sequence of aminoacids nature of m-RNA by DNA; m-RNA as a template for assembling amino acids in specific sequences to form a protein; specific roles of t-RNA and r-RNA in protein synthesis.

Explain process of protein synthesis by drawing analogies.

1.2 CELL DIVISION

Make use of prepared slides, diapositives and / or models to explain mitosis and meiosis.

1.2.1 Mitosis:

The process of mitosis. The significance of mitosis. It should be emphasised that additional cells are required by multicellular organisms for growth, for repair and for replacement and that, to become effectively integrated into an organism, such new cells should contain genetic characteristics which are identical to those of the existing cells of that organism. Attention should be directed to the way in which mitosis meets these requirements. The DNA molecules, which are the sites of the genes, make exact replicas of themselves prior to mitosis.

1.2.2 Meiosis

- (a) The process of meiosis. (Names of stages during the first prophase are not required).
- (b) The significance of meiosis. Emphasis is required on the importance of meiosis in the reduction of chromosome number and as a mechanism for the introduction of genetic variation. The importance of the role of meiosis in alternation of generations should also be stressed.

1.3 GENETIC MECHANISMS. MECHANISMS INVOLVED IN INHERITANCE

Practical Introduction of genetics :Use videos on genetic mechanism / invite speakers / experts on topic:

- 1.3.1 Introduction and terminology of Define genetics; genes; gametes; alleles; hybrid; genetic mechanisms heterozygous; homozygous; phenotype; genotype; recessive; dominant; filial generations; mutations; segregation (with reference to meiosis);
- 1.3.2 Gametes are vehicles of inheritance. Each gamete carrying only one of each pair of alleles present in the somatic cells of a parent.

1.3.3 Monohybrid crosses:

At least one example to be considered, including diagrammatic representation. Crosses between pure bred (homozygous) stocks differing in a pair of contrasting characters will produce a heterozygous generation showing only one character, the dominant, and not the other, the recessive (e.g. in garden peas; yellow peas dominant, green peas recessive, mention of incomplete dominance).

1.3.4 Dihybrid crosses :

At least one example to be considered, including diagrammatic representation; discuss independent inheritance of various characteristics resulting from the random positioning of homologous chromosomes during metaphase of meiosis, leading to the random distribution of alleles during gamete formation.

1.3.5 Sex determination.

Brief explanation of determination of sex in humans in terms of X and Y chromosomes.

1.3.6 Gene mutation; natural selection:

Explain gene mutation and natural selection Practical application. Gene mutation. A gene mutation can occur by the alteration, of a single base-pair of a DNA double helix. An example of a gene mutation. Significance of mutations for natural selection. Natural selection. Consideration of the genetic basis of natural selection in terms of the gradual increase in the gene pool of a population of those genes which produce favourable characteristics, and the corresponding decrease of alleles that result in less favourable features.

Use examples such as albinism, etc. to promote class-discussions; refer to some practical applications of genetics. Consideration of an example of plant or animal breeding which has resulted in increased productivity; heterosis; inheritance of blood groups and of Rhesus factor in humans genetically predictable, and the importance of such predictions. Other applications may be mentioned, but will not be examinable.

(Department of Education, Syllabus for Biology 1995).

APPENDIX THREE

BIDLOGY/ Mitosis / Heiosis

• Date

65

COMPARING MITOSIS AND MEIOSIS

Your body carries out two different kinds of nuclear division. One is called mitosis and results in formation of new body cells for growth and repair. A second process is called meiosis and results in formation of reproductive cells only. There are several important differences between mitosis and meiosis.

In this investigation, you will

- (a) compare the process of mitosis with meiosis.
- (b) use model diagrams to show changes in cells during mitosis and meiosis.

Materials

pages of cell outlines 4 wool strands (18 mm long) 4 wool strands (30 mm long)

Procedure

Part A. Mitosis

Your teacher will supply you with outline diagrams for Part A of this experiment. Use only diagrams A, B, and C for Part A.

• Place the diagrams one below the other in proper order on your desk.

• Diagram A represents the outline of a cell before cell division or mitosis begins. Chromosomes are present inside the nucleus (but usually cannot be seen). Use wool strands to represent chromosomes. NOTE: A cell may contain many chromosomes. You will use only 4 chromosomes to help simplify this study.

• Place two long and two short pieces of wool (chromosomes) onto diagram A.

1. What is the total number of chromosomes

present in this cell before mitosis? ______ 2. How many long chromosomes are present

- before mitosis?
- 3. How many short chromosomes are present before mitosis?

• Before the cell begins mitosis, each chromosome makes an exact copy of itself. This process is called chromosome replication.



• To show chromosome replication, match new strands of wool with each original. Long should match with long, short with short (Figure 17-1).

• Transfer your chromosomes to diagram B, and position them within the dashed outlines. During mitosis, doubled chromosomes line up along the cell's center,

4. What differences (if any) are there between the original and replicated (copy) part of each

chromosome?

Doubled chromosomes now separate, and each part is pulled toward one end of the cell.

• Move those chromosomes lined up along the left side toward the cell's left. Move those chromosomes lined up along the right side toward the cell's right. Use the arrows as guides.



• Once the doubled chromosomes separate, the original cell begins to pinch in half down the center. This process forms two new cells.

• Move the chromosomes on the left side of diagram B to the left side of diagram C.

• Move the chromosomes on the right side of diagram B to the right side of diagram C.

5. What is the total number of chromosomes present in each cell after mitosis (diagram C)?

6. How many long chromosomes are present in

each new cell? _

7. How many short chromosomes are present in

- each new cell? _
- 8. Compare your answers in questions 1-3 to those in questions 5-7. Are the two new cells just formed the same in chromosome makeup
 - as the original cell? _____

In summary, some important things about mitosis include:

- (a) every new cell formed has the same chromosome number,
- (b) every new cell formed has the same chromosome number as the original cell.
- (c) mitosis occurs in all body cells (somatic cells), and
- (d) mitosis is responsible for growth and cell repair.

Part B. Meiosis

• Your teacher will supply you with outline diagrams for Part B of this experiment. Use only diagrams D, E, F, and G for Part B. Place the diagrams one below the other in proper order on your desk.

• Diagram D represents the outline of a cell before meiosis begins. Chromosomes are present inside the cell. Place two long and two short pieces of wool (chromosomes) onto cell diagram D.

9. What is the total number of chromosomes

present in this cell before meiosis? ______ 10. How many long chromosomes are present

before meiosis? ____

- 11. How many short chromosomes are present
 - before meiosis? _____

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12. Check back to questions 1-3. Are there differences so far between mitosis and meiosis?

Before meiosis begins, the chromosomes replicate.

• Match new strands of wool with each original. Long should match with long, short with short. Before transferring your chromosomes to diagram E, one important step that is different in meiosis now occurs. One doubled long chromosome now pairs with the other doubled long chromosome.

• Place the four long chromosomes together.

• Do the same for the four short chromosomes which also pair at this stage. Each group of four is now called a tetrad (tetra = 4) (Figure 17-2).



13. Did this step occur in mitosis? ____

• Place your chromosome tetrads onto diagram E. Use the chromosome outlines to properly position them. During meiosis, the chromosome tetrads line up along the cell's center.

Chromosomes now separate and are pulled toward opposite ends of the cell. They separate, however, in a certain way. Each tetrad separates into the two original doubled chromosomes (Figure 17-3).



R5-1

Name



• Move the doubled chromosomes toward opposite cell ends. Move those pairs lined up along the left center toward the left side of the newly forming cell. Follow the arrows as guides.

• Move the pairs lined up along the right center toward the right side of the newly forming cell. Follow the arrows as guides. Two new cells are formed as the original cell (Figure 17-3) pinches into two.

• Transfer those chromosomes on the right side of diagram E to the right circle of diagram F and position them within the dashed lines. Move those on the left side of diagram E to the left circle of diagram F and position them within the dashed lines.

14. (a) How many chromosomes are now present

- in each cell?
- (b) How many chromosomes were present in

the original cell? _

(c) Is this step different from that which occurs after two cells form in mitosis?

Each new cell just formed, quickly begins to divide again into two new cells (Figure 17-4). This step results in four new cells being formed from the original cell (Figure 17-5). The doubled chromosomes then separate leaving each new cell with a reduced number of chromosomes.



• Move your chromosomes from diagram F to diagram G. Position the chromosomes within the dashed, lines.

15. (a) How many new cells are formed from one

cell by meiosis (diagram G)? _____

(b) Does this step differ from mitosis? ____

__ Explain. __

- 16. (a) What is the total number of chromosomes present in each new cell after meiosis?
 - (b) Do any of the four new cells contain two

long or two short chromosomes? _____

In summary, some important things about meiosis include:

- (a) every new cell formed by meiosis has half the number of chromosomes as the original cell.
- (b) no paired chromosomes are present,
- (c) meiosis occurs only in reproductive organs, and
- (d) meiosis is responsible for forming egg and sperm (gamete) cells.

Analysis

1. How many pairs of chromosomes are in each human body (somatic) cell? _

. . ·

2. How many pairs of chromosomes are in each egg or sperm? (Be careful.) ____

DIAGRAMS FOR INVESTIGATION 17, "COMPARING MITOSIS AND MEIOSIS"



2.

DIAGRAM A

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85-7

APPENDIX FOUR

UNIVERSITY OF ZULULAND

METHOD OF BIOLOGY GENETICS PILOT TEST

TIME : 1½ Hours DATE : 9-10-1996

MARKS; 70

INSTRUCTIONS : Answer all questions. If for any reason you think you cannot answer a particular question, please say why.

QUESTION No. 1

Give the correct scientific term for each of the following:

- A. Cells through which sexual reproduction takes place.
- B. The cellular division responsible for the formation of such cells.
- C. Structures inside the nucleus of the cell on which hereditary characteristics appear.
- D. A straight section of a chromosome forming part of a DNA molecule.
- E. The single number of unpaired chromosomes in the nucleus of a gamete.
- F. The fertilisation product with two different alleles in two corresponding loci of a chromosomal pair.
- G. The phenotype of the fertilization product mentioned in F.
- H. The specific place or position of a gene pair on homologous chromosomes. (16)

QUESTION No. 2

Arrange the following in order of size.

a gene

a base

a human chromosome

a human cell

(4)

Justify or explain your arrangement by drawing diagram(s) which will explain the relationship of the human cell to the 3 sub-cellular structures, as well as their relationship to one another. (6)

QUESTION No. 3

a.

If mitosis occurs in a cell of genotype Aa, Bb, Cc, where all the gene pairs are on separate chromosome pairs, what will be the genotypes of the resulting cells? (10)

Illustrate your answer by means of suitable diagrams that are well labelled. (10)

QUESTION No. 4

In humans, the number of tetrads formed during mitosis is:

- A. 23
- B 46
- **C** 0
- D. 4
- E. None of these

QUESTION No. 5

Human cells normally have 46 chromosomes. For each of the following stages, state the number of chromosomes present in a human cell.

i	Metaphase of mitosis					(2)
ii.	Metaphase of meiosis					(3)
iii.	Telophase of mitosis				-	(2)
iv.	Telophase 11 of meiosis					(3)
	(In your answers, count chro	matids as	chromos	somes)		(10)
For e	ach of the answers you give exp	olain you	r reasonir	lg.		(5)

QUESTION No. 6

Albinism, that is, the absence of pigment in the dermis, is a recessive property in many animals. A great number of mice which are heterozygous for the characteristic are crossed and 60 offspring are produced.

a.	How many will possibly be albinos?	(2)
b.	How many will possibly have the same genotype as the parents?	(2)
C.	How many will possibly have the same phenotype as the parents?	(2)
d.	Verify your answer in a, b and c with the aid of a simple cross diagram.	(5)
e.	Use the data in this example to explain Mendel's law of segregation.	(4)

(2)

APPENDIX 5

UNIVERSITY OF ZULULAND

METHOD OF BIOLOGY PILOT-TEST THEORY MARK SCHEME

QUESTION No. 1

A. gametesB. MeiosisC. ChromosomesD. GeneE. Haploid (N)F. HeterozygoteG. HybridH. Locus (2 marks each)





The nuclei of chromosomes cells contain ...



... genes, which are made up of ..



...DNA, which has millions of bases joined in a particular order.

(2)

(1)

(1)

(2)

(2)

QUESTION No. 3

The genotype of the resulting cells would be Aa Bb Cc.

The subjects were supposed to show the following stages in their diagrams

- a) a diagram of early prophase showing a cell whose nucleus has 6 chromosomes (2)
- b) at late prophase the diagrams must show that duplication of chromosomes has taken place(1) and that the nucleus has broken down (1)
- c) At metaphase diagrams must show chromosomes arranged at the equatorial plane (1)
- d) At anaphase the chromosomes are shown as moving toward the opposite poles (1)

e)	At early teloph	hase the chromosomes have reached the opposite poles	(1)
f)	At late telopha	ase 2 daughter cells have been formed with precisely the sar	me number of
	chromosomes		(2)

QUESTION No. 4

C = 0

(2)

QUESTION No. 5

i)	92 chromosomes (2) chromosome duplicate during prophase stage	(1)
ii)	92 chromosomes (3) chromosomes duplicate during prophase stages	(1)
iii)	46 chromosomes (2) chromosomes number remains stable at mitosis	(1)
v)	23 chromosomes (3) the chromosomes number is halved during meiosis	(2)

QUESTION No. 6

6(a)	15 albinos, i.e. 25% (2))
b)	30, i.e. 50% (heterozygotes = normal i.e. not albinos) (2))
c)	45, i.e. 75% because phenotypically we cannot distinguish between pure and hybrid	I
	breeding (2))
d)	parent genotypes : Aa x Aa (1))
	gametes : A; a and A; a (1))
Use o	of the Punnet square or simple cross diagram to show the products of fusion between the)
game	tes of the parents. (3))
e)	Parents are both Aa. After meiosis gametes can only posses one of two contrasting	3
	characteristics, i.e. A or a (1))
Altho	ugh none of the parents was phenotypically an albino, albinos, are present in the offspring	
	(1,2) where $(1,2)$ is the state of $(1,2)$)
The p	roperty of albinism must have segregated from the normal during meiosis. (2))

APPENDIX 6 UNIVERSITY OF ZULULAND METHOD OF BIOLOGY GENETICS PRE-PILOT TEST

TIME : 1 Hours DATE : 11-05-1995

MARKS: 60

INSTRUCTIONS:

Answer all questions.

If for any reason you think you cannot answer a particular question, please say why.

QUESTION No. 1

Give the correct scientific term for each of the following:

- A. Cells through which sexual reproduction takes place.
- B. The cellular division responsible for the formation of such cells.
- C. Structures inside the nucleus of the cell on which hereditary characteristics appear.
- D. A straight section of a chromosome forming part of a DNA molecule.
- E. The single number of unpaired chromosomes in the nucleus of a gamete.
- F. The fertilisation product with two different alleles in two corresponding loci of a chromosomal pair.
- G. The phenotype of the fertilization product mentioned in F.
- H. The specific place or position of a gene pair on homologous chromosomes.

QUESTION No. 2

Arrange the following in order of size.

a gene

a base

a human chromosome

a human cell

(4)

(16)

Justify or explain your arrangement by drawing diagram(s) which will explain the relationship of the human cell to the 3 sub-cellular structures, as well as their relationship to one another. (6)

QUESTION No. 3

a. If mitosis occurs in a cell of genotype Aa, Bb, Cc, where all the gene pairs are on separate chromosome pairs, what will be the genotypes of the resulting cells? (2)

QUESTION No. 4

In humans, the number of tetrads formed during mitosis is:

A. 23
B 46
C 0
D. 4
E. None of these

QUESTION No. 5

Human cells normally have 46 chromosomes. For each of the following stages, state the number of chromosomes present in a human cell.

i .	Metaphase of mitosis	(2)
ii.	Metaphase of meiosis	(2)
iii.	Telophase I of mitosis	(2)
iv.	Telophase 11 of meiosis	(3)
	(In your answers, count chromatids as chromosomes)	(10)
For e	each of the answers you give explain your reasoning.	(4)

QUESTION No. 6

A homozygous pea with green (G) seed is crossed with a homozygous peer with yellow (g) seeds. The F_1 generation pollinates itself. Represent this cross up to the end of the F_2 generation. Green is dominant over yellow. (Wessels, 1982). (14)

APPENDIX 7

PRE-PILOT GENETICS MARK SCHEME

QUESTION No. 1



QUESTION No. 3

QUESTION No. 4	
(i.e. O (2). Tetrads are not formed in mitosis (2)	!)
QUESTION No. 5	
i) 92 chromosomes (2) chromosome duplicate during prophase stage (l)
ii) 92 chromosomes (3) chromosomes duplicate during prophase stage (l)

iii)	46 chromosomes (2) chromosomes number is not reduced during mitos	chromosomes (2) chromosomes number is not reduced during mitosis - the daughter			
	cells formed are identical	(1)			
v) •	23 chromosomes (2) during meiosis the number of chromosomes is	reduced to half			
	(haploid)	(1)			

QUESTION No. 6

Parents P ₁ :	GG x gg	(2)
Gametes :	G; g and g; g	(1)
Fertilisation :	Gg; Gg; Gg; Gg	(1)
Genotype (F ₁):	All Gg (heterozygous)	(1)
Phenotype (F_1) :	All green (hybrids)	(2)
Parents (P ₁) :	Gg x Gg	(1)
Gametes :	Gg and G; g	(1)
Fertilization :	GG; Gg; Gg; Gg; gg	(2)
Genotype (F_1) :	1GG : 2Gg; 1gg	(2)
Phenotype (F_1) :	3 green; 1 yellow	(1)
		(14)

1 × 1

APPENDIX 8 UNIVERSITY OF ZULULAND

METHOD OF BIOLOGY GENETICS TEST THE RESEARCH INSTRUMENT

TIME : 1½ Hours DATE : 17-10-1998

MARKS: 70

INSTRUCTIONS : Answer all questions. If for any reason you think you cannot answer a particular question, please say why.

QUESTION No. 1

Give the correct scientific term for each of the following:

- A. Cells through which sexual reproduction takes place.
- B. The cellular division responsible for the formation of such cells.
- C. Structures inside the nucleus of the cell on which hereditary characteristics appear.
- D. A straight section of a chromosome forming part of a DNA molecule.
- E. The single number of unpaired chromosomes in the nucleus of a gamete.
- F. The fertilisation product with two different alleles in two corresponding loci of a chromosomal pair.
- G. The phenotype of the fertilization product mentioned in F.
- H. The specific place or position of a gene pair on homologous chromosomes.

QUESTION No. 2

Arrange the following in order of size.

a gene

a base

a human chromosome

a human cell

(4)

(16)

Justify or explain your arrangement by drawing diagram(s) which will explain the relationship of the human cell to the 3 sub-cellular structures, as well as their relationship to one another. (6)

QUESTION 3

Figure 1 below shows four animals cells in different stages of mitotic division.



a.	Nam	e the structure labelled A, B, C and D.	(2)
b.	(i)	Name the stages of division shown by cells 1 and 3.	(3)
ini Ali	(ii)	Using the numbers given to each cell above, arrange the stages as the	hey occur in
	alaa ah a	the mitotic sequence.	(4)

QUESTION No. 4

(i)

(ii)

Figure 2 below shows an animal cell (A) undergoing meiosis





(2) (2)

QUESTION 4

(i) 6 chromosomes (2)
(ii) ovary or testes (2)
(iii) mid prophase S (2). The homologous chromosomes come together (synapsis) forming a bivalent (2)
(iv)

° (2)

X,

i p

QUESTION 5

i)	92 chromosomes	÷.			(2)
ii)	92 chromosomes				(2)
iii)	46 chromosomes		•		(2)
v)	23 chromosomes				(2)

QUESTION 6

6(a)	15 albinos, i.e. 25%	(2)
b)	30, i.e. 50% (heterozygotes = normal i.e. not albinos)	(2)
c)	45, i.e. 75% because phenotypically we cannot distinguish between pure and	hybrid
	breeding	(2)
d)	parent genotypes : Aa x Aa	(1)
	gametes : A; a and A; a	(1)

Use of the Punnet square or simple cross diagram to show the products of fusion between the gametes of the parents. (2)

The results will be as follows after crossing the gametes:

Genotype ; 1AA; 2Aa; 1aa(1)Phenotype : normal colour (75%) (1) and 1 albino 25% (1)

e)

Parents are both Aa. After meiosis gametes can only posses one of two contrasting	
characteristics, i.e. A or a	(1)
Although none of the parents was phenotypically an albino, albinos, are present	in the
offspring.	(1)
The property of albinism must have segregated from the normal during meiosis	(2)

APPENDIX 11

UNIVERSITY OF ZULULAND PRACTICAL MARK SCHEME

Marks were allocated as follows for the practical test:

1. Metaphase stage shown correctly at equatorial plate as shown in figure P below (2)

A pair of homologous chromosomes

Figure P.

2.	Use of different colours to represent different chromosomes of the homologous pair. (2)	
3.	Beads used to represent centromeres (2)	
4.	Labels A or a put on both chromatids of a homologous pair as shown in figure P. (2) Give	
	half credit if labels put one one chromatid (1)	
5.	Loci of the alleles in the chromatids must be the same. (2)	
6.	Use of cellotape to secure the model (1)	
7.	Movement of chromosomes toward the poles shown correctly i.e. the homologous pairs	
	separating and not chromatids (2)	
8.	Anaphase is the next stage (1) [15]	
SEXUAL HARASSMENT AND GENETIC FINGERPRINTING TECHNOLOGY

VENUE : The University of Zululand Guidance Clinic

DATE : 17-10-98

Read the following extract carefully.

SEXUAL HARASSMENT AND VIOLENCE IN SOUTH AFRICA

Sex based violence in schools has been on the increase in South African schools. Female students are not only harassed by thugs outside the school premises but also by male teachers as well. Wolpe, Quinlam and Martinez (1997) state that "quality education is predicated on students being able to participate in education safely, confidently and without fear".

Now answer the following questions:

1. How do you feel about teachers who rape school girls?

2. Policeman say many rapists are not convicted because of lack of evidence. Suppose a female student who has just been raped comes to you for advice. What would you say to her?

3. What kind of technology is available to help in identifying rapists?

4. Briefly describe how the technology mentioned in question 3 works. You are not required to give details of the technical process involved in this technology. Give your general understanding of how this technology works. The numbers of each type present the ratio resulting from crossing two types of fly. Assume that A and a represent the alleles involved in the cross. Which of the following crosses would produce this ration:

Aa x aa; Aa x Aa; AA x AA; or aa x aa?

C.



The problems were taken from Beckett (1990)

HEURISTICS FOR SOLVING GENETICS PROBLEMS

MARK SCHEME

Almost all genetics problems encountered in introductory biology can be solved using the simple steps shown below. The subjects were supposed to mention the following steps in the sequence shown.

Determine the type of inheritance dealt with in the problem. Does it show complete dominance, incomplete dominance or some other feature? Are there one, two or more pairs of genes involved? Usually this information is given in the problem. If not, it can be deduced from the phenotypic ratios of the offspring (2)

2.	Determine the genotypes of the individuals involved	(2)		
3.	Determine the types of gametes each parent can produce. Arrange them in a Punnet			
	square and fill in the possible progeny genotypes.	(2)		
4.	Count the resulting phenotypes and express them as a ratio.	(2)		
		(8)		

5. If chance predictions are involved, expand the binomial (a+b)ⁿ to the proper nth power. Substitute the fractions given by the Punnet square in step 4 and solve. None of the students was aware of step 5 which is used in population genetics. Students were therefore graded on their logical presentation of steps one to four which were relevant for the solution of the genetics problems in the theory test.

SUBJECTS ERRONEOUS IDEAS ON REPRESENTING A PAIR OF HOMOLOGOUS HETEROZYGOUS CHROMOSOMES AT METAPHASE 1 OF MEIOSIS

MODEL 1 Step [; The chomosomes are different cause they compon two ents, They are here ogygois. Because the parons are of The Same Species Chron homolo gous . equitorial plane. They

MODEL 2



MODEL 3



APPENDIX 16 CONTINUED

MODEL 4



Some subjects erroneous interpretation of the meiotic stages C and D in probe 4.



GENETICS WORKSHOP

17/10/98

1. REGISTR	ATION FORM	
NAME :	••••••	••••
GENDER :	MALE []	
	FEMALE []	
AGE :	ſ	
MAJORS		
GENETICS AS A	LEARNING AREA	
1. Did vou do s	genetics in grade 11 at your school?	
2 If you did n	not do genetics at your school what do you	u think was the reason for it
omission in t		
Unitsion in t		/
		•••••••••••••••••
•••••		•••••••••••••••••••••••••••••••••••••••
3. List universit	ty courses in which you have done genetics a	t the University of Zululand.
-	· · · · · · · · · · · · · · · · · · ·	•••••

••••••		

MISCONCEPTIONS DISCOVERED BY BROWN IN THE PRACTICAL TEST ON MEIOSIS

In his study with A -level students, Brown discovered the following misconceptions concerning alleles carried on sister chromatids.





This first misconception (type 1) showed both alleles but left sister chromatids blank.





This second misconception (type 2) showed the placing of different alleles on one pair of sister



chromatids.

ł

This third type of misconception was the placing of different alleles on both pairs of sister chromatids.

Negotiation of Meaning by the Subjects in Groups.

During the activity shown in appendix 3, subjects were engaged in a lot discussion and debate: The researcher observed one group debating and negotiating meaning of question 2 on page 71. The discussion of the subjects went on as follows:

Question by subject 1 :Answer by subject 2 :Question by subject 3 :Subject 2 :Subject 1 :

How many pairs of chromosomes are in each egg or sperm? One pair What do you understand by a pair of things? Two things A pair is not just two things. The things forming a pair must be

similar, like a pair of socks. In figure 17.5 you can see a long and a short chromosome, surely that is not a pair. You must remember that the homologous pairs separated in diagram E. Diagram F and G now tells you the rest of the story.



	and the second
8h00-8h30	Registration
8h30-9h30	Variation, heredity and genetics
•	A Chromosome study
9h30-10h00	Mitosis and meiosis compared (practical activity)
10h00-10h15	TEA
10h15-10h45	Practical test activity on meiosis
10h45-12h00	Monohybrid and dihybrid crosses
12h00-12h30	Rape crisis in South Africa
12h30-13h30	LUNCH
13h30-15h00	Genetics Test
15h00-16h00	Reflection
	8h00-8h30 8h30-9h30 9h30-10h00 10h00-10h15 10h15-10h45 10h45-12h00 12h00-12h30 12h30-13h30 13h30-15h00 15h00-16h00

16H00 WORKSHOP ENDS