THE EFFECTS OF AN INSTRUCTIONAL STRATEGY ON GRADE 11 LEARNERS' UNDERSTANDING OF GENETICS

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Dedication

I present this work in memory of my late father SISEHO DANIEL SINVULA who wished to see this event, however, did not have the chance.

Certification

I hereby certify that Mr Simasiku Siseho in the School of Science and Mathematics Education, Faculty of Education, University of the Western Cape carried out this work.

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27.05.2005

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DECLARATION

I declare that **The Effects of an Instructional Strategy on Grade 11 Learners' Understanding of Genetics** is my own work, that it has not been presented for any degree in any other institution and that all the sources I have used or quoted have been indicated and acknowledged by means of references.

SIMASIKU CHARLES SISEHO

Abstract

Research into learning genetics has largely focused on issues such as problem solving and the process of meiosis. The central concept of genetics, however, has received very little attention despite the fact that it is one of the concepts that learners find difficult (Ogunniyi, 1999; Bahar, Johnstone and Hansell, 1999; Collins and Stewart, 1989). In view of this, the specific purpose of this study was to investigate: (1) concepts of genetics that grade 11 learners hold before and after a period of instruction in genetics (2) the differences in the understanding of genetics held by learners exposed to an instructional model and those not so exposed; and (3) possible influences of gender, age, and language on grade 11 learners' understanding of genetics. The method adopted for this study was a multidimensional approach in which both qualitative and quantitative approaches were used to complement each other. The role of the researcher in this study was that of the participant-as-observer. An induction workshop was conducted for both the combined instructional teacher (i.e. experimental teacher) and the traditional instructional teacher (i.e. control teacher) to help them explore and reflect on their practice with the view to create in them an appreciation for multiple teaching strategies or traditional teaching strategies to teaching and learning respectively.

Two schools and two teachers were used in this study. The instruments used in the study were pilot tested in a school with similar characteristics to the two schools used in the main study. The instruments used to generate data for the study include: Classroom Interactions Observation Schedule, Structured Interviews with teachers and learners, Genetics Achievement Test (GAT), a Cloze Test and Learner Worksheet. All the instruments were subjected to the rigour of triangulation to attain a high level of validity, reliability as well as credibility. The findings of this study amongst other things suggest differences in the interactions of behaviours of the experimental teacher and the control teacher. The control teacher tends to out-talk the learners while the experimental learners tend to out-talk their teacher. Also, the learners in the treatment group (experimental group learners) performed significantly better than those in the control group. The study was premised on the socio-constructivist epistemology, which construes the learning as knowledge construction based on one's interaction with the learning environment (Von Glasersfeld 1993; Mintzes and Wandersee, 1998). The constructivist epistemology does not assume that the learner enters into the science classroom *tabula rasa*. Rather, it assumes that the learner holds ideas and views about various phenomena based on prior experience with the environment.

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LIST OF ABBREVIATION

Abbreviation	Words written in full
C	Control (group/learners/teacher)
CTBS	Comprehensive Test of Basic Skills
E	Experimental (group/learners/teacher)
GAT	Genetics Achievement Test
GCIOS	Genetics Classroom Interaction Observation Schedule
IILTI	Individual Implicit Learning Theory Interview
LIP	Learner Interview Protocol
MER	Multiple External Representations
TIP	Teacher Interview Protocol

CHAPTER ONE

Introduction

1.1 Background

As a high school learner I found the study of genetics very fascinating and enjoyable. I thrived on doing investigations where I had to find out who in my family could roll their tongues, who had a "widow's peak", or who had attached earlobes and so on. It was interesting finding out things about my family and myself. My study of genetics has helped me to understand myself better and to gain insight into my shared inheritance. As a learner I was good at solving genetics problems because they were consistent and predictable. At the university, however, genetics became a little more difficult and confusing. It was reduced to estimating the locus of genes from the rate of crosses with other genes on the chromosome. Problems that were once rewarding to get right had become removed from the inheritance of characteristics in my family in which I had originally been interested. Nevertheless, we had several opportunities to examine various types of genetic combinations in a number of organisms. These practical activities, though rather arduous, have helped to sustain my interest in the subject.

As a teacher, I loved teaching genetics. One of the vivid memories was when my wife, a nurse, visited me during one of my afternoon classes. I was teaching a grade 10 Biology class then. The learners were laughing and chatting in anxious anticipation of the investigation we were about to conduct to find out the learners' blood groups. Of course, this was in the days when such investigations were still allowed. My wife came into my class to find out what all the excitement was about and I invited her to stay. She eagerly accepted.

During the pre-laboratory session, I demonstrated the use of sterile blood lancets and showed the learners how to prick a finger to get a few drops of blood to which they could add clotting agents to determine their blood group. Even though I had done this experiment many times before and knew it did not really hurt, I still felt my heartbeat quickening, as I was about to prick my own finger. The learner squirmed and groaned and my wife mocked them for their lack of stoicism. To my horror, one of the bold members of the class suggested that my wife should be the first to demonstrate composure while inflicting a prick wound in her finger for the purpose of scientific endeavour. I did not expect that and I racked my brain to think of an excuse that would allow my wife to leave the class with her pride still intact. To my surprise, she swabbed her finger, picked up a blood lancet, removed the wrapper and without hesitation or sign of inhibition pricked herself and drew blood that would be enough for the entire class to do their experiments. My wife's blood was O positive. The learners worked out their blood groups and had become familiar with the A, B, AB and O alleles. I found such practical exercise on human blood groups was a good way of introducing ideas like multiple alleles to my learners. Such an exercise could serve as an effective way for studying more complicated concepts in genetics.

1.2 Motivation for the study

Ever since the Dutch colonists landed in 1652, "Blacks" and "Whites" have lived apart in South Africa. Long before the historic 1948 white elections, which gave the Nationalist Party power, there was a system of segregation and unequal education in South Africa. While white schooling was free, compulsory and expanding, black education was sorely neglected. The blacks schools were under-funded and lacked essential facilities, qualified teachers and infrastructures for the swelling urban population. Prior to 1948 there was not much mixing between White and Black learners in schools (Amukugo, 1993). The Bantu Education Act of 1953 was designed to create an entirely separate educational system for African learners. According to Hendrick Verwoed, the Minister responsible for education at the time, the purpose of 'Bantu' Education was to adapt and prepare Africans for the subordinate role, which they could expect to play in a white community. According to a report in an Afrikaans newspaper 'Die Burger' (as cited by Cross, 1992), Verwoed had the following to say on equality:

> *"When I have control of 'Native' education, I will reform it so that the 'Natives' will be taught from childhood to realize that equality with Europeans is not for them" (Cross, 1992:23).*

Bantu Education Act No. 47 of 1953 was intended to separate black South Africans from the main, comparatively very well resourced education system for whites. Blacks were not allowed to attend school after 14 years except with the express permission of a high-class white person, usually to make a good slave. The schoolwork they were given was of a strikingly different syllabus to the whites and they had far lower expectations

(Amukugo, 1993). An example of how blacks were restricted was that they would be allowed to hammer a nail but would not be allowed to use the claw of the hammer to extract a nail, which was considered to be more refined work for more intelligent whites. In the apartheid system, amenities were all separated: beaches, hospitals, toilets, schools, and almost everything (Kallaway, 1984). Blacks were allowed into white churches only to clean them but not to pray in them. Under no circumstances were the black people allowed to make use of the white amenities. Even if a black child was run over by a truck, and the closest black hospital was an hour's drive away while the white hospital was just around the corner, the child would not be admitted.

Verwoed (then Minister of Native affairs, who later became Prime Minister) was tasked with the compilation of a curriculum that suited the "nature and requirements of the black people". African learners were to be educated in a way that was appropriate to their culture. No consultation occurred on this matter (Amukugo, 1993). All the definitions of culture, appropriate education content and levels, all the decisions about purpose and outcomes of the system were controlled by the apartheid government. Its stated aim was to prevent Africans receiving an education that would lead them to aspire for positions they would not be allowed to hold in society. Instead, Africans were to receive an education designed to provide them with skills to serve their own people in the Bantustans 'homelands' or to work in manual labour jobs under white control (Cross, 1992).

Over the years, the races got even more segregated, having isolated territories. The whites felt they were far superior to the black people in every way. They took slaves from black communities, and just dominated the race entirely. This disgraceful treatment was not without opposition from within the white race itself. These few people fought (unsuccessfully) for black rights. Eventually, this led to interracial relationships (Amukugo, 1993). Children born of these relationships were known as "coloureds" and were regarded with shame as little better than blacks themselves. They were perplexed in a fix because they were never truly accepted into the black or white communities. In a similar predicament were the Indian peoples, brought over by the British from their colonies. These were treated with only a tiny bit more respect, and their plight in the 1950s went mostly unrecognized. This study is delimited in the Western Cape province predominantly inhabited by the whites, coloured and Indian communities because of the legacy of the past.

Though Bantu Education was designed to deprive and isolate blacks from 'subversive' ideas, indignation of being given such 'gutter' education became a major focus for resistance, most notably in the 1976 Soweto uprising. In the wake of this effective and clear protest, some reform attempts were made, but it was a case too little, too late (Cross, 1992). This cornerstone of apartheid ideology wrecked havoc on the education of black people in South Africa, and disadvantaged millions for decades. Its devastating personal, political and economic effects continue to be felt and wrestled with today. The black people were made to suffer in this regime for a total of 46 years before Apartheid ended.

Since this study was carried out in the Western Cape Province in South Africa, I thought the opinions of experienced high school biology teachers in Cape Town schools and Atlantis about biology topics found most difficult to teach and learn in biology would provide a better understanding to this study. All the teachers interviewed without exception indicated that genetics was one of the most difficult topics to teach or learn. Further, I explored the new biology syllabus to determine how much space of time was given to the study of genetics. From the scheme of work perused from four different schools in North Metropole, genetics lessons should not be fewer than 20 teaching periods. The grade 11 syllabuses in use in South African schools are common for all schools. It is quite explicit in what it requires learners to be taught and what skills need to be developed. Also, in an earlier study Ogunniyi (1999) explored the views of 95 randomly selected grade 7-9 learners on concepts of genes, mitosis and chromosomes respectively and found that only 17%, 4% and 15% respectively expressed familiarity with genes, mitosis and chromosomes.

My contention was that if learners did not understand the basic structure and especially the functioning of genes, it would be unlikely for them to understand genetics and related concepts and generalizations. Of central importance in this regard are questions such as: What conceptions of the gene do grade 11 learners hold? How capable are the learners in applying the understanding of the concept in solving genetics problems? Before discussing the issues implied by these questions, it is appropriate to provide a brief historical background to the study of genetics.

Genetics emerged as a new scientific discipline in the early 20th century revolutionizing people's thinking and understanding about heredity and reproduction. According to Kindfield (1992), classical genetics established the foundations upon which modern molecular biology has been built. She sees genetics "not as one of many branches of biology but more as the central organizing feature of biology that has relevance in all sub-disciplines and can be studied at all levels of organization" (p.39). Her contention is that an understanding of the theories and concepts of genetics is necessary for fundamental understanding of the discipline of biology as a whole and essential for some associated aspects of biology such the theory of evolution, adaptations, populations and ecology. However, research has shown that, even after instruction, learners often hold conceptions about genetics that differ significantly from the scientific valid viewpoint (Brown, 1990; Clough and Wood-Robinson, 1985; Hackling and Treagust, 1984; Hildebrand, 1985; Kindfield, 1994; Smith, 1991; Wood-Robinson, 1994).

One of the most significant findings of these studies is that learners often do not understand the process of meiosis or the concept of the gametes as haploid cells, which carry the genetic information to the offspring. The related notion that the sperm and the egg both contribute information relevant to the determination of the phenotype of each feature of the offspring is also not well understood by most learners. For example, Deadman and Kelly (1978) investigated what high school learners understood about evolution and heredity before they were taught these topics. They found that while the learners "had a firm idea of heredity as the transmission of characteristics from one generation to another, still their understanding was shallow" (p. 10).

Kargbo, Hobbs and Erickson (1980) found that "from age seven to 13, learners have a large number of novel ideas about the nature and the mechanism of inheritance" (p. 145). They further suggested that a considerable number of children "believe that environmentally induced characteristics, such as a missing finger, can be transmitted to offspring under certain circumstances" (p.137). Clough and Wood-Robinson (1985) came to similar conclusions that many learners of all ages believe that acquired characteristics are inherited, although the results suggest some improvement in understanding with age.

Hackling's and Treagust's (1984) work is similar to those carried out by Deadman and Kelly (1978), Karbo et al. (1980), and Clough and Wood-Robinson (1985) in that it scrutinizes learners' conceptions after a ten-week genetics course. They found that inheritance of acquired characteristics was believed by only 13% of the 10-year-old learners after instruction and that 40% of the learners understood that such features were not inherited. Features of young people's understanding of inheritance described in the literature by Wood-Robinson (1994) include the widespread belief that plants do not reproduce sexually, that there is an unequal contribution by the parents to the features of the offspring and that the belief in the inheritance of the acquired characteristics is common. It is against this background that this study was construed.

1.3 Research problem

Research into young people's understanding of genetics has perhaps been more documented than any other aspect of the biological sciences. Despite this, however, Bahar, Johnstone, and Hansell (1999) have reinforced the difficulties that learners experience with concepts in genetics. Indeed, most of these studies (see, for example, reviews of the literature by Wood-Robinson, 1994; 1995) have focused on children's understanding of inheritance rather than genetics. The fact that learners themselves have admitted that they have difficulties with the concepts of genetics has been further confirmed by Bahar et al. (1999). They found that meiosis, gametes, alleles, and genes and genetic engineering, along with monohybrid and dihybrid crosses and linkages, were topics that learners found difficult.

Though the concept of genetics is reasonably well articulated in most biology textbooks, it is quite clear that the concept is not always taught in a coherent and successful way (Department of Education and Science, 1991). There are also difficulties when it comes to the translation of the curriculum into teaching. Areas such as growth, cell structure and functioning, cell division, gamete formation, sexual and asexual reproduction, inheritance, and genetics are often taught at different points in the school year or even in different years. It is therefore hard for learners to see the coherent thread that unites these areas. Whatever the case, it must be admitted that genetics is a biological concept which most learners find difficult. In view of this, it seems necessary to devise ways to present the concept in a clearer and concise manner for the learners.

One way to facilitate learners' understanding of genetics is to use relevant illustrations, models and analogies. Another way is to situate the tasks within the learners' life experiences. Whatever the drawbacks of these approaches, the ultimate goal should be to present the concept in a much less abstract form, particularly for learners whose understanding requires concrete props. As Johnstone and Mahmoud (1980) have emphasized, learners' understanding of any subject matter is largely dependent on their ability and willingness to learn. To them, "no matter how easy a teacher sees it and declares it to be, a pupil's perception of the topic's difficulty will colour the learning of it"(p. 231).

1.4 The purpose of the study

The purpose of this study was to investigate grade 11 learners' understanding of the concept of genetics. More specifically, the study sought to determine:

1) The effect of an instructional strategy on learners' understanding of genetics in terms of the characteristics and functions of the gene.
2) The conceptual change that is evident in the performance of genetics tasks.

Furthermore, this study explored how the learners shifted from one level of understanding of genetics to another as a result of an instructional intervention involving the use of the Novak and Gowin's (1984) Vee diagramming and concept mapping, Lijnse's (1990) hierarchical conceptual model and Martin's (1983) inductive instructional model.

1.5 Research questions

1. What concepts of genetics do grade 11 learners hold before and after being exposed to an instructional model in genetics?
2. Are there differences in the understanding of genetics shown by the learners exposed to the instructional model and those not so exposed?
3. Are the learners' understandings of genetics influenced by their gender, age or language?

1.6 Theoretical framework

A theoretical framework helps a researcher to focus his/her study as well as prevents him/her from the pursuit of mere fads. The theoretical framework underpinning this study is socio-cultural constructivism as espoused by Vygotsky, (see Berk, Laura and Winsler, 1995; Gergen, 1995; von Glasersfeld, 1995). Vygotsky is best known for being an educational psychologist with a focus on sociocultural constructivism. This theory suggests that social interaction leads to continuous step-by-step changes in children's thought and behaviour that can vary greatly from culture to culture (Woolfolk, 1998). Basically Vygotsky's theory suggests that learners' development depends on their interactions with people and the tools that the culture provides to help them form their own views of the world.

According to Moll (1994), there are three ways in which a cultural tool can be passed from one individual to another. The first one is imitative learning, where one person tries to imitate or copy another. The second way is by instructed learning, which involves remembering the instructions of the teacher and then using these instructions to self-regulate one's behaviour while the third, known as collaborative learning involves a group of peers who strive to understand each other and work together to learn a specific skill. Vygotsky's learning theory combines the social environment and cognition. Learners will acquire the ways of thinking and behaving that make up a culture by interacting with a more knowledgeable person.

Berk et al (1995) assert that Vygotsky believed that social interaction would lead to ongoing changes in a child's thought and behaviour. These thoughts and behaviours would vary between cultures. Research in the field of education has for several decades been dominated by behaviourism, namely, a theory that assumes that the learner comes into the class *tabula rasa* and that the job of the teacher is to fill his/her blank mind with information. However, during the last two decades there has been a paradigmatic shift towards cognitivism, particularly socio-cultural constructivism as espoused by Vygotsky. The tenet of constructivism is that "knowledge is constructed in the mind of the learner" (Bodner, 1986:873). Constructivism is a theory of knowledge that contrasts sharply with traditional epistemological theories that construe knowledge to be a representation of reality. Among others, the foremost proponents of constructivism in the last century have been Piaget and Vygotsky. The scholars have perhaps produced the most vivid description of constructivism even though the theory has been in the academic discourse for several centuries.

Constructivists maintain that when information is acquired through the transmission models, it is not always well integrated with prior knowledge and is often accessed and articulated only for formal academic occasions such as examinations (Richardson, 1997).

In contrast, constructivists believe that the only world we can know is the world of our own experience (von Glasersfeld, 1993). This theory contests the belief that knowledge can be transferred to a passive receiver. Rather, knowledge is the result of an active construction process, which "has to be built up by each individual knower" (von Glasersfeld, 1993). Bodner (1986) emphasizes that from a constructivist view, the most vital factor influencing learning is that knowledge is constructed on the basis of a learner's pre-existing cognitive structure. In other words, the construction of knowledge is a search for a fit rather than a match with reality and that each person builds his/her own view of reality.

Constructivism has been an important theory for research and practice in science education. There are, however, many forms of constructivism such as personal, radical, social, contextual and critical constructivism (Geelan, 1997; Good, 1993; Solomon, 1994). In describing constructivism as the theory of knowledge, Tobin (1990) states that knowledge is constructed and adapted as a result of successive experiences and reflections. It is this process of construction and adaptation that can be seen as conceptual change. To Spada (1994:113) "conceptual change is a process which leads from one coherent mental structure to another" and this process represents the world more adequately. Several theories of conceptual change have emerged over the years. One of the most influential in the field of science education is the conceptual change model proposed by Posner and others (Posner, Strike, Hewson and Gertzog, 1982; Strike and Posner, 1992). Other theories of conceptual change include Thagard's (1991, 1992) continuum theory, Vosniadou's (1994) framework theory, and Pintrich, Marx and Boyle's (1993) motivational perspective of conceptual change. Each of these theories will be discussed in greater detail in Chapter 2.

The theoretical framework underpinning this study is conceptual change from a constructivist viewpoint. However, in doing this, the focus would be the notions of constructivism that have had significant influence in the field of science education namely, those of Piaget, Vygotsky and Ausubel. Piaget has provided a graphic description of conceptual change in terms of personal constructivism. However, he has not paid much attention to the socio-cultural context of the learner. Unlike Piaget, Vygotsky has placed a great emphasis on socio-cultural factors such as language, the role of the knowledgeable adult compared to the novice learner, the importance of artefacts such as the medium of instruction and the social environment in which learning takes place formally or informally. Personal constructivism tends to concentrate on the individual rather than the behaviour of the group. The emphasis of Ausubel is that meaningful learning is largely determined by the ability of the learner to relate new experiences with prior experiences. I shall elaborate on this later on. Whatever the differences in the way these scholars construe learning, they agree that learning is a deliberate and an active process of knowledge construction.

Sociocultural theories are rooted in constructivism and hence focus on the role of community and environment in the creation of knowledge as opposed to the personal constructivist theory, which focuses on internal negotiation of meaning by an individual. Further, socio-cultural theorists are of the view that meaning varies in accordance with how the community of practitioners uses it. Thus, knowledge resides in communities. Meaning making is the result of active participation in socially, culturally, historically, and politically situated contexts. The intention of this study is to explore these theoretical perspectives in relation to learners' conception of genetics before and after being exposed to a constructivist based instructional strategy.

Learners have their own mental framework, which is a function of their beliefs, past experiences and knowledge. When a learner comes across new information, he/she (in the words of Piaget) accommodates and ultimately assimilates it in the context of her existing mental structures thereby constructing new knowledge. Hence, learning is seen as a process of internal negotiation of meaning (see Ausubel, 1968). From the constructivist viewpoint, the goal of instruction is to help learners develop learning and thinking strategies. This study seeks to shift cognitive labour such as analysis and synthesis of information from teachers to the learners.

Instructional techniques based on the constructivist and sociocultural theories include the notion of: (a) scaffolding- teachers support a learner's personal construction of knowledge by offering comments, suggestions, feedback, or observations; (b) fading- once the learner progresses towards mastery, teachers remove the supports they provide to make the learner self-sufficient; (c) cognitive apprenticeship- learner learn by actually engaging in the activity they want to learn about with the support of knowledgeable others in the field. This is similar to traditional apprenticeships that entail learning by doing; and (d) collaborative learning - learners develop their knowledge by sharing ideas, reflecting and interacting in learning groups.

This study considers a variety of issues surrounding a sociocultural approach to the teaching and learning of genetics. Through working with teachers and learners this study explored instructional strategies that take into account learners' views of genetics and learning. Learners' experiences when learning genetics in their own environments may reveal the way they construe reality. Given this view of knowledge and expertise, learning is construed as any meaningful participation in the construction of socially defined knowledge and values, and occurs as communities of individuals construct understanding of a domain in whatever context it is encountered. Similarly, this study shares the view expressed by Campbell (1997) that learners should demonstrate their higher-order thinking skills, generalize what they learn, provide examples, connect the content to their personal experience and apply their knowledge to new situations. In reference to Dewey (1916) the thrust of the study was to go beyond mere coverage of content and learner to apply their understandings about genetics in performing specific cognitive tasks and perhaps real life problems outside the science classroom. My motive for steering away from direct instruction and traditional teaching methods was informed by my teaching experience that children tend to learn best from shared experiences, particularly when provided with hands-on activities that require different learning styles.

Good teaching has always recognized that educators must start 'where the learner is'. 'Where the learner is', has traditionally been defined in terms of what he/she gets right or wrong relative to the scientifically acceptable knowledge. According to Ausubel (1968) the most important factor influencing learning is what the learner already knows. In order for meaningful learning to occur, therefore the learner must already possess concepts on which to anchor new ideas. These anchoring concepts are called prior knowledge. Prior knowledge is knowledge that has been gained by the learner from life experiences and has been structured into schemas constituting of his/her cognitive structure. Further, these schemas interact with and influence learners' subsequent encounters and learning experiences (Driver and Leach, 1993:104). Although this has drawn inspiration from the constructivist theories relative to conceptual change, I am well aware of the problems associated with these theories and other theories of learning. I shall elaborate on these problems briefly in chapter 2. Nevertheless, despite the weaknesses of constructivism as a learning theory, their focus on the learner has been a welcomed relief in the field of science education – a field that has been dominated largely by behaviourist and positivist theories for nearly a century.

1.7 Importance of the study

Genetics is an interesting and much talked about subject among people and myths about the subject are common (Jones, 1993). Poor instruction within schools has probably contributed to the formation of alternative frameworks and misunderstandings about genetics conceptions held by learners and the population at large. As already stated, understanding by the general public in the field of genetics is important in order to comprehend the social and scientific consequences of research in molecular genetics. Additionally, it is important for learners to have a good grounding in high school genetics for a wide variety of occupations and, where appropriate, as a foundation for tertiary studies. This study seeks to provide empirical findings on the effect of an instructional strategy on Grade 11 learners' understanding of genetics.

Enhancing learners' learning and understanding is a major objective in science education. It is widely accepted that learners hold naive conceptions of genetics prior to instruction, which need to be modified if valid understanding of the concept is to take place (Guzzeti, Snyder, Glass and Gamas, 1993). This information is of great importance to teachers, curriculum developers and educational researchers in their quest for improved conceptual development among learners.

1.8 Limitation of the study

This research has some limitations. First, because different teachers will teach different types of learners, it is likely that the teacher factor might influence the outcomes of the study despite the concerted effort made to ameliorate the effect of such a factor. Whatever is done to determine the genuine feelings of the learners, it is not always easy to decipher whether expressed feelings have been motivated by a new instructional model or a combination of other factors (including extraneous variables) such as the presence of an observer, the teacher's enthusiasm or changed instructional behaviours. Another limitation might be the short duration of the study, that is, about eight weeks. In other words, the duration may be too short to bring about improvement in the affective characteristics of the learners. Perhaps a longer duration might result in a more noticeable attitudinal changes among the learners, especially toward controversial issues in genetics. Also the short duration used to orient the experimental teacher towards a constructivist teaching is a further limitation. Kyle, Penick, and Shymansky (1979) cited Supovitz and Turner as claiming from their study that teachers experiencing fewer than 40 hours of professional development did not make any meaningful pedagogical shift and that they did so only after 80 hours of training. Since the sample was limited to two schools and the study carried out in one subject area (Biology) at one grade level, not much generalization can be made. To be able to make some generalizations would require a large number of subjects.

1.9 Definition of terms used in the study

Constructivism

(1) Based on Gredlers' book (2001) the definition of constructivism is as follows: "Several related perspectives view knowledge as a human construction. This theory was derived from Piaget's perspective of learning, which views the learner's knowledge as adaptive. The teacher's role is to challenge the child's way of thinking." An easy way to remember this theory is to relate constructivism with construction. In essence we are constructing knowledge. By doing these things we incorporate knowledge into the mind. Gredler, (2001:10).

(2) Constructivism is an approach to teaching and learning based on the premise that cognition (learning) is the result of "mental construction." In other words, learners learn by fitting new information together with what they already know. Constructivists believe that learning is affected by the context in which an idea is taught as well as by learners' beliefs and attitudes (Phillips, 1995:8).

Conceptual change

(1) Conceptual change is generally defined as learning that changes an existing conception i.e., belief, idea, or way of thinking (Hewson, Beeth, & Thorley, 1998: 199).

(2) Conceptual change focuses on characterizing transformations in learners that (with varying success) result in transformations in understanding of scientific

phenomena and promoting instructional situations that increase the likelihood of robust and generative understanding (DiSessa and Sherin, 1998: 1155).

Conceptions

(1) The formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention, as it is hereafter to be applied to practice (Rosenstock and Brini, 2004: 1654-1655).

(2) An idea of what something or someone is like, or a basic understanding of a situation or a principle (Cambridge International Dictionary of English, 2002).

Epistemology

(1) The branch of philosophy that studies knowledge. It attempts to answer the basic question: what distinguishes true (adequate) knowledge from false (inadequate) knowledge? Practically, this question translates into issues of scientific methodology (Heylighen, 2000:1).

(2) Epistemology is the theory of knowledge that deals with questions concerning the nature, scope, and sources of knowledge (Keith, 1992: 913)

Gene

(1) Gene is a basic unit of heredity. Genes are made of DNA, a substance that tells cells what to do and when to do it. The information in the genes is passed from parent to child-for example, a gene might tell some cells to make the hair red or the eyes brown (Brown and Botstein, 1999:33).

(2) The fundamental physical and functional unit of heredity, which carries information from one generation to the next; a segment of DNA, composed of a transcribed region and a regulatory sequence that makes transcription possible (Brown and Botstein, 1999:33).

Genetics

(1) A branch of biology that deals with heredity transmission and the variation of inherited characteristics among similar or related organisms (Dodd, Foley, Buckley, Eckert and Innes (2004: 1295).

(2) The scientific study of heredity and genes (Brown and Botstein, 1999:35).

Instructional strategy

(1) Instructional strategies are the techniques, methods, sequences, media, and any other means we use to teach things to learners. Most instructional strategies are based on educational theories. Cognitive theory or constructivisms for instance are backgrounds for such strategies as inductive learning, problem solving, and cooperative learning (Jonassen, 1988:158).

(2) Approaches that are used to present information in a manner that achieves learning. Approaches include tutorial, gaming, simulation, etc. Aspects of instructional strategies include the order of presentation, level of interaction, feedback, remediation, testing strategies, and the medium used to present the information (Applegate, Quinn, and Applegate (1994:35).

Prior knowledge

(1) The knowledge that stems from previous experience. Prior knowledge is a major component of schema theories of reading comprehension in spite of the redundancy inherent in the term (Gaultney, (1995:142).

(2) Knowledge, which the reader has prior to engaging in the lesson or reading. Sometimes referred to as schema. It is important to activate prior knowledge before the lesson or reading. This allows learners to connect what they are learning/reading with what they already know (Schunk, (1991:2).

Scaffolding

(1) Refers to an instructional method whereby the teacher provides temporary support while employing strategies designed to help learners accept responsibility for their learning. Scaffolding strategies can include reading aloud, frontloading, and assigning group roles (Wells, 1999:25).

(2) A teaching strategy in which instruction begins at a level encouraging learners' success and provides the right amount of support to move learners to a higher level of understanding (Schunk, (1991:12).

Socio-cultural

(1) A key feature of this emergent view of human development is that higher order functions develop out of social interaction (Lantolf, 2001:137).

(2) Relates to both social and cultural matters (Wells, 1999:20)

1.10 Conclusion

This chapter introduces the research and explains its purpose. It incorporates the background to the study of genetics, motivation to the study, research problem, purpose of the study, research questions, theoretical framework, significance of the study, limitation of the study and finally the definitions of the terms used in the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

People learn in different ways and store their knowledge in form of experiences, which can then be used in future encounters. From the constructivist viewpoint, the stored experiences serve as anchors for the new experiences that, according to Ausubel (1968), are critical to meaningful learning. However, due to the limitation of space, the thrust of this chapter will be limited to conceptual change as a pivotal mechanism in the learning process. The assumption, of course, is that learning be it mental, physical or attitudinal is ultimately stored up as experiences, which may be mobilized in response to a given context. Without the ability to store these experiences, it will be difficult to learn anything. In this regard, one would have to learn the same thing again and again (e.g. Ogunniyi and Taale, 2004).

Of the many aspects that are debated in the conceptual change literature, four issues are described and developed in this part of the literature review - namely, learners' initial conceptions of genetics, nature of conceptual change, factors influencing conceptual change and the role of instruction in bringing about such a conceptual change. To address these issues relevant to the conceptual change, literature was explored in terms of theoretical and practical considerations.

2.2 Theoretical considerations on the learning process

Four research perspectives of learning have emerged from the research process in science education (Eylon and Linn, 1988). These three perspectives, which focus on different aspects of the learner and the processes of learning and instruction, are referred to as concept learning, developmental, differential and problem-solving perspectives. An examination of these perspectives reveals some common ground: (1) the content of science; and the manner in which links between ideas are organised, play an important role in the learning process; (2) the procedures used by the learner to represent and organise knowledge, and the learner's epistemology and ability level are all crucial factors that influence the manner in which learners learn; and (3) the conceptual change model (Posner et al., 1982) as part of the concept learning perspective in which learners' existing knowledge, as well as the content and characteristics of new ideas, has an important role in the learning process.

(a) Learning as a reflection of conceptual change

Conceptual change is a research agenda that has evolved from the alternative conceptions movement that rapidly expanded during the 1980s (Wandersee, Mintzes and Novak, 1994). It differs from other learning theories in that it is an outgrowth of constructivist epistemology in which the growth of knowledge is viewed as a constructive process that involves an active generation and testing of alternative propositions.

The Posner theory has received considerable attention in the science education literature and many studies have used it as a theoretical framework even though these studies have rarely focussed explicitly on the conditions of conceptual change (Hewson and Thorley, 1989). Many studies (Chi, Slotta and deLeeuw, 1994; Hewson and Thorley, 1989; Jenson and Finley, 1995) continue to examine the manner in which learners' conceptions change and refer to the term 'conceptual change' as a theoretical framework. This is a crucial issue, as is shown later, because alternative theories of conceptual change have emerged along with new terminologies. The goal of this chapter is to examine the main issues that are discussed in the conceptual change literature in order to set the scene for discussion of the results of this study.

(b) What is conceptual change?

Before the term "conceptual change" is examined, it is important to clarify the terms "concept", "conception" and "model". Throughout this study, a concept is defined as "a conglomerate of connected ideas which can explain a certain class of problems or situations" (Schwedes and Schmidt, 1992:188). Conceptions are defined as "tangible inside-head constructs" (Linder, 1993:294) that are fundamental beliefs about how the world works which individuals form in response to experiences and in concert with others" (Dykstra, 1992: 44). The difference between the two terms is that a concept is a general word to denote any number of connected ideas associated with a particular word, whereas a conception is the specific set of connected ideas that one person has at one particular time about a certain concept. Conceptual change is related to the changes that occur over time in the conceptions that a learner has for a particular concept. The term 'model', as used here, denotes "the content of thinking" (Bliss, 1995:157). In other words, the models represent or describe a person's conceptions.

A review of the literature on conceptual change published through the eighties and early nineties reveals a range of associated terminologies capable of confusing even the most devoted reader. Terms such as assimilation and accommodation (Posner et al., 1982; Strike and Posner, 1992; Smith, Blakeslee and Anderson, 1993), weak restructuring and strong restructuring (Carey, 1985), branch jumping and tree switching (Thagard, 1991), conceptual capture and conceptual exchange (Hewson and Hewson, 1992), differentiation and reconceptualisation (Dykstra, 1992), and enrichment and revision (Vosniadou, 1994) emerge from the conceptual change literature. Are these various terms recognising discernible differences in terminology for essentially the same aspect, or is there little consonance between the various terms used to describe conceptual change? To date, with the exception of Dagher (1994) who has overtly suggested that, "while different terms are used to describe the types of change, these terms share common ground" (p. 608).

The most striking theme that runs through the various descriptions of conceptual change is that there are "big" changes and there are "small" changes. On closer examination of these descriptions, a dichotomy of two levels of conceptual change emerges (see figure 2.1). At the most basic level, there are changes, which can occur to the conceptual structure, which involve the simple addition of knowledge.

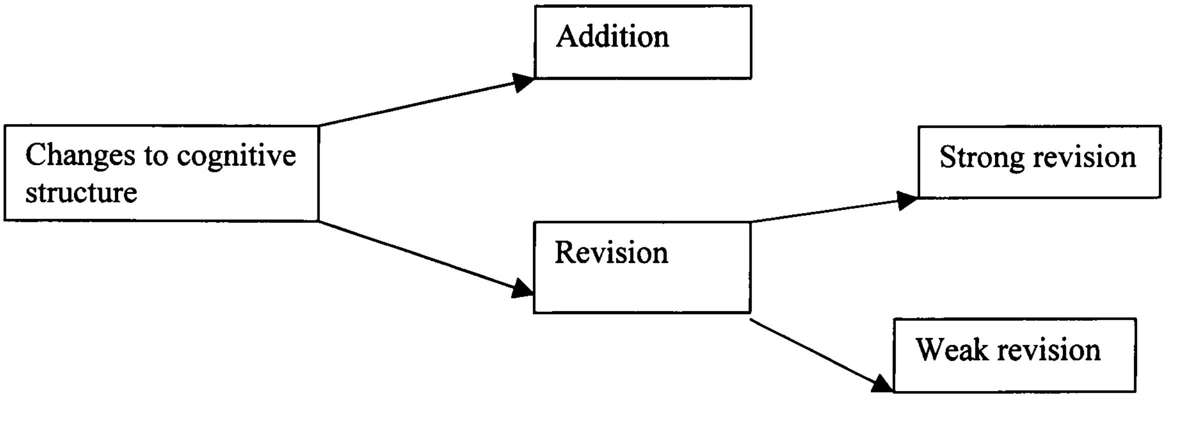

Figure 2.1: A generic model of the dichotomy of levels or kinds of conceptual change as espoused by Vosniadou (1994:47): *Learning and Instruction,* 4(special issue), 45-69.

This kind of conceptual change is described in various ways, either as rote memorization (Hewson, 1981, 1982), as knowledge accumulation that does not involve restructuring (Carey, 1985), as enrichment by the mechanism of accretion (Vosniadou, 1994) or as belief revision (Thagard, 1991). Thagard's (1992) description of conceptual change does not immediately seem to fit into this generic dichotomy because it is of a continuum of varying degrees of conceptual change as illustrated in figure 2.1. He does, however, distinguish between the first three changes as "straightforward kinds of belief revision" (p. 115) and the last two changes as "holistic replacements" (p. 116) that is, "changes that are very difficult to make on a piecemeal basis" (p. 115) and in this sense they can be classified into similar degrees of conceptual change as the other descriptions.

Vosniadou (1994) distinguishes between the most basic level of addition of knowledge and revision or conceptual change (or what he calls "conceptional change"). He says that "additions are easy to teach and learn, and trivial in that they rarely involve reconstruction of the rest of your knowledge about the concept, let alone of other concepts" (p. 118). To learn that Indian elephants have the same number of toes on front and back feet while for African ones the number of toes is different is an example of addition of knowledge to the concept of "elephant". Conversely, White and Gunstone (1992) describe conceptual change as "major shifts, that typically involve detailed explanations of phenomena [that] ... have far-reaching effect on the total meaning we place on a term" (p. 118). An example of the revision kind of conceptual change is when a learner learns how rainbows result from reflection, refraction and dispersion of light. It is interesting that, as explained above, Posner et al. (1982) use the terms assimilation and accommodation to describe the weak and strong kinds of revision. Their work clearly and explicitly focus on the stronger kind of conceptual changes that they call accommodation. Later, Strike and Posner (1985) reassert that their discussion of conceptual change is "more oriented to accommodation than to assimilation" (p. 216).

(c) What happens to the initial conceptions?

There appears to be a consensus that conceptual change is concerned with restructuring of existing knowledge but the perceived 'fare' of this existing knowledge has changed subtly over the past decade. According to Posner et al. (1982) the four cognitive conditions necessary for conceptual change are: (a) the learner must be dissatisfied with existing conceptions, (b) new conceptions must be intelligible or understood, (c) new conceptions must be plausible, helping to solve past experiences as well as reconcilable to existing conceptions, and (d) new conceptions must be fruitful and have the potential to solve problems that existing conceptions are not resolvable by present conceptions. Once these conditions have been met, then conceptual change can occur. In order for learners to successfully navigate the components of conceptual change, learners would need to engage in metacognitive reflection where they re-evaluate their prior conceptual frameworks and compare them with new ideas to ascertain whether the new ideas were plausible and fruitful (Pintrich et al., 1993).

The condition of dissatisfaction discussed by Posner et al. (1982) implied that a non-scientific conception held by a learner would be replaced or extinguished if the four conditions of the conceptual change model were met. This inspired a number of teaching strategies including conceptual conflict instruction (Hewson and Hewson, 1984) designed to help foster dissatisfaction and to remove alternative conceptions held by learners. Many researchers are now of the view (Garnett, Garnett and Hackling, 1995; Gunstone, 1994) that cognitive restructuring may occur without extinguishing prior conceptions. Duit (1994) states that:

> There is no single study listed in the leading bibliographies of research on learners' conceptions ... in which a particular learners' conception of the above deep rooted kind could be totally extinguished and replaced by a new idea ... old ideas basically stay 'alive' in particular contexts (p. 8).

Linder (1993) challenged conceptual change models suggesting that learners give up one conception for another. According to Linder, the importance of context in shaping a conception is paramount. He contends that:

> In science itself, there is much conceptual dispersion. It is the essence of context that facilitates divergent conceptualization, for example, how else could we simultaneously conceptualize the very different concepts of time vis-à-vis Galilean and special relativity contexts? (p. 295)

Driver, Asoko, Leach, Mortimer and Scott (1994) suggest that a model of learning which involves the replacement of old conceptions with new ones ignores the possibility of learners having multiple conceptions each of which may be useful in a particular context. Mortimer (1995) expands upon this by proposing the notion of a conceptual profile that makes it possible to use different ways of thinking in different domains and that a new concept does not necessarily replace an old one. Schwedes and Schmidt (1992) present a specific example of such a phenomenon in a case study of Marc who participated in a series of interviews and teaching lessons. The purpose of the case study was to investigate the conceptual change from the very common preconception in the domain of simple electric circuits of current consumption to the concept of an electric circuit where the interdependence of current, voltage and resistance is realized. The observation by Schwedes and Schmidt that the old conception is not immediately extinguished and is in competition with the new conception clearly leads to a discussion of the status of competing conceptions.

(d) What is the nature of learners ' conceptions?

Posner et al. (1982) focused explicitly on the status of learner's conceptions arguing that in order for a new conception to be incorporated into his/her schema the status of the conception must be raised by fulfilling a number of conditions. The conditions necessary for conceptual change to occur as indicated in the previous section are *dissatisfaction* with existing conceptions; *intelligibility* of the new competing conception; *plausibility* and *fruitfulness.* Posner et al. (1982) imply that in raising the status of a new conception the above conditions will be fulfilled in a linear manner starting with the dissatisfaction of the existing scientific conception and proceeding through to the fruitfulness of the new conception. Hewson (1982) suggests that competing conceptions must both fulfill the conditions of intelligibility and plausibility before dissatisfaction can be established with either of the conceptions. For Hewson, dissatisfaction is the key to the change in status of a conception.

Within the context of this study, therefore, a more detailed description of these terms is presented in Chapter 4, where it is directly related to the analysis of the data. The issue of changing the status of conceptions also has arisen within the more recently published literature on multiple representations (Spada, 1994) and the notion of a conceptual profile (Driver et al., 1994; Mortimer, 1995). Caravita and Hallden (1994) use the phrase "flickering status of conceptions" to describe the manner in which an individual will select a conception that is appropriate to a particular context. They describe change as involving "a set of ways of thinking about a conceptual domain, which are elicited in specific contexts of action and discourse. It results in an opportunistic differentiation among contexts of interpretation" (p. 89). Two questions that need to be addressed by conceptual change researchers relating to the status of learners' conceptions include: (a) how can the change in status of a conception be measured? (b) And how stable is the status of a scientifically correct conception once it has been achieved?

The early work on conceptual change assumed that prior conceptions held by the learner would be eliminated perhaps through a process of creating dissatisfaction in which the learner questioned the fruitfulness of the existing conception. The status of the existing conception would be lowered and then the process of raising the status of the new conception would begin. A successful learner would be viewed as one who has low status for alternative conceptions and high status for scientifically correct conceptions.

(e) Is the age of an individual relevant to conceptual change?

According to Biggs and Telfar (1981) throughout the lifespan of an individual, there are periods that may be characterized by the development of different physical and cognitive skills. A sketch of these developmental periods might be as follows: Infancy (birth to 18 months), early childhood (18 months - 6 years), childhood (6 - 12 years), adolescence (12 - 17 years), early adulthood (17 - 40 years), middle adulthood (40 - 60 years) and late adulthood (60 + years). According to Levinson, Darrow, Klein, and McKee (1978), there is increasing differentiation and integration of concepts as the cognitive structure grows and a cyclic form of development with periods of stability followed by instability is evident. Piaget categorized the development of intelligence from birth to age 15 years in four stages: a sensorimotor period from birth to age 2 years; preoperational from 18 months - 7 years; a concrete operations period from ages 7 to 11 years; and the commencement of formal operations ranging from ages 11 to 15 years. These ages are only approximate and have been subject to criticism, but the sequence of development is assumed to occur in almost every child.

Perry's Model of Intellectual Development (Finster, 1989) expands upon this notion of adults' reflective thinking capacities. Perry describes a series of stages that individuals pass through as they move towards intellectual maturity. The first of these is referred to as *dualism* in which a learner perceives that there is one correct answer to a problem, that truth is absolute and that uncertainty is temporary. Knowledge is considered to be right or wrong. In the second stage of *multiplism,* diversity and uncertainty are accepted and individuals are entitled to their own opinions. Then there is a period of *relativism* in which the learner recognizes that knowledge is contextual and relative. These first three positions are mainly concerned with epistemology and intellectual development whilst the final stage *commitment in relativism* is concerned with ethical issues and identity development.

If it is accepted that an individual's cognitive structure changes both qualitatively and quantitatively with increasing age (Bodner, 1986) then what are the implications of this for a generalized theory of conceptual change? Would Posner's et al. (1982) conditions of intelligibility, plausibility and fruitfulness be applicable to all types of conceptions across all age groups? For individuals who have achieved a relativist stage of intellectual development, it may be that the status of their conceptions change depending upon the context in which they are operating. It would seem reasonable that, as an individual develops his or her intellectual capacity, the importance of the metaphysical aspects of conceptual change will increase. If this is the case, then the age of an individual is likely to be relevant to a theory of conceptual change.

(f) What teaching approaches are there for conceptual change?

Overviews of conceptual change teaching approaches outlined and evaluated in the science education research literature have been presented by Duit (1994), Scott, Asoko and Driver (1992), and Smith, Blakesbee and Anderson (1993). The first two of these reviews make similar distinctions, which emphasize conceptual conflict and the resolution of the conflict by the learner and those strategies, which build on learners' existing knowledge structures. Duit refers to these strategies as discontinuous and continuous. Continuous pathways "start from aspects of learners' conceptual structures that are already mainly in accord with the science conceptions or reinterpret learners' ideas" (Duit, 1994, p. ii). Examples of this kind of strategy include bridging analogies to promote the learning within the field of mechanics (Brown and Clement, 1989), the use of analogical relations to help learners understand the conservation of matter during evaporation (Stavy, 1991), and allowing learners to arrive at a conscious understanding of the differences between everyday-life thinking and scientific thinking (Schecker and Niedderer, 1996).

Concept mapping and Vee diagramming

This study employs concept mapping and Vee diagramming as developed by Novak and Gowin as a way of capturing a picture of the learners' understanding of the portal concept (Novak and Gowin 1984). The *concept map* (see Figure 2.2) when constructed by learners is said to help learners demonstrate the use of language labels to construct concept and propositional relationships about a domain of knowledge. A concept map thus serves as a tool to illustrate the hierarchical, conceptual/propositional nature of knowledge. It also serves as a tool to help learners organize their cognitive frameworks into more powerful, integrated patterns. Thus, concept maps have been found to serve both as metaknowledge and metalearning tools. Concept maps developed by Novak and Gowin, and as used in this study, usually start with a general concept at the top of the map, and then works their way down through a hierarchical structure to more specific concepts. Concepts are placed in a box, while linking words are not. Sequences of concepts and linking words do not always form grammatically correct sentences. This style is simple and elegant. One can express complex and powerful ideas with a minimum of graphic elements. This, of course, does not prevent one from constructing maps with different shapes of boxes, lines of different colours, multiple fonts, and other fanciful features, so long as one makes an effort to avoid the mapping equivalent of 'chart junk': graphics where the very fancifulness and impressiveness of the graphic impedes the viewer's ability to clearly understand the information the graphic attempts to convey. Figure 2.2 below is an example of a concept map of components of the universe.

Along with concept mapping, Vee diagramming is a heuristic device that can be used to visually organize science concepts and ideas. It was developed by Gowin and can be used to illustrate key ideas regarding the nature of knowledge and the process by which new knowledge is made in science investigations (Novak and Gowin, 1984). *Vee diagrams* (see Figure 2.3) are tools that help learners to construct the interacting set of elements that are involved in knowledge production. The Vee serves as a scaffolding or normative device assuring that all of the elements receive due consideration in the process of seeking knowledge and value claims directed by the focus question. Some argue that Vee diagramming is more challenging than concept mapping for both learners and teachers.

This view derives in part from the *positivist* philosophy embedded in most school and college learning, whereas Vee diagramming is rooted in an event-centered and *constructivist* philosophy (Novak, 1993a). Figure 2.3: Gowin's (Novak and Gowin, 1984) Vee showing epistemological elements, which are involved in the construction or description of new knowledge. All elements interact with one another in the process of constructing new knowledge or value claims, or in seeking understanding for any set of events and questions.

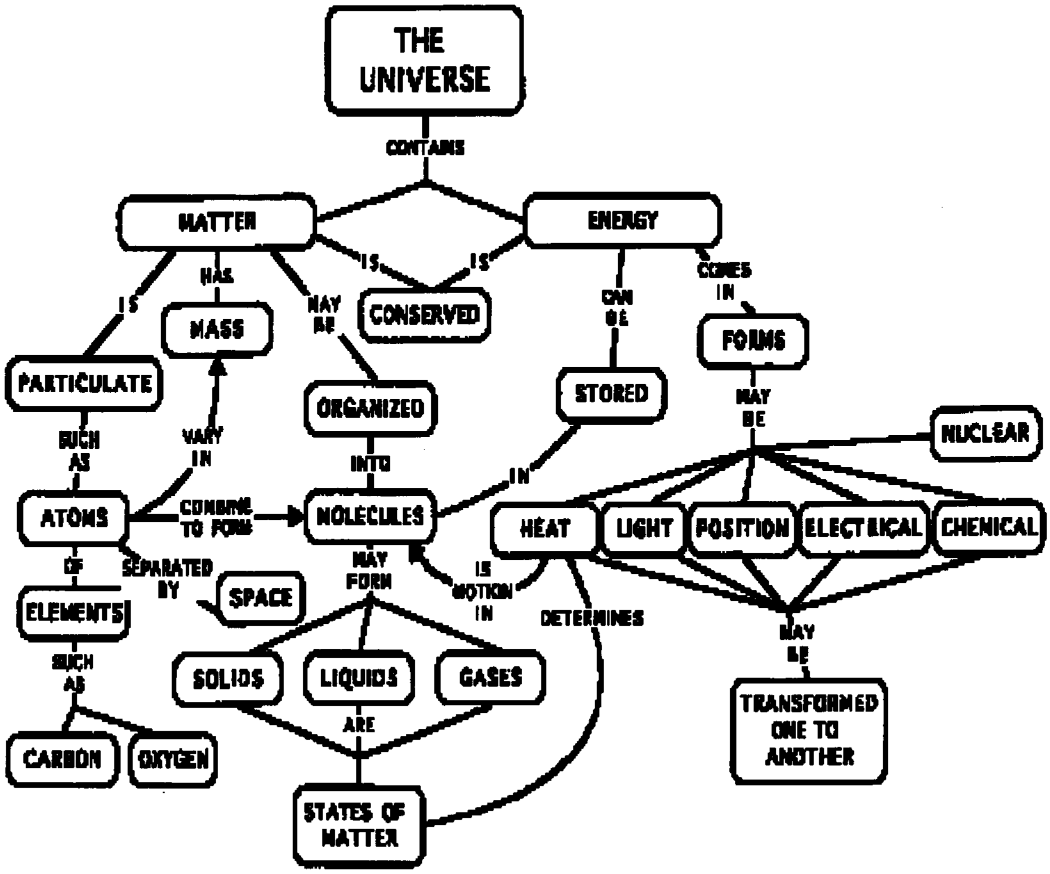

Figure 2.2 An example of the basic Novakian-Gowinian concept map (Novak, 1991:170). ***The Science Teacher, 58*****(7), 167-193).**

Concept maps and Vee diagrams are valuable tools that help learners "unpack" the knowledge in text, laboratory or lectures, and they are powerful tools for curriculum design. These metacognitive tools show promise not only for the improvement of learners, but also for the empowerment of teachers and curriculum planners (Novak and Gowin, 1984; Mintzes, Wandersee, and Novak, 1998; Novak, 1993b; 1998).

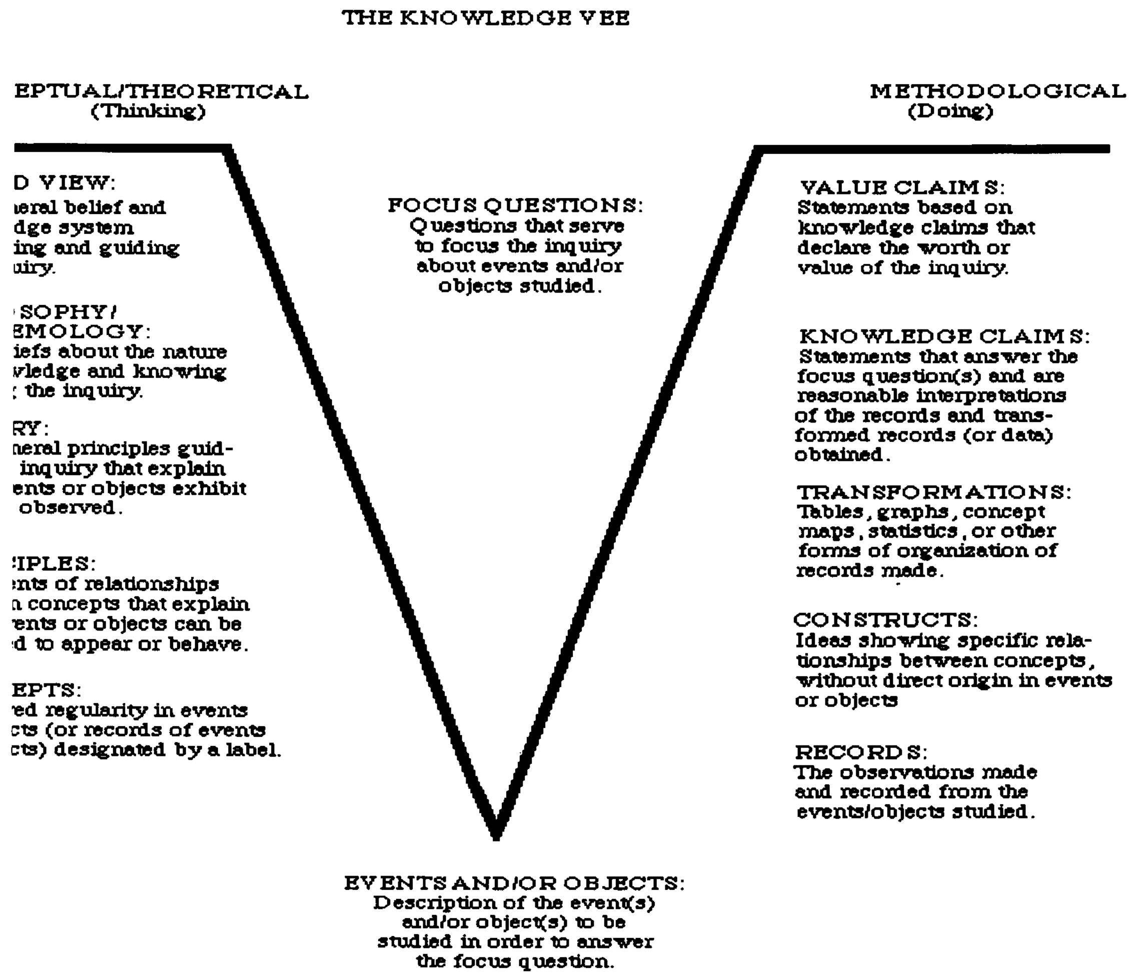

Figure 2.3: Gowin's Vee diagram showing epistemological elements ((Novak, 1991:167) *The Science Teacher, 58*(7), 167-193).

2.3 Practical considerations

As indicated in chapter 1, the concept of genetics is one of the areas of the biology syllabus in which learners encounter great difficulties. These practical difficulties are summarized in the sections that follow.

2.4 Main difficulties in the study of genetics

The main domain-specific difficulties identified in the literature on genetics education, can be divided into four categories:

a) Domain-specific vocabulary and terminology
b) Mathematical content of Mendelian genetics tasks

c) Abstract nature due to the sequencing of the biology curriculum
d) Complex nature of genetics: a macro-micro problem.

It has to be noticed that these problems are not isolated problems, but tied together. In the sections that follow, effort will be made to highlight these problems as printed in the extant literature.

(a) Domain specific vocabulary and terminology

One source of confusion and error in genetics education is the extensive and complex technical vocabulary of genetics. Learners are often not confident with the definitions of the genetics related words, and there is confusion because terms look and sound very similar, e.g. homologue, homologous, homozygous and homozygote (Bahar et al., 1999). In school practice, the genetics vocabulary is introduced to learners by three sources: the teachers, the textbook and the requirements of examinations (Pearson and Hughes, 1988). Unfortunately, the vocabulary of genetics is not always used consistently by these three different sources, and therefore a source itself can induce confusion and error. Moreover, the genetics terminology is extensive, so textbooks and teachers need to be selective and specific in their use of genetics terms, and avoid using too many synonyms. Learners can be easily overwhelmed by the number of new genetics terms.

Radford and Baumberg's (1987) glossary of terms in teaching genetics mirrors the need for accurate and consistent terminology for genetics in the educational field. Concerns about the use and misuse of terminology in genetics have been expressed by several authors, e.g. Evans (1974; 1976) and Cho et al., (1985). Pearson and Hughes (1988a; 1988b) reviewed the literature on problems related to the use of terminology in genetics education. They classified the different types of difficulties as: a) misuse of terms, b) existence of synonyms, and c) occurrence of redundant and obsolete terminology. An example of the misuse of terms is the incorrect use of the terms 'gene' and 'allele' as synonyms, which is propagated by textbooks and teachers that use these two concepts as interchangeable (Cho et al., 1985; Pearson and Hughes 1988a). Errors arise when these sources use phrases such as 'the gene for red coloured flowers' instead of 'the allele for red coloured flowers', or a 'lethal gene' instead of a 'lethal allele'. Not the gene is lethal, but the expression of a certain allele of a gene can be lethal to an organism. Due to this misuse of these genetics terms as synonyms, the misconception arises that the terms gene and allele are interchangeable. Besides, in the molecular biological context, the (true) synonym cistron is used for gene. This use of synonyms creates even more confusion for learners. Some authors (e.g. Smith and Good, 1984; Kinnear, 1983) propose the need to remove the term 'allele', because it is used inconsistently and inaccurately by the different sources (textbooks and teachers). In their view, the term 'gene' is sufficient for an adequate understanding.

Besides the misuse and use of synonyms by textbooks, teachers, and examinations, learners often misassociate terms. The term 'dominant' for instance is confusing for most learners. They often misinterpret the term 'dominant' as a synonym for frequent (Smith and Good, 1984; Kinnear, 1983), and a common idea is that 'dominant' alleles are 'good' and are needed to mask the effect of 'bad' recessive alleles (Pearson and Hughes, 1988; Mahadeva and Randerson, 1982). Learners often conclude that due to its strength the dominant allele should become more common in the course of evolution (Heim, 1991). In their view 'dominant' is frequent and stronger, and 'mutations' are rare and usually recessive.

Terms often have different meanings depending on the context of use. Plethora of studies has shown for instance that mutation is often associated with the idea of change. In fact some learners consider the term synonymous with biological developmental changes (Albaladejo and Lucas, 1988). Their study involved a group of learners from a Catalan language. In the Catalan language the term 'mutation' has a range of meanings in everyday language. Also, Pearson and Hughes (1988) reported on the term 'mutation' used for a variety of processes, which produce genetic changes. This concept is usually presented incorrectly in textbooks. Mutations are described as rare, harmful and recessive events. But mutations are changes in the DNA molecule and the expression of mutations may be rare, harmful and recessive, depending on the environment in which the organism lives at a given time (Mahedava and Ranederson, 1982). Likewise, the understanding of the concept 'linkage' is dependent on the ability of learners to differentiate the many senses in which the terms 'linkage' and 'linked' are being used in genetics (Kinnear, 1991).

Besides the misuse of terms and misassociation of terms, obsolete or redundant terms (i.e. terms which no longer have any real meaning) are also sources for confusion. For instance, the term 'element' used by Mendel has been replaced by the term 'factor' and since 1909 by 'gene'. Longden (1982) argues that 'chromatid' is a redundant term, because it adds nothing to the understanding of the process of cell division and DNA replication and is a possible source for confusion. The terms 'chromosome', 'homologous chromosomes' and 'chromatid' in particular confuse learners - firstly, because they look similar and, secondly, because the term 'chromosome' is being used for different concepts in different contexts. 'Chromosome' is synonymous with a DNA-strand in the context of duplication, with a 'pair of chromatids' during mitosis and meiosis, and with every individual chromatid after they have separated.

In conclusion, biology, and in particular school genetics, is complicated by imprecision in the use, and a lack of consensus of the meanings of particular terms (Institute of Biology, 1987). The question remains as to how to solve the problems learners have with the genetics terminology. Pearson and Hughes (1988) suggest that an adequate selection in the use of genetic terms in education should be made to prevent extensive terminology to avoid confusion. However, they do not offer the selection criteria. Besides, the discussion among authors on the genetics terminology shows that using the genetics terminology appropriately is not easy, not even for genetics education researchers (Smith, 1991; Browning and Lehman, 1991).

(b) Mathematical nature of Mendelian genetics tasks

Various studies have shown that the mathematical nature of Mendelian genetics is another source of difficulties that learners face in learning genetics. Although learners often understand the probabilistic nature of real-life problems and have no difficulties in determining the chances, they tend to fail when they have to apply the same chance events in the context of genetics (Kinnear, 1983). It seems that learners have difficulties in transferring the mathematical knowledge and insights from one context to another. The mathematical expressions, which are symbolic, cause the problems that learners face (Bahar et al., 1999). Learners indicated that a lot of symbols are used in genetic crosses and that they do not understand the crosses because they are not good in mathematics. The problems learners have with the mathematical nature of genetics are also due to the fact that the symbols are not used consistently by teachers and textbook writers (Bahar et al., 1999).

Therefore, it is not surprising that Thomson and Stewart (1985) found that learners often manipulate symbols and adjust algorithms without correct insight into the underlying genetics laws. Learners also often use the Punnett Square routinely without considering the probabilistic nature of meiosis and genetics (Kinnear, 1983). The Punnett Square model is a grid showing symbolic representation of gametes from parent organisms on the outside and combined symbols on the inside. The grid represents a statistical array of possible gametes and zygotes. Learners have to pick ratios by either appearances (phenotype), or genetic makeup (genotype) out of the Punnett Square, or have to answer probability questions concerning possibilities of appearance of a certain trait. One of the main problems is that learners perceive ratios in genetics as deterministic (Collins and Stewart, 1989), which may be due to the automatic use of the Punnett Square model. They may think that ratios are fixed by frequent and rote use of Punnett Squares in solving a problem (Longden, 1982). Cho et al., (1985) showed in their content analysis of the three main biology textbooks used in the United States of America, that these textbooks do not mention the limitations of using the Punnett Square in solving genetics problems, and that they do not relate Punnett squares to the biological processes and concepts like the random segregation of chromosomes. By placing emphasis on rote procedures it is likely that learners think that ratios are fixed and perfect.

(c) Abstract nature due to the sequencing of the biology curriculum

The difficulties in learning genetics are commonly associated with the relationship between meiosis and genetics and the sequence in which the topics have been taught. As already explained in section above, school textbooks are sources of misunderstandings. Cho et al., (1985) investigated the three most widely used biology school textbooks in America (Otto et al., 1981) and concluded that the conceptual organization of these schoolbooks is inadequate. The three textbooks discussed meiosis before genetics, and treated the two as separate topics. Moreover, the topic of meiosis was isolated from that of heredity, and Mendelian genetics was discussed within the chapter heredity. Since meiosis deals with the separation of alleles during sexual reproduction and genetics concerns the tracing of alleles from parents to offspring, these two concepts should not be separated in the textbooks, but the relations between them should be made explicit (Tolman, 1982). Other authors (Longden, 1982; Kindfield, 1994) suggested that the difficulties learners encounter in learning genetics are due to the delay between the introduction of meiosis and genetics in the textbooks. Tolman (1982) suggests a new sequence that flows from meiosis to genetics, while Ausubel et al., (1978) argue for a sequence, which runs from genetics to meiosis and then to chromosome theory. Which sequence will be best is difficult to say beforehand. But it is important to notice that the difficulties learners have in understanding the genetic relationships could be due to the delay and separation of topics (like cell division, life cycle, Mendelian genetics, and inheritance) in the curriculum by months or even years.

From this point in case, it can be viewed that this fragmentation contributes to the abstract nature of genetics, because learners have difficulties in relating these different genetics concepts. Schoolbooks (and teachers) often do not make these relationships explicit. This could contribute to learners' difficulties in relating genetics tasks with concrete biological phenomena. Moreover, in solving genetic problems, learners have to translate texts and pedigrees in diagrams, which is calling on symbolism and mathematical calculations all at the same time. Learners have difficulties in constructing a symbol key, for which they should be able to differentiate between related structures such as gene and allele, and descriptors such as dominant/recessive and homozygous/heterozygous. Using upper case and lower case letters, subscripts and superscripts, and different combinations of letters and other symbols, can create confusion when learners lack the understanding of how the symbols are related to the concepts of heterozygosity/homozygosity and gene/allele (Thomson and Stewart, 1985). The symbolism and mathematical calculations make Mendelian genetics abstract and difficult for learners, because they are often not able to relate these features to real biological phenomena, like the underlying process of meiosis. Automatic use of the Punnett Square by learners in solving genetics tasks (Kinnear, 1983; Collins and Stewart 1989), without meaningful insight into this model, only enhances the abstract (and 'symbolic') nature of genetics.

(d) The complex nature of genetics: a macro-micro problem

The complex nature of genetics is another reason why genetics is difficult to learn and to teach (Bahar et al., 1999; Collins and Stewart, 1989). The structure of the content knowledge of genetics is complex, and learners have to use this complex knowledge in solving complex genetics tasks (Collins and Stewart, 1989). Genetics concepts refer to different levels of biological organisation, and learners have difficulties with linking these different genetics concepts and processes with these different levels. Several science education researchers noted that when concepts and processes of a subject belong simultaneously to different levels of organisation, learners have difficulties in learning the subject (Lijnse et al., 1990; Sequiera and Leite, 1990). Mind that researchers in the different science disciplines appoint the levels of organisation differently. Marbach-Ad and Stavy (2000), who investigated learners' cellular and molecular explanations of genetic phenomena, distinguished the macroscopic, microscopic and sub-microscopic level in genetics (biology). They suggested from their study, in which they investigated three relatively large populations of 9th graders, 12th graders and pre-service biology teachers, that learners should first be exposed to various phenomena in human beings or higher organisms, in macro-terms only. So they suggest starting on the macro level, and when dealing with the micro-level and trying to link the macro- with the micro level, it would be better to deal with lower organisms.

Johnstone (1991) introduced a model that distinguishes three levels of thought in chemistry education, the macro-, the micro- and the symbolic level. His macro-level refers to tangible and visible concepts, and the micro to 'invisible' concepts, like 'compound' and' elements'. In chemistry the elements are represented by symbols in reaction equations. He declared that in much teaching, the three levels are mixed up and dealt with simultaneously, and that teacher may be unaware of the demands being made on the learners. He argues for teaching chemistry on the macro level only, instead of inflicting all three levels simultaneously on learners. Moreover, Johnstone draws a comparison between his levels of thought in chemistry with those in physics and biology. In a later study with Bahar et al., (1999) he applied the three levels model to the subject of genetics. They argue that the complexity of genetics is connected with the occurrence of ideas and concepts on these different levels of thought: the macro (plant of animal), the micro- (cell), and the biochemical level (DNA). They explain that a lot of processes on the macro-level are elucidated at the sub-macro (micro) level (like genes and chromosomes), which are represented by symbols (e.g. Aa and II). With these symbols learners have to calculate ratios and probabilities. Often they have to reason back from this level of representation to the macro-level, for instance when they have to determine the probability of a certain genotype and translate it into a phenotype answer. Bahar et al., (1999) suggest that in teaching practice, teachers should confine themselves to one level at a time. Learners have to develop this thinking on the different levels of thought, gradually. It has to be noticed that Johnstone firstly differentiated three levels of thought instead of levels of biological organisation. In chemistry, the macro-micro division may be sufficient, because in general there is only distinction between compounds, molecules and elements. However, in biology there are more levels to be distinguished such as the 'supramacro' level of populations and communities. Consequently, Johnstone's model would not be (completely) applicable to biology.

The above discussed studies show that different researchers are reporting on the difficulties in relating concepts on the macro- and micro levels in science education. In genetics many concepts are on the micro- and sub-micro level and are beyond senses, such as DNA, genes, and chromosomes. Learners have little or no experience in constructing such concepts (Bahar et al., 1999; Johnstone, 1991). Maybe they know the definitions, or are able to solve pedigree problems or use Punnett squares by applying tricks, but often they have no real understanding of and insight into the related concepts. Marbach-Ad (2000) also showed that learners may use concepts and terms from the micro level, like 'gene/DNA is encoded for a trait', but they were unable to explain the mechanisms and intermediate stages involved in the link. Learners used, for instance, the correct genetic term in answering a question, but the additional interviews revealed that the learners used a concept of 'gene' (micro level) as synonymous with 'trait' (macro level). So, using proper terms in answering genetic questions does not necessarily indicate that a learner understands the scientific meaning of a term. This risk in misinterpretation of learners' understanding of genetics has also been noticed by Stewart et al., (1990).

Summing up, science education researchers are well aware of the difficulties learners experience with interrelating the macro-, micro and sub-micro level. Genetics is a complex subject to learn and to teach, because genetics concepts are linked to different levels of organisation, and learners have difficulties in interrelating the genetic concepts and processes of these different levels. Almost all the above-discussed studies advise to start education of a (science) topic on the concrete macro-level, i.e. the organismic level in biology.

2.5 Review of studies on conceptual change in genetics

Tyson, Venville, Harrison, and Treagust (1997) investigated a three-dimensional analysis of conceptual change in grade 10 genetics classes. The study was to investigate the extent to which computer multimedia brought about learners' conceptual change of genetics. Learners' conceptual learning was analysed and interpreted within Tyson et al.,'s (1997) framework along the social/affective dimension (motivations and interests), the epistemological dimension (genetics reasoning), and the ontological dimension (change in gene conceptions). The findings indicate that a multidimensional model of conceptual change could assess learners' learning of genetics effectively. However, learning outcomes in the social/affective dimension were more evident than in the epistemological and the ontological dimensions. The findings also have implications for using interactive and online multimedia in teaching and learning science for conceptual change. Although interactive computer programs may hold promise in providing new opportunities for classroom learning, there are new learning costs for learners and challenges for teachers (Ainsworth, Bibby, and Wood, 1998) such as how to support low-achieving learners in their learning. It is believed that the teachers' role remains a critical determinant of how technology can support conceptual change learning.

Ogunsola-Bandele and Oyedokun (1998) examined the effectiveness of a conceptual change teaching strategy over the traditional method on 152 high school learners' attitudes towards learning biology. The study employed a two-group experimental control design. The experimental group was taught using a conceptual change teaching strategy. A 21-item instrument that was validated and based on a three-point scale was administered to the learners. Analysis of the learners' post-instructional attitude towards the strategy suggested that there was a significant difference in the attitude of learners in the two classes after the treatment. The Mann – Whitney U-test value of the groups was significant and led to the rejection of the only hypothesis.

The goal of a study by Coleman (1998) was to examine whether a "scaffolded" explanation-based intervention - that uses procedural (explanation) prompts requiring learners to explain, justify, evaluate and contrast their personal knowledge with scientific knowledge - promotes learners' conceptual understanding of photosynthesis" (p. 391). The study was conducted in Canada, with 4th and 5th grade learners, described as upper- to middle-class. The subject matter was photosynthesis. This study was unusual in that all the conditions used Concept mapping, both as an assessment tool but also as a learning tool. The treatment involved some recurrent prompts that required the learners to explain, justify, etc., the decisions they made while engaging with the Concept mapping as a learning tool. That is, all groups did essentially the same thing. The difference had to do with the "explanation" requirement in the treatment group. The study investigated the concept of "intentional learning" (e.g., Bereiter and Scardemalia, 1989). Intentional learning involves an active, inquiry-based, approach to learning, which is often associated with enhanced learning outcomes. A number of instruments were utilized. First, there was a problem solving or "intentional learning" instrument (the Individual Implicit Learning Theory Interview, IILTI). This is an instrument that measures degree of "intentional learning approach" employed by learners. The basic assumption was that learners scoring high on this instrument would already be using active learning strategies associated with intentional learning. If these were introduced in the learning of lower scorers, the lower scorers could raise their learning achievement to the level of those scoring high on intentional learning. Achievement was measured in three different ways. There was a Comprehension Test with multiple choice questions said to measure both declarative knowledge and higher-level "inferential knowledge." There was a Concept mapping task, in which learners were presented a set of concepts and were required to link up the concepts using a list of links generated by an expert and the researchers. Then all groups attempted to solve the problems and were given incremental hints until they were successful. Concept Map groups were nearly identical and IILTI group required only half as many hints.

2.6 Studies on instructional strategies

2.6.1 Studies with random assignment of learners to conditions

The purpose of a study by Esiobu and Soyibo (1995) was to test effects of Concept mapping and Vee diagramming in different forms of instruction, e.g., small group vs. large group, cooperative, vs. competitive. The study took place in Nigeria and involved secondary school learners (said to be equivalent to tenth grade high school learners in South Africa). The subject matter was ecology and genetics. This was a large-scale study with 406 learners in the treatment groups and 402 in the controls. Achievement was measured by three specially developed tests (all 40 item multiple choice): a biology achievement test, an ecology achievement test and a genetics achievement test. The results were that learners in the treatment conditions greatly outscored those in the controls in all learning conditions. There appear to have been some general benefits of cooperation as well. This is one of the strongest demonstrations of the educational effectiveness of Concept mapping to be found. Unfortunately, as is the case in many pertinent studies, the effects of Concept mapping are confounded with those of Vee-diagramming.

2.6.2 The addition of concept mapping to instruction would aid achievement and reduce anxiety toward biology subject matter

The goal of Jegede, Alaiyemola and Okebukola (1990) was to test whether the addition of Concept mapping to instruction would aid achievement and reduce anxiety in the particular subject matter of nutrition in green plants and respiration in cells. The treatment group was familiarized to Concept mapping for three weeks before the start of the study. It is difficult to determine what the learners actually did during these three weeks. The report can be interpreted to mean that this instruction focused entirely on the philosophy and construction (practicing) of Concept Maps and not on biology. The only statement in this regard is "The control group was introduced to the treatments' science concepts via expository teaching, which was devoid of any metacognitive strategy" (pp.953-954). Again it is not clear what the control group was doing during these same three weeks. The results were fairly dramatic in favor of Concept mapping. There were positive Effect Sizes in favor of the Concept Mappers of 2.02 for achievement, and 1.01 for anxiety reduction. There are various aspects of this study that could make one wary. What exactly were the learners doing during the three weeks of warm-up? What, in any detail, were they actually doing during the experimental phase? In addition, classes were randomized, not learners. Another concern is with the control group. The changes from pre- to post-test seem quite large in the treatment group (over ten scale points), but there was essentially no change at all in the control group. As with Bascones and Novak (1985), one is left wondering about the nature and quality of the instruction within the control class.

2.6.3 Testing the effectiveness of concept mapping on high school biology achievement to assess learner's academic ability level

Schmid and Telaro (1990) sought to test the effectiveness of Concept mapping on high school biology achievement and to assess this by learner's academic ability level. The study was conducted in Montreal, Canada and involved learners at levels "4 and 5" of the Canadian system. The subject matter was a unit of a biology course on the nervous system. The experimental design combined Treatment and Control crossed with three levels of Academic Ability (high, medium, and low). The tests used for measuring biology achievement were all composed of a combination of items taken from state examinations, textbook questions, and teacher-made questions.

As in Esiobu and Soyibo (1995), the Concept mapping seems to have been used as an integrating and consolidating experience after some body of traditional educational presentation. Although the Concept mapping group generally surpassed the control on the criterial tests, the only statistically significant result of particular interest is that in the lowest ability groups the Concept Mappers greatly outperformed the controls, but only on the special part of the post-test that was supposed to measure relationships among concepts etc., the "mapping-friendly" section of the exam -the effect size on this part was approximately 1.4. The number of learners in the statistical comparisons was quite small and test duration was short. These factors could account for the fact that the results, while generally favouring the Concept mapping groups, showed only one statistically significant effect. The results did indicate that the helpfulness of Concept mapping increased as groups went from high to medium to low ability. The authors speculate that Concept mapping helps low ability learners because it requires them to take an organized and deliberative approach to learning, which higher ability learners are likely to do anyway.

2.6.4 Studies in which an alternative educational intervention was compared to concept mapping

A study by Spaulding (1989) addressed the effects of concept mapping versus "concept defining" on learning achievement in biology and chemistry. The study was conducted at a Florida public high school said to have average ability learners. The subject matter was chemistry and biology, not further specified. The design involved two conditions, Concept mapping and "concept defining" as the control. Four biology and two physics classes were assigned in equal numbers to the two conditions. It is not clear how this assignment was made. The biology classes involved 107 learners, and the physics classes 44. General aptitude (i.e., prior achievement) was measured by the CTBS (Comprehensive Test of Basic Skills) standardized test. To measure achievement, a test was constructed to cover the content to be addressed during the period of the study. This test is not described in any detail. The pre-test (the CTBS) was administered one week in advance of the experiment. During the following week, the treatment groups were taught and practiced Concept mapping. It is not stated what kind of material or subject matter was the topic for the practice. The study utilized intact classes. All received their regular course of instruction. However, 15 minutes before the end of each class, groups in both conditions were given a set of concepts covered in the instruction. Concept Mappers were asked to Concept Map them, and "definers" were simply asked to define the concepts. (There is no specification of exactly what form this "defining" took.) Materials from both groups were then handed in and graded, and returned to learners the next day. The achievement test was given at the end of three weeks. The results showed no differences between Concept Mappers and Definers. There was also no differential effect for chemistry vs. biology. The statistical interactions indicated that lower ability (as defined by the CTBS) learners performed better with Concept mapping, and higher ability learners performed better when just defining the concepts.

2.6.5 Summary

These studies allow us to sketch some patterns of use that appear to enhance the learning effectiveness of Concept mapping and Vee diagramming. First, when Concept mapping is used in a course of instruction, it is better that it be an integral, on-going feature of the learning process, not just some isolated "add-on" at the beginning or end. In this regard, Concept mapping appears to be particularly beneficial when it is used in an on-going way to consolidate or crystallize educational experiences in the classroom, for example, a lecture, demonstration, or laboratory experience. In this mode, learners experience an educational event and then use Concept mapping in a reflective way to enhance the learning from the event. There are also indications that learning effects are enhanced when in the course of Concept mapping learners adopt an active, deep and questioning approach to the subject matter. Such active, self-engaging, transformational interaction with learning material has been suggested to enhance learning in general (e.g., Duit,

1994) and this appears to carry over to learning with Concept Maps as a tool. This kind of interaction can be engendered by a teacher/facilitator who challenges the learner to, for example, explain, justify, and formulate questions in the course of building a Concept Map. It can also be induced by the nature of the Concept mapping task itself, as when learners are to find and correct the errors in an "expert's" map. When Concept mapping is compared with other sorts of activities, such as outlining or defining concepts, that also can induce the learner to take a thoughtful, systematic approach to engaging subject matter - the positive benefit of Concept mapping often diminishes (a finding noted also in the review by Horton, 1993). However, even in these situations, it appears that Concept mapping is especially good, in comparison to other interventions, for the learning of *relationships* among concepts.

From several of the studies reviewed, there are indications that Concept mapping may be particularly beneficial for lower ability learners, partly because it does induce the active, inquiring, orderly approach to learning that is likely a more natural part of the higher ability learner's approach to learning. On the other hand, when learners *are not yet facile* with constructing concept maps, there is some indication that the cognitive load of creating maps from scratch may hinder learning. When learners are novice mappers, other "scaffolding" ways of interacting with concept maps, for example, filling in the blank content nodes of a concept map already containing the labelled relationships of a completed concept map, may be beneficial. Finally, the degree of facility with the Concept-Mapping procedure necessary to optimise the benefits of constructing Concept Maps from scratch is an issue open for investigation.

2.7 Problems associated with constructivist theory of conceptual change

During the last twenty years, many theoretical approaches on conceptual change have been developed. The classic approach of Posner et al. (1982) and its revised version (cf. Strike and Posner, 1992) is considered to support a radical form of conceptual change. Science educators faced several difficulties when they attempted to put into practice the four proposed conditions (dissatisfaction, intelligibility, plausibility and fruitfulness) in order to promote successful conceptual change. Strike and Posner (1992) criticise their theory for being too linear and overly rational, based on the assumption that learners have well-articulated conceptions or misconceptions for most science concepts. Hewson and Hewson (1992) suggest that conceptual change can be seen through a change of *status* attributed to a particular conception. Chi (1992) differentiates between *normal conceptual change* and *radical conceptual change*. Carey (1991) and Vosniadou (1994) consider a form of *weak restructuring* with elements of *enrichment* of pre-existing knowledge and *strong* or *radical restructuring* with elements of *revision* of prior knowledge and interpretative frameworks. A radical notion of conceptual change is often related to restructuring, revision or accommodation of new conceptions to the learners' existing systems of beliefs or knowledge. Nevertheless, as Duit (1992) contends, there is no documentation of a case where a learner's conception could be completely extinguished and then replaced by a new idea. In this sense, conceptual change may not always be a radical, revolutionary shift in a learner's conceptions of a phenomenon. It can also be a gradual, evolutionary change in the way learners reconstruct their ideas and conceptions. Moreover, learning as conceptual change can be seen as "a change in the way of seeing something" (Marton, 1990). Special teaching strategies, assessment techniques, as well as metaphors, analogies and models often need to be constructed in order to promote the necessary conditions for conceptual change (Scott et al., 1992).

Constructivist approaches to teaching and cooperative-learning techniques can be thought of as having both personal and interpersonal components. Each person constructs his or her own mental frameworks and conceptions using preferred learning styles. However, this is seldom done in isolation. The cognitive developmental perspective emphasizes that participants should engage in discussion in which cognitive conflict is resolved and inadequate reasoning is modified. Language passing back and forth between individuals in written and oral forms is viewed as indispensable for the development of understanding (Belenky et al., 1986; Driver, 1995; von Glasersfeld, 1995). The social interdependence perspective has the assumption that the way social interdependence is structured determines how individuals interact. This, in turn, determines what is accomplished by the group (Marton, 1990).

2.8 Summary and conclusions

In this chapter, six key issues influencing the conceptual change research agenda have been discussed in order to synthesize the theory building and empirical collection of data that has occurred over the past decade and a half. The reviewed literature on genetics education identified four major domain-specific difficulties, described in this section. It has to be noticed that these different problems that learners and teachers perceive in learning and teaching genetics, are not isolated problems. These difficulties are in a way all related to one another and can reinforce the problems learners' experience on the concept. Further, learners face problems in representing genetics texts into schemes and symbols, and *vice versa*, in reading schemes and symbols. Knowledge of the extensive genetic terminology is required for understanding a classical genetic problem. Moreover, they have to do mathematical calculations with those symbols in solving the problem, and to connect these probabilities with biological phenomena. The structuring of the biology curriculum in which the topic of meiosis is isolated from heredity adds to the abstract character of genetics. In this regard, learners have poor understanding of the genetic relationships due to misunderstandings about the process of meiosis and the underlying chromosome behaviour. Also they encounter difficulties in linking the different concepts of the macro-, micro- and sub-micro level. The described domain-related difficulties identified by research into genetics education are relatively well defined and several suggestions have been made to solve these difficulties. Despite this, their implications for educational practice are rather vague and difficult to implement in the classroom; and hence the adoption of a combination of instructional strategies in this study.

A review of the literature seems to suggest that conceptual change does not imply that initial conceptions are "extinguished'. Initial conceptions, especially those that hold explanatory power in non-scientific contexts, may be held concurrently with new conceptions. In other words, successful learners have learned to utilize different conceptions in appropriate contexts. In view of the theoretical and practical considerations relating to the study of genetics, the successes and failures of the instructional methods used to address the problem that learners encounter in the study of genetics, the surprisingly small amount of research on conceptual change in genetics and the inconclusive findings in such studies, it seems apposite that more investigations be carried out to provide additional insight in the area, and hence the present study. That is, the status of one particular conception may change in differing contexts. To date, a surprisingly small amount of research has been conducted on conceptual change in the field of genetics, and that is a good rationale for investigating the genetics content in this mini-thesis within a framework of conceptual change.

Despite the progress that has been made with respect to learners' conceptual change in genetics, the findings remain inconclusive, and hence the present study. It was hoped that the study would provide additional insights into the difficulties that learners encounter in the study of genetics. The method used in the pursuit of this objective is presented in chapter 3.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

According to Ogunniyi and Taale (2004), learners' under-achievement in science has for several decades been a major concern in many countries. Among other factors believed to be contributing to this problem, two of the mostly frequently mentioned in the extant literature are: (1) poor instructional practices and (2) learners' alternative conceptions. If the claim that alternative conceptions exert a stranglehold effect on learners' scientific understanding is valid (e.g. see Aikenhead and Jegede, 1999; Ebenezer and Connor, 1998; Osborne and Freyberg 1985) what instructional strategies could be used to reduce that negative effect? This question influenced my choice of a combination of instructional strategies, which were believed to have the potential for ameliorating grade 11 learners' misconceptions of genetics (i.e. from the curriculum viewpoint, see Ebenezer and Connor, 1998). In chapter 2, a review was made of learners' conceptual change and instructional strategies, especially those involving the use of concept mapping. The purpose of this chapter is to present in detail the design of the study including the procedure for sampling, instrumentation development, data collection and analysis and how ethical issues were addressed. Also, a detailed account of how the learning material was developed has been provided in the chapter.

3.2 Research design

A research design is an investigator's overall strategy for answering the research questions. The choice of the design used in this study was underpinned by the assumption that learners' misconceptions are so varied and multi-faceted that no single instructional style is adequate for remedying such misconceptions. Also, according to Goodman and Alder (cited by Fraenkel and Wallen, 1993), the rationale for choosing one methodology over the other is connected with the nature of the subject under study and the underlying goals of the research. Different instructional methods have their strengths and weakness. Some are better for answering certain types of questions while others are better for yet other types of questions. As Ogunniyi and Taale (2004) have argued, the use of a combination of instructional strategies - rather than one - could assist learners to see the need to revise their own ideas or at least to become aware of other alternative ideas (revealed by different instructional strategies) which they could use in appropriate contexts.

Likewise, the feasibility of an instructional approach could be an important determinant of the type of design chosen. According to Streibel (1995), instructional design theories, such as Gagne's theory, take the cognitivist paradigm one logical step further by claiming that an instructional plan can generate both appropriate environmental stimuli and instructional interactions. These then bring about a change in the cognitive structures and operations of the learner. Gagne investigated the foundations of effective instruction, which he referred to as conditions of learning. The design of any experiment is of utmost important because it ultimately controls the methodological inquiry adopted for such an experiment.

Likewise, Bell (1993) points out that the nature of the research inquiry and the type of information required influence both the approach the researcher adopts and the methods of data collection used. A review of the research literature shows that the best approach is to control for as many confounding variables as much as possible in order to eliminate or reduce errors in the assumptions that will be made. It is also extremely desirable that any threats to internal or external validity be neutralized through a rigorous research design (see Ogunniyi, 1992). In an ideal situation a sound research design should produce predictable outcomes. However, in the real world, such is not often the case, as human subjects tend to act and react to the various stimuli. Besides, these are the constraints of time, space, resources and situations, which often result in a less than perfect condition for gathering data.

Many factors influence the choice of a research design. Some of them are: resources (time, budget, experts), practicalities, purpose of the research, type of data required for the study, and the researcher's ability to effectively apply and use the methods of the research. Taking into consideration these factors, the study was based on a quasi-experimental control group design in that the two groups involved are intact rather than randomized groups. The use of intact groups (classes) is inevitable in that the school principals did not want the research to disrupt the normal life in a biology classroom. However, this limitation is compensated for by the fact that the subjects were studied under real classroom situations. Despite this, the design was considered robust enough for the present study. Two groups, one experimental group E (n=30) and the other the control group C (n=31), were pre- and post-tested on an assessment instrument on genetics known as the "Genetics Achievement Test" (GAT). The GAT test was used to determine the subjects' conceptions of genetics. Some of the items in the GAT were open-ended so that the subjects could make free comments. This was to enable the researcher to probe the subjects' comments and to get further insight into their conceptual difficulties. The GAT has also helped me to obtain additional qualitative data apart from the classroom interaction observation schedule, learner worksheet and the teacher and learner interview protocols. Also, this research used a cloze procedure developed by Taylor (1993) in evaluating language proficiency and content emphasis.

The two groups are similar with respect to their chronological age, sex, achievement in biology and socio-economic status. When the search for schools began, a number of schools were contacted telephonically and by school visits. The timing of the data collection also influenced my choice of the schools; hence the study specifically looked at a particular topic of genetics in biology. A number of much previously disadvantaged schools shied away from taking part in this research citing the topic to be a difficult one, while others preferred to teach the topic in one week or in an even shorter period because they were pressurized by the examinations. Carrying out a research with the former would defeat the real purpose of this study.

The investigation proceeded on the basis of willingness of the two biology teachers, and on the comparable nature of the two schools in terms of similar grade 12-examination results over the past four years, and similar demographics (e.g. learners' home language, age ranging from 16-18 years, and number of boys and girls). The study was carried out in the so-called Model C schools i.e., schools located in the previously advantaged areas of Cape Town. As it is well known, the coloured community is the predominant social group in the Western Cape Province and hence the dominant group in the two schools. Both schools offer English and Afrikaans language. The specific classes were chosen on the basis of their language proficiency in English. Though the experimental school had learners whose home background is mainly Afrikaans compared to the control school which is English, the balance was maintained by choosing a class in the experimental school that had an English stream - commonly called a special class - in the school. Both schools are in the same Education District (North Metropole) though a desirable distance existed between the schools. The experimental school is in Parow suburb and the control school is in Durbanville suburb, a distance enough to minimize extraneous variables in data contamination.

One teacher and one class per school were used for the two research groups. The teacher in the experimental school (E) used a combination of three instructional strategies described later in this chapter on page 40. He is hereafter referred to as the experimental teacher. His counterpart in the control school (C) used the traditional teaching strategies, hereafter referred to as control teacher. The teaching experience of the experimental teacher was 17 years while the control teacher was 21 years. The experimental teacher was exposed to the instructional model for two weeks of training sessions of at least three hours per day (total of 30 hours) from Monday to Friday. The emphasis of issues rising from the training persisted throughout the research study. The control teacher too, was exposed to the "genetics material course" for the same duration from Monday to Friday; however, he was deprived of the instructional models and was left to use biology textbooks of his choice and a teaching style that he deemed suitable.

Learners in the experimental group (E) were exposed to three types of instructional models. The three instructional models are: (1) Concept mapping and Vee diagramming; (2) Martin's (1983) inductive instructional model and (3) Lijnse's (1990) hierarchical conceptual model; while the learners in control group (C) were exposed to the traditional teaching strategy. The control group was used as a means for checking to what extent the experimental group was affected by the three instructional strategies. Concerted efforts were made during the study to ensure that the three instructional strategies were interactive and met the requirements of clarity, simplicity, user-friendliness and conceptual quality. More details about these instructional methods will be provided later. The research design adopted for this study is as follows:

O_1	X	O_2	(Experimental Group)
O_3		O_4	(Control Group)

Figure 3.1 A quasi-experimental control group design

O_1 and **O_3**, represent the pre-test while **O_2** and **O_4** represent post-test observations. The vertical observations, **O_1** and **O_3** were assessed simultaneously at the pre-test stage while **O_2** and **O_4** were assessed simultaneously at the post-test stage. 'X', was the treatment condition.

The method adopted for this study was an eclectic approach in which both qualitative and quantitative approaches were used to complement each other. As Mills (1959) and Berg (1989) argue, studying humans in a symbolically reduced, statistically reduced fashion, posits a danger that conclusions which may be arithmetically precise, may not fit reality. Bell (1993) argues that qualitative studies describe and interpret, "what is in" and they are personal in nature with humanistic concerns and ideologies. The term, qualitative research, means a type of research that produces findings not arrived at by statistical procedures or other means of quantification. It permits the researcher to study selected issues, cases or events in depth and detail. It emphasises the quality of entities and meanings rather than experimentally examined or measured entities in terms of quantity, amount, intensity or frequency (Denzin and Lincoln, 2000)

According to Patton (1987) the qualitative approach has three main perspectives. First, qualitative approaches are naturalistic to the extent that the researcher does not attempt to manipulate the participants for the purpose of his/her own research activities or processes. These activities are "natural", i.e. they are not planned or manipulated by the researcher as would be in the case of an experiment. Similarly, Punch (1994) points out that qualitative research is natural in the sense that it focuses on meanings and attempts to understand the culture of those being studied as well as predisposes researchers to work as far as possible in natural settings.

Second, the holistic perspective implies that researchers using qualitative methods strive to understand situations as a whole. By using this perspective, the researcher searches the totality and unifying nature of particular settings. This approach assumes that the whole is greater than the sum of its parts. According to Punch (1994) qualitative research is also holistic in the sense that it attempts to provide a contextual understanding that affects human behaviour. Third, qualitative research, instead of testing pre-conceived hypotheses, aims at generating hypotheses from the data that emerge, or ground theory, in an attempt to avoid the imposition of the previous, and possibly inappropriate frame of reference on the subject of the research.

Quantitative methods, on the other hand, use standardized measures that fit various options and experiences into predetermined response categories. The advantage of a quantitative approach is that it measures the reactions of many people to a limited set of questions, thus facilitating comparison and statistical aggregation of data. This gives a broad and possibly generalizable set of findings. By contrast, qualitative methods typically produce a wealth of detailed data about a much smaller number of people and cases. Quantitative measures are easily aggregated for analysis. They are systematic and easily presented in a short space. On the other hand, qualitative responses are longer, more detailed and variable in content, and the analysis is difficult because responses are neither systematic nor standardized (Patton, 1987 and Punch, 1994).

Traditionally, qualitative and quantitative approaches have been seen as diametrically opposed, and many researchers still strongly espouse one approach or the other. Flick (1998) argues that such an approach is very parochial and places an undue jacket on research. The social world is complex. It is vital then that consideration should be given to the methods that are appropriate for the particular research problems. However, this opposition is beginning to soften, and more researchers are beginning to see the merits of combining both approaches in response to different research contexts. For example, if the purpose of an investigation is to determine the instructional effectiveness, and its outcomes are well defined, then a quantitative approach may well be appropriate. If, on the other hand, the purpose of an investigation is to determine the instructional effectiveness but the instructional strategies and its outcomes are poorly defined, a researcher might start with a qualitative approach to identify critical instructional features and potential outcomes and then employ a quantitative approach to assess their attainment (Berg, 1989). However, as stated earlier, a combination of the two methods has been adopted for this study. In differentiating qualitative and quantitative strategies, it should be noted that such differences are tendencies not absolutes (Patton 1987). It is not being argued that quantitative strategies always test pre-conceived hypotheses or that qualitative strategies never do so. Rather, it is that such a difference in emphasis is fairly typical.

According to Courneyer and Klein (2000), researchers need to recognize when the nature of the research questions calls for an approach that is either qualitative (inductive) or quantitative (deductive). When the researcher has few or weak theories to guide in making predictions or offering explanations he/she should be drawn more to an inductive approach. On the other hand, when there is strong literature about what has been done in the past that can serve to guide him/her as he/she shapes the future, it is wasteful to disregard this knowledge by failing to utilize deductive approaches. They further argue that researchers need to fully appreciate that the inductive and deductive questions can be informed by data that take either numeric or non-numeric forms.

As Flick (1998:231) has stated:

> The combination of multiple methodological practices, empirical materials, perspectives and observers in a single study is best understood as a strategy that adds rigor, breath, complexity, richness and depth to any inquiry.

It is in light of the statement of Flick (1998) above the present study employed both qualitative and quantitative research methods in investigating the effects of an instructional strategy on grade 11 learners' understanding of genetics. Below is an outline of the research approach taken in this study.

3.3. Research methods

3.3.1 The experimental group's programme

As mentioned earlier, the concept of combining instructional teaching strategies does not as such mean something outstanding and flawless. It refers to a proto-type teaching approach that is perceived, within the context in which it is used, to produce the desired results, worthy of emulating in related contexts. Starting from this premise then, a genetics curriculum package was developed for the experimental group (E) and used to guide instructional strategies in teaching genetics. The curriculum package consisted of the scheme of work (Appendix 1A), structured teacher's guide (Appendix 1B), lesson plans (Appendix 1C) and a Genetics Achievement Test (GAT) (Appendix 1D).

Table 3.1 An outline of the research approach taken in this study

Aspects of the Research Process	Approach Taken in this Study
Research Paradigm	Constructivism
Theoretical framework	Conceptual change
Research Design	Quasi-experimental
Data collection	Genetics achievement test (GAT) Classroom interaction observation schedule Learner interviews Teacher interviews Cloze test Learner worksheet
Data interpretation	Analysis of GAT and learner worksheet Analysis of Classroom observation schedule Analysis of learner and teacher interviews Classification of status of conceptions
Trustworthiness	Credibility Triangulation Dependability
Ethical issues	Informed consent Confidentiality

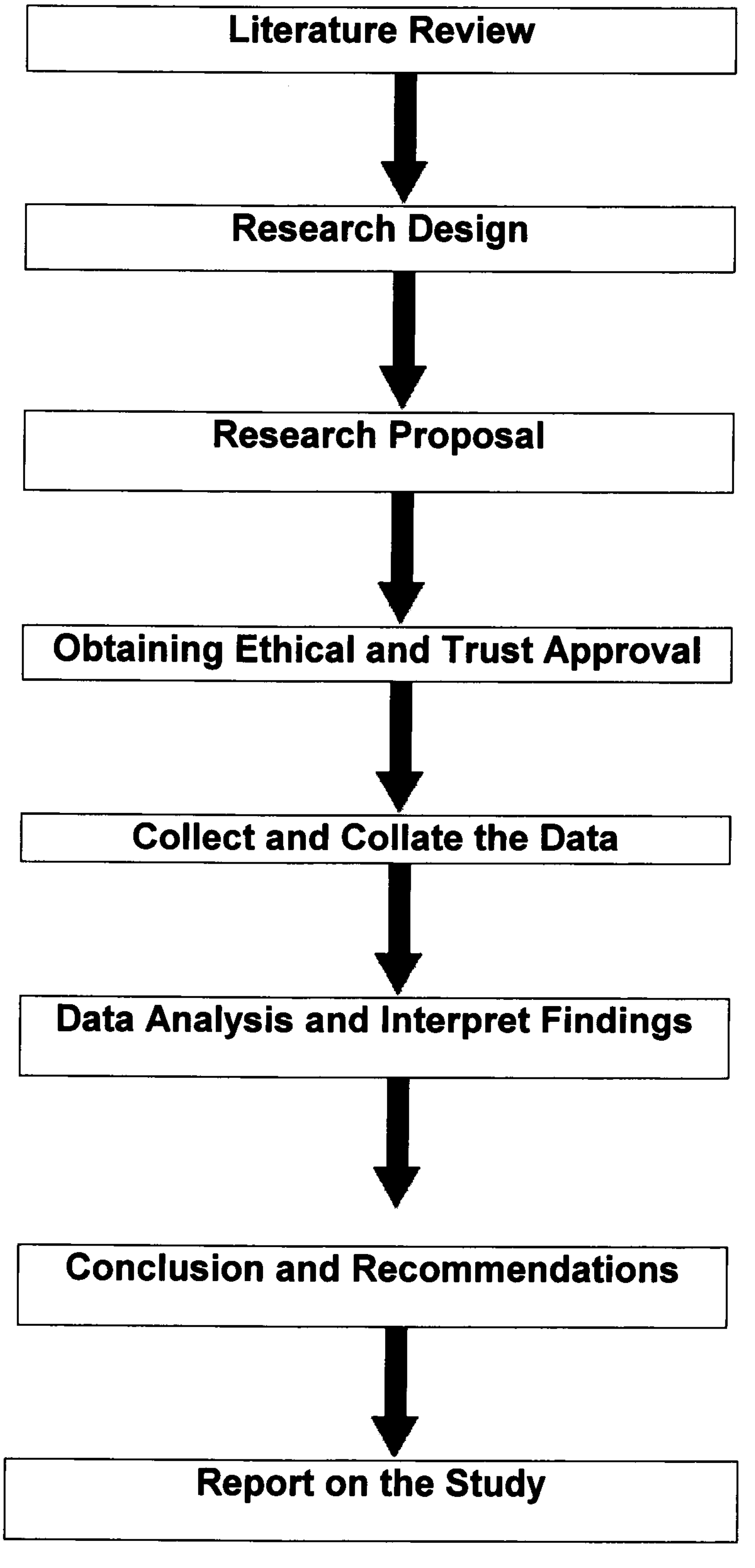

Figure 3.2 Research process flow chart

The curriculum package contained twenty lessons (Appendix 1B and 1C), each lasting for a class period (i.e. 35-40 minutes). The lesson content was structured so that the learners are central in the learning process. They were to do the experiments and demonstrations while the teacher served as a facilitator. The materials were arranged such that each learner had enough opportunity to participate in discussions and presentations. Also, the learners were allowed to talk or write their viewpoints while performing the assigned tasks. This reduced the teacher's effects in deciding what was worthwhile knowledge and increased pupils' leverage in sharing their ideas and in reaching consensus in a group or whole class discussions (Wheatley, 1991). The lesson plans (Appendix 1C) gave a comprehensive guidance to the teacher concerning the materials and equipment needed, the group sizes, the way to divide the learners, the tasks learners should do and the way to assign the tasks and the approximate time activities were expected to last.

3.3.2 The control group's programme

Starting from the similar premise as indicated above, a genetics curriculum package was developed for the control group (C) and used to guide instructional strategies in teaching genetics. The curriculum package consisted of the scheme of work (Appendix 2A), structured teacher's guide (Appendix 2B), lesson plans (Appendix 2C) and a Genetics Achievement Test (GAT) (Appendix 2D, common as 1D).

The curriculum package contained twenty lessons (Appendix 2B and 2C), each lasting for a class period (i.e. 35-40 minutes). The lesson content was structured so that the learners are central in the learning process. They were to do the experiments and demonstrations while the teacher served as a facilitator. The materials were arranged such that each learner had enough opportunity to participate in discussions and presentations. Also, the learners were allowed to talk or write their viewpoints while performing the assigned tasks. This reduced the teacher's effects in deciding what was worthwhile knowledge and increased pupils' leverage in sharing their ideas and in reaching consensus in a group or whole class discussions (Wheatley, 1991). The lesson plans (Appendix 2C) gave a comprehensive guidance to the teacher concerning the materials and equipment needed, the group sizes, the way to divide the learners, the tasks learners should do and the way to assign the tasks and the approximate time activities were expected to last.

3.4 Sampling

Sampling is the process of selecting a number of individuals for a study in such a way that the individuals represent the large group from which they were selected. The individuals selected comprise a sample and the larger group is referred to as the population. The purpose of sampling is to gain information about a population. The population is the group of interest to the researcher, the group to which he/she would like the results of the research to be generalizable (Gay, 1981). Even though there are seven education districts in the Western Cape Province, this study is limited to only one education district, in the North Metropole, due to a number of logistical constraints viz: the time limited to collect the data, the funds available for the exercise, the distance to be covered, differing work schedule (scheme of work) in schools, willingness to take part in the research, medium of instruction in school, etc. Thus, the population of this research was grade 11 biology teachers and learners.

Specifically, the purposive sample consisted of 61 learners in two grade 11 classes from schools in the northern part of Cape Town. Each class selected completed the Genetics Achievement Test (GAT), the cloze test, and the learner worksheet. Also, a total of 12 willing learners (six from each class) participated in the interview. Also, four willing experienced teachers (two from each school) were selected for the interview. As Patton (1987) has noted, most sampling in qualitative research uses purposive sampling because persons or events are selected deliberately in order to provide important information that cannot otherwise be obtained from less knowledgeable or interested subjects. The Western Cape Education Department has seven education districts in the province. Four of the districts are in the metropolitan region of Cape Town, and three are in rural areas. The distribution of the districts is shown in figure 3.3 below.

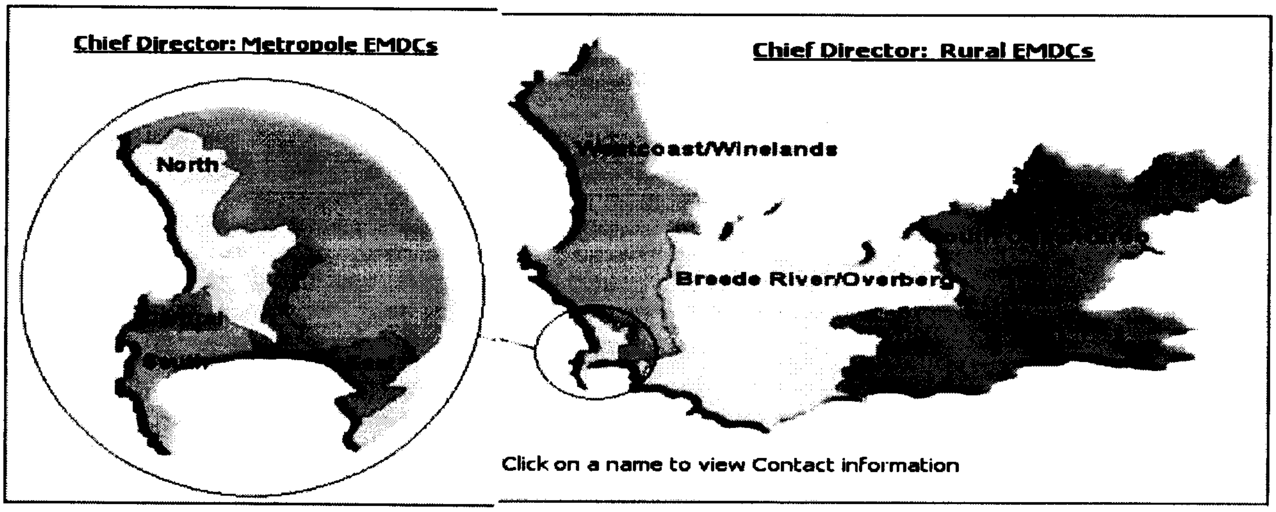

Figure 3.3 Education Districts: Education Management and Development Centres (EMDCs)

The sample of the pilot study, however, was picked from a cluster of five schools in the North Metropole of Cape Town. These were: St George's Diocesan High School, Wennie Du Plessis High School, Peninsula High School, Protea High School, and Voortrekkers High School (names of the schools are fictitious for anonymity). Out of these, Voortrekkers High School was picked purposively because of their willingness to take part in the pilot study and, more importantly, happened to have scheduled to teach genetics at the same time when the pilot study was carried out in May-June 2004. The sample of the main study was drawn from the 28 schools in the North Metropole of Cape Town. These are: Peninsula High School (experimental group) and Protea High School (control group). The same procedure of purposive sampling was used here as well. The purpose of purposive sampling is to be sure to understand cases, which are likely to be information-rich because they may reveal major teaching weakness, which is a target of opportunity for the instructional improvement (Patton, 1987: 56). Frankel and Wallen (1993:383) in their studies about qualitative design confirmed that: "virtually all qualitative researchers are using purposive sampling techniques since they want to ensure that they obtain a sample that possess a certain characteristics that is relevant to the study." Below is a profile of the learners involved in the study according to gender, age and language.

Table 3.2: A profile of the learners involved in the main study according to gender, age and language

Group of Learners	Experimental Group E (n = 31)	Control Group C (n = 30)	Total T (N = 61)
Gender: Female	17	20	37
: Male	14	10	24
Age: 16 and below	12	14	26
: 17 years	15	15	30
: 18 years	3	1	4
: 18 and above	1	0	1
Language: English	16	23	39
:	10	3	13
Afrikaans	5	3	8
: Xhosa	0	1	1
: Zulu			

3.5 Instrumentation

To explore the effects of an instructional strategy on grade 11 learners' understanding of genetics, a total of six research instruments were produced and used to collect data in this study. Three of these focused on quantitative data while the other three were used to collect qualitative data. The quantitative data gathering instruments included the Genetics Achievement Test (Appendix 1D), the Genetics Classroom Interaction Observation Schedule (Appendix 3) and the Cloze Test (Appendix 4) while the qualitative data gathering instruments included the Semi-Structured Teacher and Learner Interview Protocols (Appendix 5 and 6) and Learner Worksheet (Appendix 7). The Genetics Classroom Interaction Observation Schedule (GCIOS) was developed mainly for use in "traditional" classroom lessons, not for use in monitoring lessons in which 30-40 learners are each doing different things at the same time, so cannot be observed accurately. These instruments and the data collection procedures are presented next.

3.5.1 The Genetics Achievement Test (GAT)

In preparing the Genetics Achievement Test, Frankel and Wallen (1993) asserted that open-ended questions could be lengthier than close-ended questions such as multiple choice, or yes/no questions. Similarly, the close-ended questions seem to be easier for respondents to fill and for the researcher to compile. On the other hand, Mathison (1988) argues that open-ended questions are very versatile and therefore play a variety of roles in research. Open-ended questions are often used to generate ideas or obtain a fundamental understanding of the phenomenon, issue or topic being investigated when little is known about it. The above-mentioned points justify the reason why this study incorporated both open-ended and closed questions.

Designing the GAT questions for the grade 11 learners went through the following process. The main research question and sub-questions were developed in relation to the aim of the research. Past question papers for biology grade 11 were obtained to measure the level required. I discussed with my supervisor about the item difficulty and item easiness index in detail and incorporated his comments and feedbacks.

After going through a rigorous validation process and pilot testing at the Voortrekkers High School, the original instrument, which consisted of 50 multiple-choice and open-ended questions, was reduced to 22 questions (14 multiple-choice questions and eight open ended questions on genetics. Hence, a 22-item achievement test (the GAT – Appendix 1D) was developed to measure conceptual understanding and cognitive achievement of the grade 11 learners in the treatment and control groups. The instructional learning materials were designed such that the learners had the opportunity to negotiate meanings and construct their own knowledge as they interacted with the learning materials. It was a conscious effort to avoid a situation where the learning activities would encourage them to memorise the concepts. In the same spirit, the achievement test was set in such a way that it was thought-provoking. The GAT at the piloting stage was too wordy and had long and winding questions. To solve this, the instruments were divided amongst the classes, such that each class responded to half the number of the items.

To attain the face, content and construct validity, five experienced grade 11 teachers were asked to appraise the suitability and appropriateness of the GAT items. In addition, the

GAT was given to another five experienced science educators to rank the GAT items for relevance on a scale of 1-5. Items ranked below four were automatically eliminated. The inter-rater correlation of five judges stood at 0.86 using the Spearman-Brown formula. Reliability coefficients of 0.78 and 0.83 respectively were obtained using the split-half and Kuder-Richardson 21. According to Cohen and Manion (1989:168), correlation within this range make possible group predictions that that are accurate enough for most purposes.

3.5.2 The Genetics Classroom Interaction Observation Schedule (GCIOS)

Flanders' Interaction Analysis modified by Ogunniyi (1983) and further modified by Ramorogo (1998) interaction categories was adapted for use in this study (see Appendix 3). Flanders' categories contained ten items, Ogunniyi modified it to 15 items to take care of non-verbal activities and Ramorogo further modified it to 18 items. All 18 items were considered robust for the study and were adopted as such. In adapting it, special attention was paid to the criticism labeled against science teachers in South Africa. Amongst other things, these include the fact that: (1) teachers do not take learners' ideas aboard when they plan and teach their lessons; (2) they tend to ignore learners' incorrect responses; (3) they do not challenge learners' responses to encourage logical thinking; and (4) they out talk their learners. These all point to poor instructional strategies (Prophet, 1990; Fuller and Snyder, 1991; Ogunniyi and Ramorogo, 1994).

A section the GCIOS dealing with teacher instructional behaviours consisted of twelve categories, three dealt specifically with the criticisms leveled against science teachers. Six categories dealt with learner behaviours. One of the serious discrepancies of systematic observation, of which GCIOS is representative, is that: (i) the data that are collected are mainly data that can be captured into the pre-specified categories and hence qualitative data that may be useful in creating a more comprehensive picture of classroom life is often ignored, obscured and distorted because the instruments are crude, ill-defined and insensitive to such data (Delamont and Hamilton, 1984); (ii) they tend to concentrate on small bits of information rather than a holistic approach to the concepts under investigation and; (iii) they deny the observer reflexivity so necessary to the observer in a complex teaching and learning situation (Delamont and Hamilton, 1984). To address the problem above the GCIOS contained a section that dealt with more qualitative aspects of the lesson. During classroom observations, I assumed the role of a participant observer. The learners knew my activities and my participation in class was secondary to my role of an information gatherer (Merriam, 1988: 93). Throughout the investigation, I did not interfere in the classroom so that the locus of control remained with the teacher in the form of naturalistic observation (Alder and Alder, 1994). I recorded field notes and classroom activities of specific interest to the research, audio taped and tapes fully transcribed. Some lessons were videotaped as well. Data were collected in most of the lessons depending on the amount of time that the teachers were prepared to have the researcher in their classrooms and the availability of time for the interviews and for filling the worksheets.

3.5.3 Semi-structured interviews

An interview is an important tool for collecting data. According to Mason (1996:39-40), to understand people's knowledge, views, interpretations, experiences, understandings and interactions, one needs to interact with people, talk to them, listen to them, and to gain access to their accounts and articulations. Using interviews as a method of data collection has both advantages and disadvantages. According to May (1997: 229) the advantages are: (1) the interview is a flexible adaptable way of finding things out; (2) face-to-face interviews offer the possibility of modifying one's line of inquiry; (3) it permits a follow-up of interesting responses and investigating underlying motives in a way that self-administered questionnaires cannot; (4) non-verbal cues may give messages which help in understanding the verbal responses, possibly changing or even, in extreme cases, reversing its meaning; and (5) an interview has the potential for providing rich and highly illuminating material.

However, interviewing also has a certain limitations in that, to get rich qualitative data, it requires a considerable skill and experience on the part of the interviewer. Besides, it is also a time-consuming process compared to a self-completed questionnaire. In this study, I have used a semi-structured interview with the teachers and learners. As May (1997:111) has argued, a semi-structured interview enables the interviewer to have the latitude to probe beyond the answers and thus, enter into a dialogue with the interviewee. This type of interview is said to allow people to answer more on their own terms than the focused interview. Also, Kane and Brun (2001:115) contend that semi-structured interviews have advantages when compared to unstructured interviews, in that they have a clear pre-determined focus, but flexible in how questions are organized, with allowance for open-ended discussions of the answers. They add that semi-structured interviews are appropriate when the researcher wants to explore something in some depth with a group or a number of individuals when there is a need to get a better understanding of information gathered through other means and in investigating and monitoring projects.

3.5.3.1 The Learner Interview Protocol (LIP)

To further probe the learners' perceptions and ideas about combining alternative teaching strategies and learning, a semi-structured interview schedule (Appendix 5) was produced and administered to the learners when they finished using the genetics instructional package. The questions required information regarding the achievement test the learners wrote, the practical work they did using the genetics instructional package, what they considered to be their level of participation and how the teaching strategies could have enhanced the learning outcomes.

The content of the learners interviews took the form of an "interview about concepts" (Carr, 1996; White and Gunstone, 1992), which aimed to probe the post-instruction understanding that each learner had about genetics concepts from the lessons, particularly the gene concept. Consequently, the interviews were conducted close to the end of the genetics course in each class. The semi-structured meetings consisted of a prescribed interview protocol within which the interviewer probes and expands the interviewee's responses (see Fontana and Frey, 1994; Hitchcock and Hughes, 1989). An example of a learner interview protocol is included in Appendix 5. The semi-structured interview was considered to be appropriate for the data collection in this research because a certain level of structure was desirable for the interviews in order to give direction to the data collection and facilitate data analysis (Fontana and Frey, 1994). Each teaching episode was different; however, it was considered appropriate that the interviewer had some flexibility during the interviews with the interviewees so that aspects particular to each classroom could be pursued. Additionally, since each learner possessed an individual knowledge base, flexibility to allow for these differences was desirable. Each interview, which took between 10-15 minutes to conduct, was both audio and video recorded and fully transcribed. A total of 12 learners were interviewed from the two classes.

Several criteria were used in a process of purposeful sampling to select learners for the interview (Patton, 1990). During the classroom observation, I noted learners who might be of interest to interview e.g. those who had asked pertinent questions in class and demonstrated some understanding of what was taught; or who were having trouble with the concept in question. Consequently, the teacher was consulted about such learners before they were selected for the interview.

3.5.3.2 The Teacher Interview Protocol (TIP)

A semi-structured teacher interview schedule (Appendix 6) was developed to explore the teachers' beliefs, ideas and perceptions about the conceptual understanding of the grade 11 learners in the genetics class and the varied utility of instructional strategies. It also explored the views of teachers about the achievement test that the learners wrote and the constraints they experienced working with the genetics instructional package.

Four experienced biology teachers were interviewed at the beginning of the research with particular reference to the kind of analogies that they used to teach genetics, which, as explained in Chapter 1, was the original focus of this study. All interviews at this stage were treated as formal, taped and fully transcribed as such. Two of these teachers became further involved in the study and were interviewed on a more formal basis. These formal interviews consisted of a discussion before, during and after class when time allowed. They centred around issues related to the teaching process and were recorded as field notes (Fontana and Frey, 1994). More details about the outcomes of these interviews are provided in Chapter 4.

3.5.4 The student worksheets

The learner worksheets (Appendix 7) were used by the teachers in the series of two case studies analyzed in Chapter 4. The worksheets were given to the learners before and after the genetics instruction and were designed to elucidate information about their understanding of genes, chromosomes and DNA. Worksheet information was used to help develop a generalized model of learning demonstrated by the learners. The worksheet was also used to triangulate information from the learner interviews. All learners' pre-instructional and post-instructional conceptions of "genes", "chromosomes" and "DNA" were determined by the worksheets given before and after the course (see Appendix 7). The terms "DNA" and "chromosomes" were considered to be closely connected with the concept "gene", and it was thought that information that the learners wrote about these additional terms could be used to help determine their understanding about genes. Further, the learners were considered to be heterogeneous because none of the schools had a special selection process of entry to the classes; hence these data are discussed together. Consequently, a total of 61 learners completed the pre-instructional worksheets and 60 learners completed the post- instructional worksheets at the end of the five-week course.

The worksheets simply asked the learners to write down what they knew about the terms "genes", "chromosomes" and "DNA". It was assumed that they would write down the things that they considered most important about the concepts. Their responses were scrutinized for their ideas about genes, chromosomes and DNA. A list of these ideas was made up and the number of learners with the same idea was recorded. In this way, the ideas they held about genes emerged from the data. At the end of the course, interviews were conducted with a total of 12 purposely-selected learners, six from each of two classes (Patton, 1990).

3.5.5 Cloze test

A cloze test (Appendix 4) is a special type of fill-in exercise where, for example, every 6^{th} or 7th word in a paragraph of about 300 words is deleted. Cloze tests are a very good indicator of learners' language and comprehension ability. Hence, a learner's score in a cloze text could be indicative of a good "all-rounder" in the language of the text (Merzyn, 1987). This version of the test resembles the directions to a computer game, describing the game's rules. This task requires learners to build an internal representation of the text, to put the words together in a meaningful way, so that they will be able to interpolate what words belong in the blanks.

The Cloze procedure is another method commonly used to measure readability and language proficiency and had been in use since the 1950s for testing readability of materials. The reader constructs the author's message through a mixture of perception and guesswork. To prepare a Cloze test, a text of some or more than 300 words is selected and every n^{th} word is omitted (the value of n between 5 and 10 are normally chosen). The reader has to supply the omitted words from the option list (Merzyn, 1987). There are a number of advantages of the Cloze procedure:

- The child is being tested with the materials he/she uses in the classroom.
- It taps the comprehension process and provides a way of examining the reader's ability to process the authors' language.
- It has the capacity to measure readability factors (other than word and sentence length) like sentence structure, size of print, concept load interest, language and author style giving it a decided advantage over the more traditional formulae (Russell, 1978).

Despite the above advantages the Cloze test does have some limitations such as: (1) it measures essentially a reader's ability to make a guess; thus readers for certain reasons perform better or less on the Cloze test than their ability would justify; (2) it is restricted to a fairly high level range of reading and is ineffective for certain kinds of contents, e.g. texts with a lots of mathematical symbols. Despite these limitations, the Cloze procedure is widely used method of measuring readability and language proficiency (Russell, 1978).

In this study, I have used the Cloze procedure to measure the readability and language proficiency of grade 11 learners because this method have been found accurate and easy to apply to scientific materials, easy to mark and easy to calculate (Ogunniyi, 1999). This involves the selection of a long passage, titled Genetics Mechanism, from the grade 11 Exploring Biology textbook by Thienel et al (1986:292-293). This passage was selected because it is long enough to provide 50 meaningful blank spaces by deleting every eighth word, leaving the first sentence of the passage. Also this passage was taught to learners in the preliminary lessons of genetics before taking the Cloze test. The Cloze test consists of 50 blank spaces with four alternative answers for each blank space (Appendix 4)

To measure the validity of the cloze test, I consulted three biology teachers who assisted me in testing both the face and content validity of the test. To obtain the reliability of the Cloze test, Kuder-Richardson 21 modified by Ebel (1979) was calculated. The value stood at 0.96 indicating that the cloze test is reliable. According to Gay (1981:122) for achievement tests (cloze test implied) the minimum reliability coefficient acceptable is at least 0.75 and comfortable 0.80. However, a lower value could still be used, particularly when it is used among learners whom English is not their first language (Ogunniyi, 1992). The teachers administered the cloze test in my presence to 47 learners in both schools.

3.6 Validity and reliability

To ensure that the instruments used measure what they purported to measure as well as give comparable results, several corroboration techniques were used. This entailed a thorough scrutiny of the instruments by a panel of five experienced teachers who gave their comments about their suitability for the intended purposes. In addition these teachers were asked to: (1) assess whether or not, the level of the language used is appropriate for the target learners, (2) whether or not, the concepts were presented in a way that they were easily comprehensible to the learners and (3) whether the questions were asked at the appropriate levels.

After several revisions, the instruments were passed on to a panel of five science educators, three from the University of the Western Cape and two from the University of Namibia. Similarly, they were asked to: (1) assess the level of language used, (2) assess whether or not the questions were presented in a logical manner, and (3) ensure that the questions are non-overlapping and well structured. Their comments were used to refine the final versions of the instruments. All the instruments were trial tested in a class comparable to those involved in the actual study.

As mentioned earlier, the five judges rated the GAT and the interview protocols out of five. Hence, a rating score of 5 implies the item is excellent while a rating of 1 is indicative of a very poor item. From the ratings of the five judges the validity was obtained using the Spearman-Rank Difference correlation coefficient (Ogunniyi, 1984, 1992). The GAT inter-rater correlation of five judges stood at 0.86 using the Spearman-Brown formula while the reliability coefficients of 0.78 and 0.83 respectively were obtained using the split-half and Kuder-Richardson 21. The interview protocols' inter-rater correlation stood at 0.85 using the Spearman-Brown formula while the reliability coefficient of 0.83 was obtained using the Kuder-Richardson 21 formula. Since the Observation Schedule, Learners Worksheet and Cloze Test were adapted from previous studies, it was taken to be effective for the study. According to Frankel and Wallen (1993: 149), "For a research purpose reliability should be at least 0.70 or higher", therefore, all the instruments were appropriate to collect data. Based on the experts' opinions and the reliability values, the instruments were considered valid and reliable for the study.

3.7 Methods of data analysis

The data consisting of numerical values were treated quantitatively while those not amenable to quantification were analyzed qualitatively. For instance, the quantitative data were collated and analyzed through the use of descriptive and inferential statistics. On the other hand, the qualitative data obtained mainly from the free comments made by the learners on the GAT, the Observation Schedule and the interviews were assembled together, coded and condensed together into interpretable themes or categories and finally interpreted in the form of narratives and excerpts to reinforce the quantitative analyses.

The goal of the analysis was to provide a comprehensive and holistic description of the overall findings in the study. The interviews were transcribed and reworded into a set of discrete elements of knowledge as suggested by White and Gunstone (1992). White and Gunstone (1992: 88) assert that, "a reworded set of an interview is useful as a permanent record and a basis of scoring". The thematic set of the interviews was made to provide a thicker qualitative description in the support of the quantitative data analysis. The cloze test scores were analyzed using the Bormuth readability categories. Hence, scores running between 58%-100% were indicative of an independent level, 34%-57% as an instructional level; and 0%-34% as frustrational level. Subjects in the independent level can read and learn from the textbook independently while learners in the instructional level can read and learn from the textbook with the help of their teacher but learners in the frustrational level cannot read and learn from the textbook even with the help of their teacher.

While this study was more inclined to an interpretive approach, aspects of discourse analysis were not altogether neglected. Of particular interest in the discourse analysis was the argumentative organisation of utterances in the classrooms (Miles and Huberman 1994). This is particularly important in the study because learners' participation in genetics lessons was construed not only more hands-on activities but also mind-on. A concern for rhetoric in this sense is primarily a concern about how learners structured and used language such that they succeeded in putting forward their ideas in such a way that they out-compete alternative ideas from the group (Miles and Huberman 1994).

3.8 Ethical issues

A substantial consideration was given to ethical issues in conducting this study. As defined by May (1997), the word 'ethics' suggests that a set of standards by which a particular group or community decides to regulate its behaviour to distinguish what is legitimate or acceptable in the pursuit of an aim from what is not. This awareness helped me to know how to go about collecting the data for the study. I assured all the participants that there would not be in any way illegitimate use of research findings.

The data collected for this study have not been of a highly sensitive nature, politically, socially, or physically. Regardless of this, it has been of utmost importance for me to maintain an ethical approach to the research process. The most important ethical issues for this study are related to the participants, namely the teachers, their learners and the schools in which the research was conducted (Brickhouse, 1991). The researcher has highly valued the interactions he had with the participants and the ethical approach that guided this study is outlined below as a set of codes (Punch, 1994).

3.8.1 A code of informed consent

In some form of research, deception has been justified in that the value of the results of the research outweighs the harm it may cause the participants (Guba and Lincoln, 1989; Punch, 1994). In this study, this has not been the case and a code of informed consent has guided the involvement of the teachers, learners and schools in the research. The teachers were invited to participate in the research by the researcher and were fully informed about the nature of the research. Although the direction that a research study would take might not always be entirely predictable, this makes informing the participant about the exact nature of the research questions difficult (Brickhouse, 1991). Despite this, participants were informed as accurately as possible about the purpose of the data collection at that particular time. I maintained a friendly and collegial relationship with the teachers and explained the overall benefit of the study to them. This made them to be enthusiastic in participating in the study.

In order to maintain a code of consent, it was important that the teacher was able to negotiate with the researcher the extent to which he became involved in the research. This negotiation was upheld throughout the research so that the teachers could maintain control of the research process within the classroom. Although there existed some inconsistency between the control group and experimental group classes, the ethical issue of whether or not to use valuable classroom teaching for interviews was considered important. Learners and their parents or guardians were informed by letter about the presence of the researcher in the classroom, the purpose of the research and the how the learners would be asked to participate in interviews. This letter also informed the parents and guardians their children's involvement in the interview process was voluntary (Appendix 8).

The learners were asked if they would be willing to participate in the interviews. Only one learner from all the classes declined. Before the interviews, the learners were also asked if they would object to the use of a tape or a video recorder for recording the transactions. They unanimously agreed. Permission was also sought from the principals of participating schools (see an example of the letters sent to principals in Appendix 9).

3.8.2 A code of confidentiality

Confidentiality was considered important to this study because the participating teachers' professional status could be at risk if any disclosure was made about their teaching and learning classrooms atmosphere. Confidentiality is something that cannot be ensured because the nature of the descriptive reporting process means that if someone wanted to identify a participant, it is highly possible (Deyle, Hess and LeCompte, 1992; Punch, 1994). Regardless of this, I embraced the code of confidentiality so that the teachers, learners, and participating schools in the research were not immediately identifiable to people who might read any documents pertaining to the study. For example names that could identify participants were altered or removed to enhance confidentiality. The raw data were kept in a filling cabinet and only the researcher and his supervisor had access to it. These strategies helped to protect the privacy of the participants and prevent any bias on the part of the reader/ reviewers should they know the teachers, learners or participating schools.

3.9 Conclusion

The descriptive and interpretive approach taken in this study has been outlined in this chapter, and summarized in Table 3. This study was conducted in the constructivist research paradigm where the theory evolved in the process of conducting the study. The next chapter, Chapter 4, analyses the data collected from the GAT, GCIOS, Structured Interview Protocols, Cloze Test and Learners Worksheets all in an attempt to address the four research questions outlined in Chapter 1. These are: (1) What concepts of genetics do Grade 11 learners hold before and after a period of instruction in genetics? (2) Are there differences in the understanding of genetics shown by learners exposed to an instructional model and those not so exposed? (3) Are Grade 11 learners' understandings of genetics influenced by gender, age and language?

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter comprises the results of this study and largely addresses all the three research questions presented in Chapter 1. It provides a broad examination of the grade 11 learners' understanding of genetics before and after being exposed to a genetics course. The data set for the study was collected using the instruments indicated in Chapter 3. These instruments include: Genetics Achievement Test, Genetics Classroom Interaction Observation Schedule, Cloze Test, Learner Worksheet and Teacher and Learner Interviews protocols. The data collected are presented and analyzed in terms of the descriptive, interpretive and analytical categories as indicated in the methodology chapter. The results and discussions will be done together. Also, the quantitative data will be corroborated with qualitative data for ease of reference. Details of the instructional strategies, namely, Concept mapping and Vee diagramming, Martin's (1983) inductive instructional models and Lijnse's (1990) hierarchical conceptual model have been provided in Chapter 3. Also as indicated in Chapter 3, it was assumed that using a diversity of instructional strategies rather one might be a more effective way of teaching a heterogeneous group as was the case in this study.

4.2 Research Question 1: What concepts of genetics do Grade 11 learners hold before and after a period of instruction in genetics?

4.2.1 Valid conceptions of genes, chromosomes and the DNA (student worksheet,) at the pre- and post-test stages

Learners' pre-instructional and post-instructional conceptions of genetics were determined by using worksheets containing the tasks to be performed (see Appendix 7). The terms "DNA" and "chromosomes" were considered to be closely connected with the concept "gene", and it was thought that information that learners wrote about these additional terms could be used to help determine their understanding about genetics. The learners were considered to be heterogeneous because none of the schools had a special selection process of entry to the classes. Consequently, a total of 61 learners completed pre-instructional worksheets and 60 completed post-instructional worksheets at the end of the four-weeks course.

Before examining the data, it is apposite to state that genetics is the biology of heredity, especially the study of mechanisms of hereditary transmission and variation in the characteristics of organisms. In this sense, genetics is not the same as the study of genes in isolation from other associated sub-structures or nucleic acids, e.g. the DNA and RNA or super-structures such as chromosomes on which the genes are located. Both the DNA and RNA are polymers of nucleotides. The DNA makes up the genes and, along with the RNA, controls protein synthesis within the cell (Mader, 1985). However, to simplify this analysis, the focus will be on the learners' understandings of genetics in terms of the gene and its characteristics and behaviours. As argued in chapter 1 (see p. 4) unless learners understand the basic characteristics of the gene, they are not likely to understand genetics and related concepts and generalizations.

At the secondary school level, genetics is normally introduced to learners in terms of the structures and functions of the gene, chromosomes and the DNA. Hence, the learners were asked to write down on the worksheet what they knew about these terms "genes", "chromosomes" and "DNA". It was assumed that learners would write down the things that they considered most important about the concepts. The responses of the learners to the worksheets were then analyzed to determine their knowledge of these terms. This was followed by interviews involving 12 learners, six from each class group. The learners' ideas about genes, chromosomes and DNA are presented in Table 4.1 below. An examination of Table 4.1 (item 1) indicates that learners in both the experimental group (E) and the control group (C) seemed to have increased their understanding about the fact that "genes make you resemble your parents" moving from 4% and 5% at the pre-test stage to 80% and 20% at the post-test stage. Similarly, they have increased in their knowledge that "genes are passed through sexual intercourse" of organisms (item A2) with E and C moving respectively from 2% and 4% to 80% and 30%; or that genes are located on chromosomes, moving from 5% and 20% to 75% and 65% respectively at pre- and post-test stages. However, E seemed to be aware that genes are passed to offspring through sexual intercourse of both parents. A similar pattern of increment is noticeable on the learners' conceptions of chromosomes. With few exceptions, their understanding of the characteristics of chromosomes remained relatively low even after the course of instruction. However, their understanding about the DNA seemed to increase by leaps and bounds particularly in the E group. Hewson and Hewson (1992) explained clearly that the status of a person's conception is the extent to which the conception meets the conditions of intelligibility, plausibility and fruitfulness and that the more conditions that a conception meets, the higher will be its status.

Table 4.1: Valid conceptions of genes, chromosomes and the DNA held by the learners on the student worksheet at the pre- and post-test stages

Concept	Pre-test (n=61)		Post-test (n=60)	
	(E) %	(C)%	(E) %	(C)%
A. Genes				
1. Genes make you resemble your parents	4	5	80	20
2. Genes are passed through sexual intercourse	2	4	80	30
3. Genes are located on chromosomes	5	20	75	65
Mean %	**3.6**	**9.7**	**78**	**38**
B. Chromosomes				
1. Chromosomes determine sex	10	12	74	28
2. Chromosomes are made up of genes	4	8	30	3
3. Too many chromosomes can cause problems e.g. Downs Syndrome	4	12	70	0
Mean %	**6**	**12**	**58**	**10**
C. DNA				
1. DNA is different in every human being	18	15	73	52
2. DNA is a helix (ladder) arrangement	1	8	59	28
3. People are made up of DNA.	13	10	54	20
Mean %	**11**	**11**	**62**	**33**

Key: E = Experimental group
C = Control group

As indicated earlier, the notion of DNA, genes and chromosomes are inextricably interwoven. However, for ease of reference, the concepts are separated in order to determine the learners' understanding of these concepts. This section analyses interview transcripts of learners from both the experimental and control groups in interpreting the status of their conceptions using Thorley's and Hewson (1990) status analysis categories. Further insight about the learners' understanding of genes was gained by examining the comments. The excerpts below are representative of such comments.

Sam: [Genes are] what your parents pass to you so that you get your characteristics.

Peter: Genes are things that you inherit from your parents; they affect things like your hair and eye colour etc.

Maureen: [Genes are] something you inherit from your parents.

Charles: They [genes] are characteristic cells that are passed from one generation to another.

Bianca: [Genes are] inherited characteristics that are passed down generation to generation by your ancestors.

Michael: [Genes are] the cells that make you different, which you get from your parents.

Comments such as "genes are things"; "they are characteristic cells" and "genes are something," suggest that learners have an image of genes as some kind of particle. The most important thing about this passive and active gene according to the majority of learners (75% and 65% respectively) is that they "are passed down through sexual intercourse". This suggests that many of the learners initially saw genes as being passive. Before instruction, 4% and 5% respectively of learners indicated in their worksheets that genes make you resemble your parents. In other words, the idea that genes get passed from parents to offspring is more prominent in the majority of learners' minds than the idea that genes have an effect on characteristics. This initial, passive view of genes is consistent with Martins and Ogborn's (1997) basic model that primary school teachers used. This logical view that a gene is a particle rather than something else, such as an event, a characteristic or an instruction, for example, is probably the most common way that learners in these two classes saw genes prior to instruction. The "passive gene" model is, therefore, an appropriate starting point to consider the changes in many of these learners' conceptions about the gene in terms of specific themes.

Discussion

The salient features of multiple external representations (MERs) of Biologica constituted the situational interests to which learners responded differently depending on their own individual interest and became motivated. The classroom research in the USA, from 1996 to 1998, clearly demonstrates the *BioLogica* hypermodel to be more effective than the traditional approaches to genetics instruction at developing reasoning proficiency across domain-general and domain-specific dimensions but learners were unable to solve closely related paper-and-pencil problems (Horwitz, 1999). In this study, the intrinsically motivating effects of these situational interests increased the intelligibility of the concepts of genetics with which learners learnt to reason. In interviews, as well as in the teacher's tests/assignments, most learners knew what genetics is. They verbalized their genetics conceptions using human examples or represented them in drawings. At the same time, many learners talked about how they enjoyed learning genetics because of concept mapping and Vee diagramming or other multimedia. As Hewson and Thorley (1989) pointed out, the essence of intelligibility can be captured by representability such as the use of images, exemplars or language. Drawings on the analyses in table 4.1 and 4.2 above in the results chapter supported by the review of literature in chapter 2, it is argued here that the complementary role of using different information or processes can be considered as an effective way of raising the intelligibility of learners' conceptions of genes for scientific reasoning or genetics reasoning.

A concept must first be intelligible to learners before it can be plausible and then fruitful. If Ainsworth et al. (1998) functional taxonomy of MERs is of any relevance here, alternating instructional strategies appeared to have provided motivating complimentary information or processes that were useful in making the difficult concepts of genetics initially intelligible to the learners. From the conceptual change perspective, genetics reasoning is related to the plausibility of the learner's conception of genetics. Thorley and Hewson's (1990) status elements for plausibility are mainly about the consistency and causal mechanism, which are closely related to demand about genetics reasoning.

4.2.2 Concepts of genetics on the GAT held by grade 11 learners at the pre- and post-test stages

Clearly, discussing all statements in the Genetics Achievement Test (GAT) may result in a rather murky and pedantic picture of the learners' understanding of the concepts of genetics. To avoid this, only purposeful selected items that make a pattern of learners' understandings on the GAT will be discussed. These seem to portray a clear agreement or disagreement with a statement while other cases seem to be characterised by indecision on the part of the learners. Kendall (1954), cited by Ogunniyi (1977:43) argues with respect to the conflict of goals that when subjects are asked to express their viewpoints on a subject matter, the extreme responses seem to be more stable and reflect the intensity of belief than the middle or neutral responses.

A close examination of table 4.2 below indicates that, the results of the written test (GAT) shows that the learners were able to solve the genetic cross problems. The insertion of genetic cross problems (item 2.1 and 3.1) was an explicit request of the biology teachers to the case studies. There was an assumption that when learners know and can reason the main relationships in inheritance, then they should not find it hard to solve genetics crosses meaningfully. So teachers could dedicate two more lessons on genetic crosses after this trial, but they did not rely on it. Even without the extra lessons to rehearse the genetic crosses problems, learners were able to solve these problems rather well. Experimental group learners scored extremely well on question 2.1 and 3.1 (94% and 95% respectively, table 4.2) on standard monohybrid cross. A complicated dihybrid cross - proved to be more troublesome at this point (question 9, 45% and 38%; question 11, 58% and 51%, table 4.2). Analysis of question 4.1 and 5.1 can both be largely affirmed. Learners were able to explain and reason the relationship between sexual reproduction, meiosis and inheritance. Finally learners were able to insightfully solve monohybrid and simple dihybrid genetics cross problems without much training. Table 4.2 shows the relative score of correct answer to question 4.1 in the Control group to be 89%.

Table 4.2: Concepts of genetics on the GAT held by grade 11 learners at the pre- and post-test stages

Conceptions	Pre-test (n=61)		Post-test (n=60)	
	(E) %	*(C)%*	(E) %	(C)%
Section A				
1.1 Monohybrid cross of F1 plants	**64**	**55**	**80**	**70**
1.2 Explanation of choice in 1.1 in own words as the correct one	**54**	**45**	**73**	**62**
2.1 Genetic cross between two F1-hybrid pea plants	**62**	**54**	**94**	**80**
2.2 Explanation of own choice in 2.1 as the correct one	**61**	**45**	**78**	**66**
3.1 Mendelian experiment of crossing two Tt plants	**65**	**50**	**95**	**75**
3.2 Explanation of own choice in 3.1 as the correct one	**64**	**53**	**77**	**60**
4.1 X and Y – chromosomes inheritance	**50**	**57**	**53**	**89**
4.2 Explanation of own choice in 4.1 as the correct one	**50**	**35**	**63**	**57**
5.1 Why the X and Y – chromosomes are called sex chromosomes	**59**	**44**	**71**	**60**
5.2 Explanation of own choice in 5.1 as the correct one	**50**	**38**	**75**	**63**
Mean %				
Section B				
8. Applications of genetics in agriculture and medicine	**50**	**52**	**74**	**78**
9. Biologists claim the existence of things and process they cannot actually see	**45**	**38**	**80**	**63**
10. Perception to genetic-related disease i.e. Huntington's disease	**54**	**72**	**60**	**80**
11. Chances of boys and girls born are determined by the chromosomes	**58**	**51**	**78**	**62**
13. Using a Punnet Square to construct crosses for F1 and F2 generations	**64**	**40**	**93**	**77**
Mean %				

Key: **E** = Experimental group
C = Control group

The written answer of Susan shows how well the learners of the Control group were able to describe this relationship.

> Susan: Reproduction is generating offspring, this happens by means of sexual intercourse, an egg cell of a woman and a sperm cell of a man come together. They are both haploid cells and together they form a diploid cell. Haploid cells (that is reproduction cells) are formed through meiosis. [She clarifies the process of meiosis by means of a drawing of cells with chromosomes during division]. On the chromosomes that are in those cells are genes of the parents. These are passed on to the child. The child inherits these features from the parents and that is heredity.

However, the E learners scored considerably lower (53%, Table 4.2). One of the reasons may be that the written answers of the E learners were ambiguous to interpret than the written answers of the C learners. The answers of the E learners were less extensive, and their wording was often ambiguous. It seems that these learners had a lower linguistic competence than the C learners, which is a disadvantage in a written test. In contrast to the Control group, the Experimental group was a multicultural class (see table 3.2, p.56) in which a part of the learners may have a bilingual upbringing. The written answer of Xolani illustrates the difficulties in interpreting the written answers (it is translated with the same grammatical and verbal mistakes)

> Xolani: It connection is that for the making of child meiosis occurs and get half of the features of the mother and the father to make to make the child about heredity.

Generally, the overall performances of the learners to the written test (GAT) proved that it was adequate, e.g. see Table 4.7.

4.3 Research Question 2: Are there differences in the understanding of genetics shown by learners exposed to an instructional model and those not so exposed?

The following sections provide a quantitative analysis of the data obtained from the two groups of subjects using the traditional instruction and combined instruction teaching approaches in the study of genetics. The notion that teaching and learning are complex, variegated and dynamic activities is unequivocal (Ramorogo, 1996; Ramorogo and Kiboss, 1997). If this is the case, then, instruction-teaching approaches cannot be a context free activity. In other words, they are embedded in a contextual matrix of belief systems of both the teachers and the learners alike.

As recorded in Appendix 1B and Appendix 2B, and in Table 4.3 on page 78, the two teachers discussed in Chapter 3 serving as vignettes in this study utilised different analogies in their approach to teaching the concept of the gene. It is interesting to look at the progress of the interviewed learners in each of these classes along the pathway of models as depicted above. There is no intention to rank the two teachers in terms of their competencies or otherwise. Rather, only their instructional consequences in terms of the learners' progressive understanding of the gene concept are inferred.

The two male teachers fictitiously named: Mr. Duran for the experimental group and Mr. Carlson for the control group respectively used grade 11 biology syllabus. The specific objective in this unit, which relates to learners' conceptions of genes, simply asserts that, "learners will be able to describe the nature of the gene". Other related objectives deals with topics such as dominance and recessiveness, sex linkage, monohybrid crosses and Gregor Mendel's work. However, nothing specific about the structure or function of the gene is indicated. Due to the non-specific and generalized nature of the objective about genes in this unit, the details of the gene structure and function that were taught were very much determined by the teacher.

The two teachers involved in this study used different teaching strategies and also emphasized different aspect of the genes. Mr Duran concentrated on the structure and function of the DNA, chromosomes and genes and used a detailed twisted ladder analogue, which lasted at least 20 minutes of the class time. The analogue clearly drew the similarities between the rungs of a ladder and the nucleotides of the DNA using concept mapping and Vee diagrams, Martin's (1983) inductive instructional model and Lijnse's (1990) hierarchical conceptual model. Mr Duran also outlined differences between the DNA and the ladder analogy, such as size and the twisted nature of DNA using Martin's (1983) inductive instructional model. He informed me that he felt it was important for his learners to learn the structure of the DNA because many of them would need to understand how the genetic code is stored when they studied genetics in more depth in Human Biology or Biology in grade 12. Mr Duran did not teach protein synthesis in a detailed fashion because he felt it was unnecessary and too difficult for grade 11 learners.

Table 4.3: A summary of the two classroom contexts included in the case study

	Experimental group	Control group
Teacher	Mr Duran	Mr Carlson
Unit Objectives	➢ Distinguish between a gene and a chromosome in terms of their structure and their role in the inheritance process ➢ Describe the nature of the DNA	➢ Distinguish between a gene and a chromosome in terms of their structure and their role in the inheritance process ➢ Describe the nature of a gene
Classroom strategies	➢ Detailed twisted ladder analogy (concept mapping and Vee diagrams) (≈20 minutes) ➢ Gene paper cut out model (Martin's (1983) inductive instructional model) (1.5 lessons) ➢ Brief lookout tower analogy for DNA structure Lijnse's (1990) hierarchical conceptual model (2 lessons)	➢ Brief lookout at the tower analogy for the DNA structure (< 5mins) ➢ Blueprint of architect's plan analogy for genetic code
No of learners interviewed	6	6

Furthermore, Mr Duran organized his learners to work in groups so that they could construct paper cut out models to show how the nucleotides represented a code. Learners used their model of DNA to determine the order of amino acids in a protein. Mr Duran commented further that he believed by using the models, his learners could understand the idea of protein synthesis without a detailed knowledge of transcription and translation.

On the other hand, Mr Carlson explained to his class that the nucleus of the cell is like a "brain or a computer" because it "controls the cells' functions". He also said the structure of DNA is like a lookout tower in one of South African parks before he showed the learners a diagrammatic model of the DNA structure on an overhead projector. Mr Carlson did not, however, go into a detailed description of any of these analogies. Mr Carlson did not describe the function of genes or DNA in detail. However he briefly described the genetic code as being like a "blueprint or an architect's plan of what you are going to look like".

4.3.1 Mr Duran's teaching approach and its influence on grade 11 learners' understanding of genetics

The interviews with six learners from Mr Duran's class included a question about the differences between the twisted ladder and the structure of the DNA. The question was included to determine if learners could define the limitations of the analogies.

Interviewer: Can you describe to me what DNA looks like?

Daniel: It's like a ladder but it is spiral. It looks like the King's Park spiral lookout (in Peninsula botanical garden) and it's got sugar molecules and I've forgotten, and they join together to make bases, which determine what the characteristics are…

Interviewer: Ok, and what about differences between the ladder and the real DNA?

Daniel: Definitely because I mean a real ladder is hard and DNA is I don't think is hard. A ladder is mainly an example of the basic shape, but probably the real DNA is a lot smaller, softer, and more complex than the actual ladder…

Daniel seemed to understand that a twisted ladder is simply used to explain one aspect of DNA, that is, its structure, and that there are many limitations to the analogy. Being able to understand the utility and recognise the limitations of analogies and models is an important aspect of learner' modelling ability (Grosslight, Unger, Jay and Smith, 1991) and something which teachers should promote. Through interviews with grade 11 learners and experts, Grosslight et al. (1991) identified three levels of thinking about models. In general level 1 understanding, models are thought of as either as toys or simple copies of reality. In the level 2 understanding, the learner realises there is a specific explicit purpose that mediates the way the model is constructed and the model must no longer exactly corresponds with the real-world object. In the third, expert level, the purpose of the model is seen to be for developing and testing ideas rather than a copy of reality. Daniel is at least at level 2 in this scheme from Grosslight et al., (1991) because she understood that the model was used to explain the basic shape of the DNA and that it does not correspond to the real-world object.

In the following excerpt from the classroom transcript, it can be seen that Mr Duran explained to his learners that the reason for talking about the ladder analogy or some other form of models (like the concept maps used concomitantly) was to help them understand the basic structure of DNA. Mr Duran used models and analogies frequently when observed by the researcher and discussed the nature of modelling and the reasons for modelling with the learners in this grade 11 class on at least one previous occasion. Mr Duran used an overhead transparent sheet showing a diagrammatic representation of a DNA molecule during the following discussion.

Mr Duran: Now if you could imagine that particular structure untwisted, what might it resemble? Put your hands up. Think about it carefully, there seems to be horizontal rungs. If we to untwist that, what might it resemble, Patricia?

Learner: A ladder.

Mr Duran: A ladder, good. Can you imagine a simple ladder, which just has two sides to it and a whole lot of horizontal rungs joining the two sides? Well that is very commonly used example to help you understand what the basic structure of the DNA molecule is like. It is like a ladder, a simple ladder with simple horizontal rungs, but what does the ladder do?

Learners: Twists.

Mr Duran: It twists, that's right. ... Let's now have a look at the structures, which make up this molecule. And to do this you have to look at the second worksheet. ... Can we look at this molecule here to start with, this five-sided molecule and I have labelled it a sugar molecule...

Mr Duran continued to identify the similarities between the ladder analogy and DNA structure by explaining that the sides of the ladder are also made up of phosphate molecules in addition to sugar molecules and that the rungs are made up of pairs of bases – which can be represented by the letters G, A, C and T respectively. Mr Duran pointed out the limitations of the analogy by explaining that the DNA is different from a real ladder in that it twists and early in the lesson he emphasised the difference in size between the real DNA and the representations that they were going to use. Interviews following the lesson indicated that many of the learners were able to discuss the limitations of the analogy in a similar way to Patricia.

Abigail: [I don't really know what a DNA looks like] maybe because we've just been shown on the board how a model looks, not what the actual thing looks like. The model is stiff and phosphates are complete in you. Maybe it does look like that really...

Not only could many of the learners discuss the limitations of the analogy, most, like Abigail, were able to discuss the twisted ladder as a model and articulate why they felt their teacher used analogical model to explain the structure of DNA. Mr Duran confronted the problems of concepts such as the DNA structure not being open to common experience by using analogies and models; however, he did not neglect the problems associated with these strategies. He fostered in his learners a clear understanding of why models are used and established a habit of pointing out at least some of the limitations of the analogies and models he used with his learners.

Mr Duran's teaching strategies with regard to the use of analogies and model in his teaching were exemplary. The important information gained from examining the influence of Mr Duran's teaching approach on conceptual change or on the understandings of grade 11 learners of genetics was useful for the learners to create an image of DNA structure. More significantly, however, this image does not enhance the conceptual change process unless the learners are able to make connection between the structure and the function of the DNA. Mr Duran suggested that he was establishing in his learners a sound base on which to move to more complex concepts where they could start to learn more about the functioning of the genes. The alternative argument presented here is that if learners only memorise ideas about the structure of the DNA but do not understand why it is significant and make no connections to other ideas, then it is not likely to remain in their cognitive structures for very long.

4.3.2 Mr Carlson's teaching approach and its influence on grade 11 learners' understanding of genetics

Six learners were interviewed from Mr Carlson's class and of those learners; two ended the course with a low conception of the gene. No learners progressed to having a clear conception like those in Mr Duran's class or level three of Grosslight et al. (1991). Mr Carlson did not emphasise the structure of the DNA or the idea of code of information nor did he discuss protein synthesis. However he briefly described the genetic code as being like a "blueprint or an architect's plan of what you are going to look like". It is not surprising then, that learners in this class did not progress very far along the pathway of models. Brenda, for example, understood that genes have information about what you look like, but had no idea about how the information is stored or how the genes act to cause characteristics like blond hair.

Interviewer: What do you know about genes, tell me again?

Brenda: That it's got information about what you look like.

Interviewer: And how does it decide what you look like?

Brenda: Um, there are different genes for different things so you might have a gene, which says that it will be blond hair, and ones that are something else.

Interviewer: Alright, so how does it make you have blond hair, do you know?

Brenda: I don't know, you've just got the gene for blond hair.

Interviewer: Okay, and do you know how it stores the information at all about that?

Brenda: Not sure.

There has been criticism of the "blueprint" analogy, one of the analogies Mr Carlson used.

> Dawkins (1989) has pointed out that our modern knowledge of the way in which genes are expressed has rendered a concept of a genetic blueprint obsolete. He suggests that it would be better to visualise the genetic information as a recipe or series of instructions for creating an organism. In a blueprint there is a one-to one correspondence between each element of the plan and its manifestation in the real world. But genes do not really encode for characters: they produce sequences of proteins, which, interacting under suitable conditions, will result in the construction of a new organism (Bowler, 1989, p.181).

> The cliché that compares DNA to a set of blueprints is another of science's misleading metaphors. Blueprints are drawn up before a job starts, then put in drawer (or indeed lost. It usually makes very little difference). But DNA is an active administrator of the modern kind and intimately involved in the running of the cell from conception to the grave, and extremely sensitive to events all around it (Tudge, 1993, pp 77-78).

Not only were the analogies (the "brain" or "computer" analogy of the nucleus, the "lookout tower" that Mr Carlson used rather obsolete, the manner in which he used them was – in passing – not well executed. In a similar way to teachers observed by Treagust et al. (1992), Mr Carlson did not outline any specific features that were similar between the analogy and the scientific concept, and certainly not any features that might be different. Not only are analogies used in this limited manner in the classroom discourse, Thiele et al. (1995) found that biology textbooks also frequently include simple analogies that may result in learners misunderstanding the concept that is being discussed. It is now well documented that analogies need to be presented in a systematic, extended and useful way for learners to benefit from their use (Glynn, 1991; Harrison and Treagust, 1993 and Treagust et al., 1996). Even more notable than the analogies that Mr Carlson used to explain the gene structure and function, is the small amount of time he devoted to helping the learners understand the concepts. When this is taken in consideration, the lack of progress made by his learners, like Brenda, is not surprising.

4.3.3 The interaction behaviours of biology teachers and learners in Control (C) and Experimental group (E) models

In addition to the learners' performance on the GAT, classroom observations were carried out in 30 lessons to gain a better insight into the relationship that existed between the E and C teachers and their learners. My assumption was that the classroom observations would assist me to know how well the instructional strategies (particularly how the teacher in the E group) had implemented the strategies in question. Table 4.4 indicates the percentage of verbal and non-verbal interactions in the normal genetics lessons in the experimental (E) and Control group (C) using the Genetics Classroom Interaction Observation Schedule (GCIOS) in 15 lessons each. The frequency of occurrence of interactions (based on 10-seconds intervals) was converted to percentages. Descriptive rather than inferential statistics were used in the analysis of the data due to the complex nature of the classroom dynamics. Also, the latter does not seem to provide a distinct advantage over the former when the phenomenon is studied in a holistic and fluid setting as classroom interactions (Dunkin and Biddle, 1974; Ogunniyi, 1992; Ogunniyi and Ramorogo, 1994). The results of this study suggest that the interactions in the Experimental group, where the combined instructional strategies were used were different (though not in all cases) from the Control group class where the traditional teaching method was used.

However, there seems to be observable differences in other aspects of classroom interactions. The C group teacher using the traditional instructional approach tends to:

a) Ignore learners' responses more than the E group teacher (i.e. 8.3% compared to 2.6%).
b) Lectures more than his E group counterpart (i.e. 15.6% compared to 5.2%).
c) Directs more than his E group counterpart (i.e. 14.1% compared to 10.7%).
d) Rebukes, criticizes and exerts authority more than his counterpart (i.e. 11.3% compared to 1.7%).

On the other hand, the E group teacher tends to: (a) supervise and give individual attention more than the C group teacher (i.e. 11.5% compared to 1.4%); (b) accept and reinforce learners' responses (i.e. 6.0% compared to 4.7%) and challenge learners' responses more than the C group teacher (i.e. 6.0% compared to 3.5%).

However, learners in the C group lessons tend to:

a) Read, write, or draw more than their counterparts in the E group lessons (i.e. 11.8% compared to 6.9%).
b) Be involved more in non-productive activities than those in the E group lessons (i.e. 2.8% compared to 1.7%).

Learners in combined instruction lessons, however, tend to respond to more questions from the teacher than those in the traditional instruction lessons (7.9% compared to 6.1%), they ask their teacher more questions than their counterparts (5.2% compared to 1.2%), they initiate talk more than their counterparts (3.5% compared to 1.2%) and they tend to do more experiments than those in the traditional classroom (7.8% compared to 2.4%)

On the whole, these findings seem to suggest that the C group teacher is more direct than the combined instruction teacher. This evidence confirms findings in other regions of the world (Bellack et al., 1960 and Kyle et al., 1979). The issue addressed here is not whether teachers should be direct or indirect but rather whether the interaction patterns they portray are conducive to construction of knowledge by learners. Horton et al. (1993) conducted a meta-analysis and examined the effectiveness of concept mapping as an instructional tool for improving learners' achievement and as a strategy for improving learners' attitudes.

Table 4.4: Percentage of verbal and non-verbal interactions in a sample of 30 lessons involving the use of traditional and combined instructional strategies of genetics

Categories	Control group (15 lessons observed)	Experimental group (15 lessons observed)
Teacher	%	%
1. Empathises	1.9	1.7
2. Gives verbal reward	3.5	4.3
3. Accepts and reinforces learner's responses	4.7	6.0
4. Ignores learner's response	8.3	2.6
5. Challenges learner's response	3.5	6.0
6. Lectures	15.6	5.2
7. Questions: QR, QP, QL, QF	5.9	7.8
8. Responds to question	2.8	5.2
9. Directs	14.1	10.7
10. Supervises/individual attention	1.4	11.5
11. Manipulates apparatus	1.2	4.3
12. Rebukes, criticizes, exerts authority	11.3	1.7
Sub-total %	**74.2%**	**67%**
Learner	%	%
13. Responds to question	6.1	7.9
14. Questions	1.2	5.2
15. Initiates talk	1.5	3.5
16. Experiments	2.4	7.8
17. Reads, writes and or draws	11.8	6.9
18. Non-productive activities	2.8	1.7
Sub-total %	**25.8%**	**33%**
Total %	**100 %**	**100 %**

They found that the top-down instructional strategy of concept mapping has had generally positive effects on learners' achievement, and learners' attitudes. The results also showed that there was little difference in the effectiveness of teacher-prepared versus learner-prepared concept maps in improving learners' achievement. Therefore, concept mapping has also been shown to be an effective strategy in improving achievement. As Jonassen (1988) mentioned, individual differences may play an important role in the use of learning strategies. It is necessary to explore the impact of combining teaching strategies. Learning strategies have been proven to be effective ways of enhancing learning in print-based media (Ryan, 1984; Swanson, 1990; Applegate et al., 1994; Park, 1995).

4.3.3 Patterns of verbal and non-verbal interactions in genetics lessons

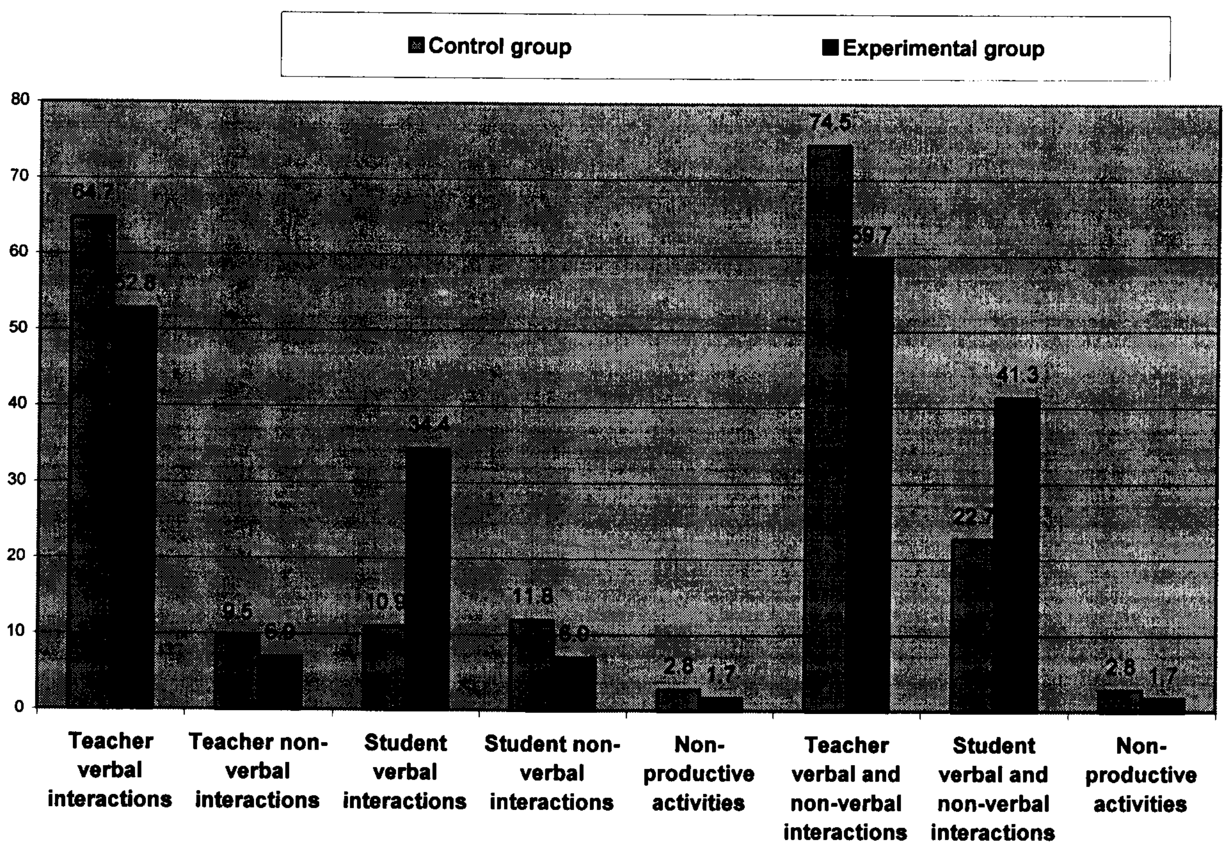

Figure 4.1: Percentage of class time occupied by verbal and non-verbal interactions in a sample of 20 biology lessons on genetics

A learning environment that espouses construction of knowledge by learners should provide learners with ample opportunities to experience phenomena as well as negotiation of meanings by the learners. In other words, learners should be actively involved in experiments, demonstrations and discussions both in small groups and in whole class activities in order for them to make sense of their ideas and experiences. Figure 4.1 shows the percentage of verbal and non-verbal interactions in a sample of 10 each Control and Experimental group lessons. The overall teacher verbal interactions in a sample of C group lessons amount to 64.7% against 52.8% for E group lessons. The learner verbal interactions in the same sample of E group lessons amount to 10.9% against 34.4% in a combined instruction model lessons. This is an indication that the control group teacher out-talked his learners.

This finding corroborates earlier studies in the area (e.g. Fuller and Snyder, 1991; Ogunniyi and Ramorogo, 1994), which suggest that teachers out-talk their learners in science lessons. The consequence of this style of instruction is that the learners' voices to some extent are silenced, thus making it difficult for the teacher to know whether or not his learners are encountering any problem in the lesson. Teacher verbal and non-verbal interactions constitute 74.5% of the C group class time against 59.7 for the E group. Learners' verbal and non-verbal interactions are 22.7% in the C group and 41.3% in the E group. This suggests a fundamental difference in the two classroom environments.

The teacher in the C group tends to dominate the verbal interactions while the learners in the E group class seem to exhibit greater verbal interactions. This finding confirms earlier findings in the area (Corey, 1940; Flanders, 1970; Wragg, 1973 and Ogunniyi, 1977; 1983). The latter is related to freer learner-learner interactions allowed by the E group teacher to engender a more conducive environment for freedom of expression, sharing of meanings and consequently, conceptual change. Figure 4.2 shows the proportions of four types of questions teachers ask in the traditional instruction and combined instruction lessons. While there appears not to be much difference between the factual questions asked by the teachers in the traditional instruction and combined instruction lessons, there seems to be a marked difference in other forms of questions. The teachers' questions in both cases are predominantly factual, i.e. 53.8% and 58.5% for the former and the latter respectively.

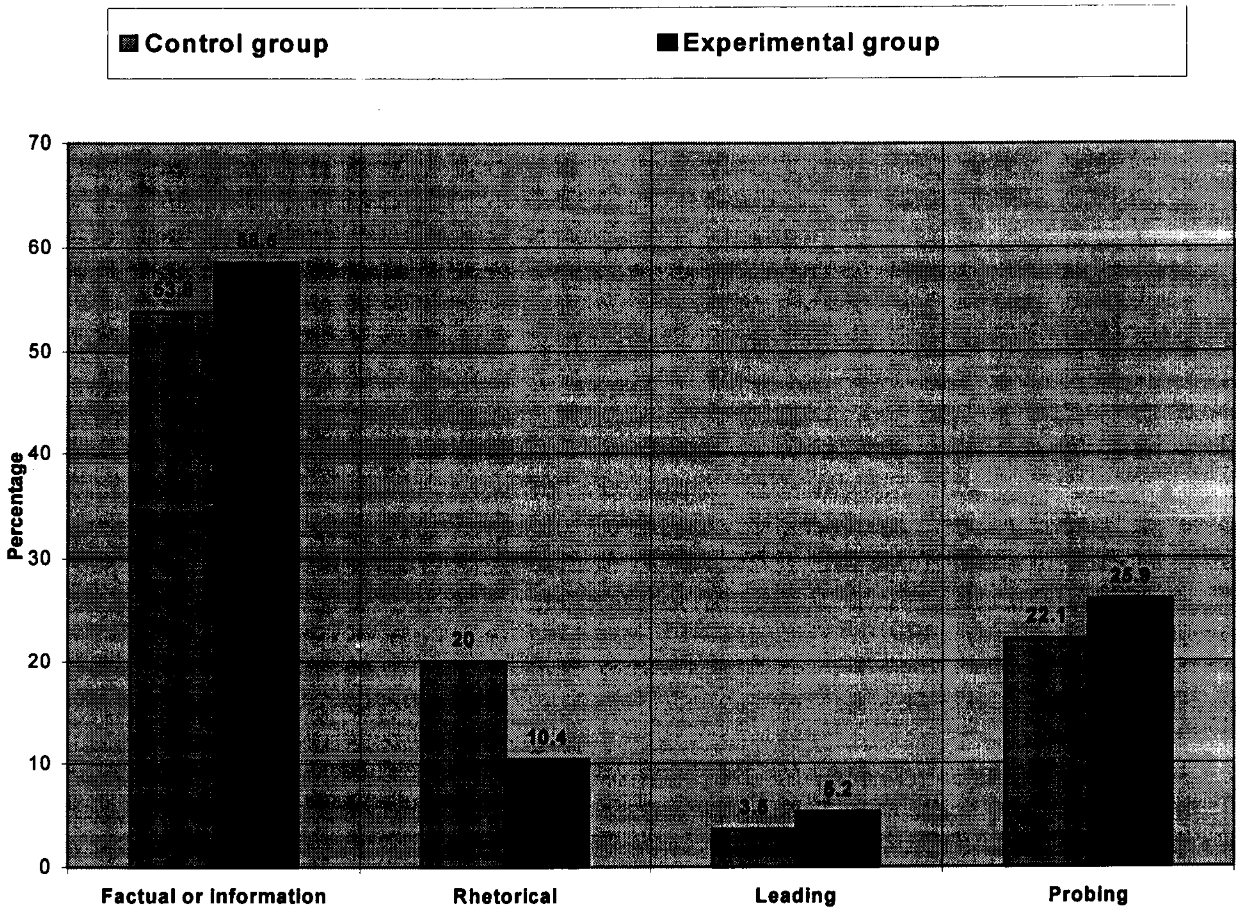

Figure 4.2: Types of questions used by the teachers during a sample of 20 genetics lessons

The implication is that more than half of the questions asked during the genetics lessons were factual. The tendency for teachers to ask predominantly factual questions has been frequently encountered in earlier studies (Ogunniyi, 1983; Rammiki, 1992; Ngueja, 1992 and Ogunniyi and Ramorogo, 1994). This pattern of interactions may not be unrelated to the fact-oriented Western Cape Education examination questions.

While the efficacy of using higher order questions over factual questions to enhance learning awaits further corroboration, factual questions tend to be associated with instructional strategies that encourage rote learning (Gall, 1970; Ogunniyi, 1981; 1983; Ogunniyi and Ramorogo, 1994). As regards other types of questions, the teacher in the traditional genetics lessons seems to ask far more rhetorical questions (20%) than his counterpart (10.4%) in the combined instruction lessons. However, he asks fewer leading and probing questions than the combined instruction teacher (3.5 % compared to 5.2% and 22.10% compared to 25.9% respectively).

If learning were perceived to involve construction of knowledge by the learner, it would seem appropriate that teachers should involve the learners in a process of negotiating meanings. This goes beyond the perception of teacher transmitting knowledge to a conscious reflection of one s' own experiences, ideas, belief systems and the sense one makes of these. A situation where a teacher asks more rhetorical questions and fewer leading and probing questions might encourage less of sense-making from their experiences than otherwise is the case. It probably reflects a scenario where a teacher perceives learning as a mere transmission of knowledge.

While the combined instruction teacher asks generally few questions in his lessons, the quality of his questions in terms of leading and probing questions is higher than that of the traditional instruction teacher. If learning is considered to involve a move from viewing the learner as a passive recipient of information to the one that encourages the negotiation of meaning and knowledge construction, then it seems reasonable to expose the learners to questions that would challenge them to organise their thoughts in such a way that would result in meaningful learning.

This study sought to test if the addition of Concept mapping and Vee diagramming, Martin's (1983) inductive instructional model and Lijnse's (1990) hierarchical conceptual model - used as a means for checking to what extent the experimental group was affected to instruction in a genetics course - would improve achievement. First, when Concept mapping and Vee diagramming are used in a course of instruction, it is better that they be an integral, on-going feature of the learning process, not just some isolated "add-on" at the beginning or end. In this regard, Concept mapping and Vee diagramming appear to be particularly beneficial when used in an on-going way to consolidate or crystallize educational experiences in the classroom - for example, demonstration, or laboratory experience. In this mode, learners experience an educational event and then use Concept mapping in a reflective way to enhance the learning from the event. There is also an indication that learning effects are enhanced when, in the course of Concept mapping and Vee diagramming, learners adopt an active, deep and questioning approach to the subject matter. Such active, self-engaging, transformational interaction with learning material has been suggested to enhance learning in general (e.g., Feltovich, Spiro and Coulson, 1993) and this appears to carry over to learning with Concept mapping and Vee diagramming as a tool. This kind of interaction can be engendered by a teacher/facilitator who challenges the learner to, for example, explain, justify, and formulate questions in the course of building a concept map and Vee diagramming. It can also be induced by the nature of the Concept mapping and Vee diagramming task itself, as when learners are to find and correct the errors in an "expert's" map.

When Concept mapping and Vee diagramming are compared with other sorts of activities, such as outlining or defining concepts, that also can induce the learner to take a thoughtful, systematic approach to engaging subject matter, the positive benefit of Concept mapping and Vee diagramming often diminishes (a finding noted also in the review by Horton, 1993). However, even in these situations, it appears that Concept mapping and Vee diagramming are especially good, in comparison to other interventions, for the learning of *relationships* among concepts. From several of the studies reviewed, there is indication that Concept mapping and Vee diagramming may be particularly beneficial for lower ability learners, partly because they does induce an active, inquiring, orderly approach to learning that is likely a more natural part of the higher ability learner's approach to learning. Finally, the degree of facility with the Concept mapping and Vee diagramming procedure necessary to optimize the benefits of constructing concept maps from scratch is an issue open for investigation.

4.4 Research Question 3: Are Grade 11 learners' understanding of genetics influenced by gender, age and language?

The scores of the Cloze Test performances of the two selected high schools are given in Table 4.5 below. To examine the readability of the text, a cloze test was given to 61 learners (37 females and 24 males). The cloze test results were interpreted using the Bormuth (1968) Readability Categories. Bormuth's research suggests the following criteria for judging the match between text difficulty and readability: cloze test scores greater than 57% place the material at the reader's independent reading level; scores 34% to 57% indicate the material is at the reader's instructional level; and scores less than 34% mean that the material is at the reader's frustration level.

Table 4.5 Cloze test scores of the two selected schools on the passage "Genetic Mechanism" (Thienel et al., 1986, pages 292-293)

Range	Experimental School	Control School	Mean	Description
	N_1=31	N_2=30	N= 61	Independent Level
90-100	-	3 (10%)	3 (4.9%)	
80-89	8 (22.2%)	20 (66.7%)	28 (45.9 %)	
70-79	12 (38.7%)	7 (23.3 %)	19 (31.1 %)	
58-69	8 (22.2%)	-	6 (9.8 %)	
50-57	-	-	-	Instructional Level
44-49	-	-	-	
34-44	1 (3.2%)	-	3 (4.9%)	
0-34	2 (5.6%)	-	2 (3.3%)	Frustration Level

A close examination of Table 4.5 indicates that the cloze test scores range from 3% to 90%. Applying the Bormuth's (1968) readability categories to Table 4.5, it indicates that: 92% of the subjects fall within the independent level; 5% of the subjects fall within the instructional level; and 3% of the subjects fall within the frustration level. These results, when interpreted based on the Bormuth's method of interpreting cloze test results (Rush, 1985: 279-280), imply that: 92% of the subjects can read and learn from the text passage independently; 5% of the subjects can read and learn from the text with the help of their teacher; and 3% of the subjects cannot read and learn from the textbook even with the help of their teacher.

Based on the above interpretations of the cloze test results, one can deduce that, 97% of the subjects can benefit from the textbook passage. However, about one-eighth (3%) of the subjects may face difficulties in reading the text and may not benefit from the textbook, even with the help of a teacher. When these results are interpreted according to the population of the study, 97% of the grade 11 genetics learners in the two governmental high schools in North Metropole of the Western Cape Department in South Africa can read and learn by using the textbook, while 3% of the grade 11 biology learners in these schools may face difficulties in comprehending the textbook. It seems that for the textbook to cater for all learners, some complex sentences and related problems must be addressed. In the context of the current emphasis on inclusive education, textbook writers must aim at making textual materials in any subject accessible to both strong and weak learners without compromising the quality of such textbooks.

A comparison of the cloze test scores of the two high schools indicated in Table 4.6 indicates that the control school (Traditional instruction school) has the largest percentage (100%) of learners who fall in the independent level, compared to their counterparts (90%) in the experimental school (Combined instruction school). When the schools are compared in terms of the total percentage of learners that fall in the independent and instructional levels, that is, the learners who can use and benefit from the use of a biology textbook, still the same, the control school has the largest percentage (100 %) of learners who fall in this category compared to 94% of the experimental school. The differences in the cloze test scores observed in the two schools are assumed to be related to individual differences among learners as well as the prevailing circumstances, such as school culture and also the classroom culture in these schools.

However, considerations of the complex factors responsible for the relative differences are beyond the scope of this study. Certainly, future studies might examine a range of factors influencing learners' reading abilities viz: socio-economic backgrounds of the learners; nature of instructional practices in the two schools; nature of learning environment and school culture, etc. (Fensham, 1991 and Ogunniyi, 1992). Also, as Ogunniyi (1982) has warned, using inferential statistics to determine differences in reading abilities should be avoided as it tends to collapse possible effects of a congeries of complex factors or to assume linearity where there is none. The mean cloze test results in the two selected schools in terms of sex and age of the learners are summarised in Table 4.6 below.

Table 4.6 indicates that 88% of the males and 84 % of the females fall into the independent level, 8% of the males and 14% of the females fall into the instructional level; and 4 % of the males and 3% of the females fall into the frustration level. This implies that a higher percentage of the male subjects fall in to the independent level and again a slightly higher percentage of the males fall into the frustration level. However, the percentage of both sexes falling into the categories of reading or comprehending abilities are relatively close that is, 95.8% and 97.6% for the males and females respectively.

Table 4.6. Cloze Test scores and percentages in terms of age and sex

Range	Gender		Age				Description
	M	F	16	17	18	18+	
90-100%	-	1 (2.7)	-	1 (1.6)	-	-	
80-89%	9 (37.5)	15 (40.5)	11 (18)	8 (13.1)	-	-	
70-79%	7 (29.2)	6 (16.6)	8 (13.1)	6 (9.8)	-	1 (1.6)	**Independent level**
58-69%	5 (20.8)	9 (24.3)	7 (11.4)	7 (11.4)	3 (4.9)	-	
50-57%	-	-	-	-	-	-	
44-49	-	-	-	-	-	-	**Instructional level**
34-44%	2 (8.3)	5 (13.5)	-	6 (9.8)	1 (1.6)	-	
0-34%	1 (4.2)	1 (2.7)	-	2 (3.3)	-	-	**Frustration level**
Total	**24 (100)**	**37 (100)**	**26 (42.6)**	**30 (49.2)**	**4 (6.6)**	**1 (1.6)**	**61 (100)**

In terms of age, Table 4.6 indicates that the 16-year-olds have the largest percentage at the independent level (42.5%) compared to the 17-year-olds (35.9%), 18-year-olds (4.9%) and 18+ year-olds (1.6%). On the other hand, the 17-year-olds have the largest percentage at the instructional level (9.8%) compared to the 16- and 18+ year-olds (0%) and 1.6% for the 18-year-olds. The 17-year-olds are the only ones appearing at the frustration level.

In summary, the data set in Table 4.9 shows that:

- The percentage of male learners who fall into the independent level is larger than the percentage of female learners.
- The percentage of female learners who fall into the instructional level is larger than the percentage of male learners.
- The percentage of male learners who fall into the frustration level is larger than the percentage of female learners.

- A relatively large percentage of learners aged 16 falls into the independent and instructional levels, followed by 17 years, 18 years and lastly above 18 years.
- 17-year-olds are the only ones falling into the frustration level.
- An examination of Table 4.6 also indicates that about 90 %-100% of the 16, 18 and above 18 year olds fall into the instructional and independent levels.
- Based on these cloze test results, it seems that the language used (viz. in biology textbook and genetics package material) is relatively suitable for most of the subjects involved in the study. The implications of these results for instructional practice will be highlighted in the next chapter.

4.5.1 Learners' gender, academic ability and their achievement on GAT in genetics

Table 4.7: ANOVA of pre-test and post-test scores on the GAT

Group	n	Pre-test		Post-test		t-test	t-value
		Mean	**SD**	**Mean**	**SD**		
Experimental (E)	31	34.27	36.3	42.15	9.79	**1.17**	$t_{obs}(14.19) < t_{crit}(1.68)$
Control (C)	30	32.86	38.30	36.57	5.19	**0.53**	$t_{obs}(10.20) < t_{crit}(1.68)$
E vs. C		**t= 0.15**		**t= 2.70**			
[redacted]							
Female	37	32.50	8.71	41.27	6.90	**4.80**	
Male	24	32.24	9.65	35.86	22.75	**0.67**	
Female vs. Male		**t= 0.11**		**t= 1.35**			
t-test		$t_{obs}(0.23) < t_{crit}(1.99)$		$t_{obs}(0.06) < t_{crit}(1.98)$			

* Significant at < 0.05

Key: E = Experimental group
C = Control group

To explore the differences and similarities in the performance of learners in their Experimental (E) and Control (C) groups and gender, a comparison of means on GAT was performed and the t-test was used to determine the strength and direction of the relationships. Table 4.7 above shows a comparison of means of the pre-test and post-test scores of the Genetics Achievement Test according to the groups and sex of the subjects. The Experimental group (E) mean scores obtained for the pre-test were 34.27 while that for the post-test were 42.15. On the other hand, the Control group (C) mean scores obtained for the pre-test were 32.86 while that for the post-test were 36.57.

The level of significance was set at 0.05, obtaining a t-value of 14.19 and 10.20 for the E and the C groups respectively, which were higher than the t-critical value set at 1.68. The difference between the pre- and post-test means could not have occurred by chance. The effect of a combination of instructional strategies on the learners' conceptual understandings of genetics was noticeable.

The pre-test means by sex of the learners suggests that both boys and girls had a similar performance. Although the groups are not random samples, the pre-test means indicates that the two groups were initially equal, i.e. the two groups are comparable. When post-test scores are analysed by groups, statistics based on the t-test with the observed value of 0.23, which is less than the critical value of 1.99, suggests that the difference between the performances of learners in groups is not significant.

On the other hand, when post-test scores are analysed by sex, statistics based on the t-test with the observed value of 0.23, by conventional criteria, this difference is considered to be statistically significant. The result of post-test means by sex of the learners, suggests that girls out-performed the boys. That is, the initial non-difference during the pre-test stage in the performance of the two sexes seems to have disappeared. It is interesting to notice that the long and disturbing history for boys to perform better than girls in science has been broken in this particular study. As such, the pre-test and the sex of the learners do not seem to explain the cognitive gains of the learners.

This significant cognitive gain in combined interaction models of instruction over the traditional ones has been encountered before (Ogunniyi and Okebukola, 1984). There are, however, significant differences in the performance of learners in the experimental group (E) during the post-test compared to the control group (C) respectively. However, like Okebukola (1985), there seems to be a significant difference in the cognitive gains of learners in the experimental group. While the learners in the control group also used the instructional materials to study genetics, the lack of significant cognitive gains seems to suggest the importance of the social environment in the learning process. As such higher cognitive gains seem to result when knowledge that is personally constructed is socially mediated.

The gender of the learner is an important factor in classroom interactions for several reasons. The most compelling reason is that unlike sex, which simply implies that an individual is either male or female, gender refers to the manner in which males and females are socialized into socio-cultural roles (Dirasee, 1990). For this reason, the manner in which the learners are socialized into their socio-cultural roles would be expected to affect the way they would interact and participate in genetics lessons as well as their perceptions of their roles in the learning environment. In Table 4.7, an analysis of variance for scores on the Genetics Achievement Test for the experimental group and the true control group against the sex of the learners shows significant differences in the post-test scores of the learners. Thus, exposing learners to the instructional teaching and learning materials seems to have regressed the achievement of the learners towards the mean. In a sense, the girls have improved their performance towards the mean while the performance of the boys seems to have regressed towards the mean. The mean scores for boys were 35.86 while that for girls were 41.27 suggesting that the performance of girls was significantly higher than that of the boys after exposure to the instructional practice.

The influence of gender on learning can be viewed from a variety of perspectives. From a behaviorist perspective, the external stimuli applied to the learner would cause him/her to behave in a certain way. That is, the learner would behave the way he/she is rewarded to respond. In this sense, if a teacher and or parents reward the learner to display certain feminine or masculine behaviours, he/she will learn such behaviours and display them when the appropriate stimuli are presented. This study, however, does not seem to condone this view, in the sense that the girls in this perspective would be expected to have maintained their advantage and continued to out- perform the boys.

Viewed from a social constructivist perspective, however, when the learner is socialized into the culture of the society, he/she does not simply imbibe the cultural matter presented to him/her, but rather actively interacts with such matter making sense of it and in the course of this interaction making judgments about what constitutes his/her own reality which would in turn determine how he/she wants to behave. Hence the way the learner behaves is largely a matter of his/her interpretations of the cultural cues he/she receives. Task specialization espoused in the genetics teaching protocols (Appendix 1/2B and Appendix 1/2C) in this study, might have made it possible that learners irrespective of gender should get ample opportunities to interact with the learning environment and make sense of their experiences, thus reducing the effects of social stereotypes that the learners may bring into the learning situation.

The effects of an instructional strategy on the learners' performance may not only reduce the disparities between the achievement of boys and girls, but also the achievement of learners of different academic abilities. Thus, combined teaching strategies seem to have had significant cognitive impact for the slow and high ability learners. It is acknowledged that these findings represent the performance of learners on a small slice of knowledge. Perhaps future studies might attempt to explore the effects of a broader spectrum of topics over a longer period of time than was available for this study.

4.5.2 Language and construction of knowledge

An analysis of utterances in groups in which learners spontaneously converse in English and in Afrikaans/Xhosa/Zulu respectively (with sample transcripts attached in Appendix 11), suggests that learners who readily use English as a medium of interaction seem to i) discuss ideas to a greater depth; and ii) show a greater understanding of the concepts involved. Their counterparts on the other hand: i) appear not to go into much depth discussing their concepts; ii) tend to digress into chatting and humor; iii) very often, pose arguments which are variegated with folklore and non-task related talk and iv) bring into the discussion their everyday experiences.

It appears that the learners who spontaneously discuss their ideas in English are more likely to follow their discussion to a logical end than their counterparts who used Afrikaans/Xhosa/Zulu in their discussions. An analysis of discourse in the groups that spontaneously used English tends to indicate that the learners actually make more sense of the concepts discussed, and are able to go beyond the information given more than those who use Afrikaans/Xhosa/Zulu. This phenomenon may not be unrelated to the fact that a lot of people in South Africa still consider anything that has colonial overtones as superior or desirable. For instance, it is not uncommon to find a beautiful child likened to a white (English) person or civilized person; a brilliant child described in terms that connote English superiority (modern or civilized) or a perfume with as sweet smell described as smelling "English".

As a result, learners who seek social approval would identify with this notion of superiority, initially by using the English language and subsequently by showing a higher mastery goal orientation. A mastery goal orientation relates positively to increased self-confidence and the use of learning strategies that enhance meaningful learning (Graham and Golan, 1991; Meece and Jones, 1996). Consequently, while Afrikaans/Xhosa/Zulu as languages may not have a lot of words that would be the equivalent descriptive of a lot of concepts in science, not enough seems to have been done to explore the potential of using it as a medium of instruction. The few cases where science concepts were communicated in Afrikaans/Xhosa/Zulu belie the potential to which Afrikaans/Xhosa/Zulu can be used to communicate science concepts. For instance, the metaphoric nature of the Xhosa/Zulu language exemplifies this phenomenon.

Learners who are alienated because of their lack of competence in the English language may demonstrate work-avoidant goal orientation. Learners who *display work* avoidant behaviour want to complete the assigned tasks without working sufficiently hard (Meece and Jones, 1996). Perhaps this may explain why those learners who conversed in Afrikaans/Xhosa/Zulu did not seem to reflect a deeper conceptual understanding of the issues at stake. Beyond the view that Xhosa/Zulu cannot accommodate scientific concepts, the findings may suggest a broader picture of how learners learn science. This embraces the realization that learners bring into the genetics-learning situation their worldviews, which are not necessarily consonant with the scientific worldview. As such, if teaching does not take cognisance of both the learners' worldviews and their language, the result could be that the learners may actually hold conflicting ideas about phenomena.

Learners may hold such conflicting ideas without learning, or what Ogunniyi (1988) calls harmonious dualism. Perhaps the difference observed when learners discuss their ideas in English and Afrikaans/Xhosa/Zulu respectively suggests a case of collateral learning in which the learners would compartmentalize knowledge in their long-term memory and draw on appropriate knowledge for strategic use in either the English (Western) or Afrikaans/Xhosa/Zulu (Traditional) environments. It also appears that learners who would spontaneously speak Afrikaans/Xhosa/Zulu in their groups bring into the discussions a lot of folklore and their everyday experiences, as recorded and documented in Appendix 11.

The learners use language to communicate their ideas to others and to make sense of their learning experiences. Viewing it from this perspective, language becomes an important determinant of what can be learnt meaningfully because it determines the extent to which the learners may convey their ideas for others to understand. Language switching between English and Afrikaans/Xhosa/Zulu in genetics classrooms is a common phenomenon though, officially, the learners are expected to learn their science in English.

However, there were times in class when learners communicated predominantly in English and those when learners communicated predominantly in Afrikaans/Xhosa/Zulu in their small groups. Moje (1995) observes that language in classrooms can be controlled and used to maintain classroom identity. In other words, teachers may use the elite language of science to maintain some degree of identity with the scientific community. Likewise, learners who wish to be successful might want to adopt this language as a form of identity with the teacher and the class community.

Some learners, however, may not want to be part of this dominant culture and hence may reject it in order to identify with other cultures and, as such, remain alienated from the dominant classroom community. It appeared that the experimental (E) teacher was quite flexible with the language he used throughout the lessons. Such teacher would use both Afrikaans and English as he taught. Learners of such teachers seem to show an increased tendency to freely converse in both English and Afrikaans. An analysis of discourse in small groups in the control class (as attached in Appendix 11), where the dominant medium of communication is English shows some contrast between groups consisting mainly of fast learners and those consisting mainly of slow learners.

4.6 Summary

In this chapter, the results of the study were analysed and discussed. The results indicate that the interaction patterns of the combined instruction and traditional instruction teachers differ. The traditional instruction teacher in this study seemed to give more verbal rewards, accept and challenge learners' responses, lecture, and rebuke, criticize and exert authority on the class more than his combined instruction counterpart. The combined instruction teacher, however, seem to supervise and give more individual attention to the learners than the traditional instruction teacher. An ontological perspective of conceptual change (Martins and Ogborn, 1997) was initially used in this study to investigate what concepts of genetics do grade 11 learners hold before and after a period of instruction in genetics, not only on the student worksheet but also for each item/question on the GAT in detail, especially those item which made a relevant pattern to the study.

CHAPTER FIVE

Conclusion, Implications and Recommendations

5.1 Introduction

The purposes of this final chapter are to summarise the conclusions of this mini-thesis; to discuss its implications for genetics education and conceptual change; and to suggest recommendations emanating from the study. Finally, the possibilities for further research in this area and the limitations of this research are discussed.

5.2 Summary of the results

The conclusions that can be drawn from this study include, among others, the following:

1) The teaching approach was one factor that influenced learners' progress and this was best illustrated by Mr. Duran's approach (combinations of instructional strategies) that seemed to be most successful in facilitating conceptual change (see Table 4.3). He overtly addressed the need of learners to understand the process aspects of genes. Mr. Carlson's learners on the other hand did not develop a fruitful understanding of the gene concept. Though he encouraged his learners to develop clear ideas of the DNA structure; however, these ideas were limited because many of his learners did not understand the significance of the blueprint of architect's plan analogy – they did not know why it was important.
2) Interest was identified as a factor that inhibited learners' progress to more sophisticated models of genes in their conceptual structures. Learners, generally, were interested in the human heredity of genetics and during interviews; they focussed on simple Mendelian ideas of dominance and recessiveness of alleles when asked how genes control characteristics.
3) Learners in the experimental group performed significantly better in the post-test than those in the control group in the Genetics Achievement Test.
4) At the pre-test, the sex of the learners do not seem to affect the performance of learners, the use of the combination of instructional strategies and materials seems to have had an effect on the performance of the learners, particularly weaker learners.
5) There is no significant difference between the achievement of boys and girls

involved in this study with respect to the selected concepts of genetics.

6) The teacher of the traditional instruction class spent more time talking than his learners. In the combined instruction class however, the learners spent more time talking than their teacher.
7) The induction workshop seems to have had some salutary effects on the interaction behaviours of the combined instruction teacher in the sense that his verbal interactions are substantially fewer than those of the traditional instruction teacher.
8) Despite the induction workshop, the teachers continue to ask a lot of factual questions. There seems to be no difference in the number of factual questions asked by the combined instruction teacher and the traditional instruction teacher during genetics lessons. The tendency for teachers to use factual questions seems to be a common occurrence in science classrooms (e.g. Gall, 1970; Onocha and Okpala, 1990; Ogunniyi, 1984). This may not be unrelated to the predominantly factual nature of the questions in the national examinations. The combined instruction teacher however, tends to ask more leading and probing questions and fewer rhetorical questions in line with the objectives of the training workshop.
9) The learners' participation and achievement in genetics lessons does not seem to vary with the learners' sex.
10) The language that the learners use to communicate their ideas seems to affect their rate of concept formation. The tendency for learners to switch from English to Afrikaans/Xhosa/Zulu is not uncommon. Learners, who, without coercion, choose to discuss their ideas in English, appear to discuss their ideas and concepts to a greater depth than their counterparts who spontaneously discuss their ideas in Afrikaans/Xhosa/Zulu.
11) The data obtained from the worksheet and interviews suggested changes in the learners' ideas about genes. A noticeable change in the learners' ideas probably as a result of the combined instructional strategy, is their shifting from passive to an active notion of the gene. For instance, learners described genes by saying they "determine", "control" or "influence" characteristics.
12) Another noticeable change in the learners' ideas about the physical nature of the gene. Before the course, they used words like "thing" or a "cell" to describe genes, which indicates that initially genes were viewed as being passive. For some learners, this passive view of a gene changed to a more active meaning of the

concept.

13) The third noticeable conceptual change among some learners was their perceptions of the gene with the process of protein synthesis.

14) The majority of the learners' conceptions did not change from one extreme of the pathway to another. The data presented indicate that the majority of learners' conceptions did not progress beyond the gene model in this pathway.

15) The conceptual change demonstrated by the learners is what Hewson (1981, 1982, 1986) calls a weak conceptual change. In other words, it is merely a form of reconciliation with their old conceptions (Strike and Posner, 1992) rather a stronger change in conception or what Posner et al. (1992) calls conceptual exchange (p.43).

5.2 Implications

One of the main factors that influenced learner learning about the gene concept was the teaching approach. Mr Duran's approach seemed to be more effective than Mr Carlson in terms of enhancing learners' understanding of the concept of the gene. However, both teachers were teaching within the guidelines of the syllabus. Perhaps then, part of the problem lies within the syllabus. An implication of this study is that syllabus material could use the gene concept as a central organizing concept in introductory genetics. The functional aspects of the gene should not be given a merely cursory mention, but clearly stated. The development of links that this central organizing concept of the gene has with other concepts in genetics (such as the cell, meiosis, chromosomes, DNA, proteins and patterns of inheritance) also should be encouraged by the way the syllabus is written and, consequently, by the way that teachers teach. The importance of central concepts such as the gene also has been highlighted in the literature. According to Smith (1992), teachers of genetics should be more concerned with teaching the fundamental concept in genetics thoroughly than trying to cover too much material in introductory courses. He suggested teachers should be focusing on the important things and omitting the rest.

> In this age of knowledge explosion (especially in genetics), the time has come to focus our instruction more on meaningful understanding of foundational concepts than on shallow "exposure" or "coverage" (Smith, 1992: 78)

The concept of the gene is indeed a central organizing concept in genetics, but it is surprising how the national syllabus materials in South Africa address the concept, usually with little more than a simple objective. This research suggests that - for teachers to be able to encourage learners to construct a "productive sequence of instructions", gene conception in their cognitive structures - they must include certain strategies in their teaching. Examples of these strategies include linking concepts (using concept maps and Vee diagrams) in genetics, improving the teaching of genetics processes, and raising the status of learners' conceptions.

One of the findings of this research that has clear implications for the teaching of genetics is that learners have difficulty linking concepts in genetics. This implication could have immediate impact on classroom teaching if teachers employ teaching strategies that will facilitate the connection of concepts about genes and about genetics in general. Understanding the concept means, among other things, to know its relationship with many other concepts (Fisher, 1986). Much has been written in the science education research literature about strategies that will facilitate the process of integration between concepts and conceptual change. One of these strategies is concept mapping and Vee diagramming. Concept maps are a tool that allows the learner to link ideas and create a physical picture of a large topic (White and Gunstone, 1992; Novak, 1996). Novak (1996) claims that concept maps are an important tool for improving science teaching and learning because they "serve to show relationships between concepts, and it is from these relationship that concepts derive their meanings" (p.32). Fisher (1996) points out that genetic systems are very complex and cannot be reduced to simple relationships such as those used in other science fields (such as the relationship between force, mass and acceleration). In this sense, the complexity that Fisher (1996) describes in genetics can be better represented by concept maps and Vee diagrams.

White and Gunstone (1992) suggest a number of strategies that are useful for guiding learners in constructing understanding. A number of these strategies would be particularly useful for genetics in the light of the findings of this study. For example, drawings are a useful strategy to probe understandings that are hidden from other procedures. In this study, to probe learners' conceptions of genetics, drawings were useful when other strategies such as the worksheet and verbal non-verbal interactions did not provide enough information about learners' understanding (see chapter 4, for example).

Unlike the combined instruction classroom, traditional instruction classroom in genetics lessons are characterized by lots of straightforward teacher talk and fewer occasions of learner talk. Considering that the learners in the combined instruction classroom out-performed those who were in the traditional instruction classroom, the usefulness of excessive teacher talk in learning situations becomes questionable. The important implication from this finding is how best to articulate both the teacher's and learners' interactions in such a way that would enhance conceptual understanding among the learners. Thus it is not enough to encourage teachers to talk less in their lessons without putting concomitant strategies in place to ensure that learners not only have more time to talk in their lessons, but also use such talk meaningfully to construct their own knowledge.

While learners who used English to discuss their ideas in small groups seemed to go into much more detail, their counterparts who used Afrikaans/Xhosa/Zulu used more of their daily experiences in their discussions. The implications of these findings warranting further investigation are: (1) What influences the learners' choice of discourse language in small group discussions? (2) What are the effects of familiar and unfamiliar topics on learners' choice and use of language in small groups? (3) What are the pedagogical implications of the learners' choice and use of a given language in small group discussions? (4) What are the effects of using a learners' preferred language on the participation and achievement in genetics?

5.3 Recommendations

On the basis of the findings of this study, the following recommendations are proposed.

1) Learners should be given opportunities to (a) select the relevant methods to investigate the problem at hand, (b) determine what data to collect and when to collect them.
2) The examination questions should demand deeper understanding so that the teachers espouse teaching strategies that encourage construction of knowledge in their lessons. It is reasonable to expect that the examination should be used to

direct the processes of teaching and learning in line with the constructivist perspective espoused in the curriculum 2005.

3) In making recommendations to promote the understanding of genetics processes, Kindfield (1992) sees learning about subcellular processes as fundamentally model building. The first recommendation is for teachers to treat learning as model building and view learners as model builders. Active engagement in reasoning about processes can be encouraged by asking "learners" to talk about or explain their thinking and attempt to persuade others. This is one of the recommendations of the Teaching Genetics Conference sponsored by the National Science Foundation (Smith and Simmons, 1992). Unfortunately, none of these activities were observed in the classrooms that were part of this study.
4) Further, on the topic of model building and processes, another recommendation is that DNA models should be built by asking the learners to explain how structure explains function. This was something missing from Mr Carlson's approach to teaching DNA structure. There connection between the structure of the gene and its function was not made explicit. Hence many learners failed to understand the significance of the double helix.
5) In order to enhance the learners' understanding of the "productive sequence of instruction gene model", they should be encouraged to follow the examples of researchers by searching for scientific information on specific genes and their effects (Kindfield, 1992).

5.4 Possibilities for further research

1) The possibility for further research that has become evident from this study is the investigation of "learners' conceptions" of genes at different ages or with different amounts of education. This study focused on grade 11 (16-18+ years old) learners. Chapter 4 includes evidence suggesting that younger learners may not distinguish between genes and characteristics in a manner similar to that of early geneticists and whether there are other alternative conceptions of genetics held by learners. Further research with younger learners is required to determine if this is the case, and whether there is any other alternative conception learners have about genetics.

2) It might be informative to find out the effects of using the gene as the central organizing concept in a similar case study to this one or where other forms of combined instructional strategies are used.

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APPENDIX 1A

Scheme of Work

BIOLOGY: GRADE 11

Note

The scheme of work were written by practising teachers and are intended as an overview for science teachers to check or prepare their own preferred activities and resources. The units of the scheme of work are numbered according to the direct reference point within the appropriate subject policy specification.

10.1 - Cell Division

Approximate teaching time: 1 hour

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Each and every chromosome carries a large number of genes. Chromosomes are found in pairs in body cells. Many genes have different forms called alleles, which may produce different characteristics.	It might be useful at this stage to review their understanding of genes, chromosomes and DNA. Students could use the microscope to look at root squashes showing chromosomes. Look at human karyograms. It is useful to teach the **idea** of chromosome replication, even to lower abilities. *It would be useful at this stage to introduce one gene and represent its two alleles on the model chromosome. This should then be used to illustrate that one of each pair of alleles comes from each parent.*	Know DNA, genes and chromosome structures and their functions. *Know the difference between mitosis and meiosis.* *Know that the gametes are produced from the parental cells by meiosis.*	

Suggested Resources Data cards. Suitable worksheets. For suitable textbooks see Resources list.

Assessment Opportunities
Homework Suggestions

10.2 - Genetics and DNA

Approximate teaching time: 5 hours.

Prior learning/context
The genetic basis of sexual reproduction.
Chromosomes contain long molecules of DNA.

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
The terminology associated with monohybrid crosses. In human body cells, one of the 23 pairs of chromosomes carries the genes, which determine sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY). Chromosomes have long molecules of a substance called DNA. A gene is a section of a DNA molecule. For certain characteristics, the characteristic is controlled by one gene. Some genes have two different forms called alleles.	Review the earlier work on Mendel and the arrangement of chromosomes, genes and alleles in the cell. Students need to be made fully aware of how DNA relates to genes and chromosomes. Look at a human karyograms. Identify the sex chromosomes and the 22 "other pairs". Note the differences between the X and Y. Use models to work out why there is an equal chance of male and female offspring. Lower ability students can play the "gender game". Use letters alone to do the same in a genetic diagram. Punnett squares pose fewer problems for genetic crosses. Use models to illustrate the behaviour of an autosome.		

10.2 - continued

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
An allele, which controls the development of a characteristic when it is present on only one of the chromosomes, is a dominant allele. An allele, which controls the development of characteristics only if the dominant allele is not present, is a recessive allele. Three different genetically determined disorders: Huntington's disease, cystic fibrosis, and sickle-cell anaemia. *If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene.* *If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene.* *Analyse likely parentage and possible offspring from information given to students in various forms.* *The relationship between DNA and the structure of proteins.*	Use one of the characteristics in 13.1 to show what happens to an autosome during sexual reproduction, putting appropriate letters on the chromosome. Use letters alone to do the same. Discuss each genetic disorder in turn. Encourage students to consider the lifestyle of people with the disorder – how would their lives be different? Explain how people might be carriers and how that might change their lives. Learn how to produce family trees. Use maps to compare the distribution of sickle-cell anaemia and malaria. This can be used to reinforce the work on evolution. *Each time get students to carry out the crosses using the model and then using letters.* *Students could be asked to construct a poster to illustrate the processes involved in the formation of proteins.*	*Some will be able to predict and explain the outcomes of crosses.* *Most students will know that DNA contains the coded information for the production of proteins.* *Some students will be able to describe the process by which the code is used to determine the sequence of amino acids.*	Attention is drawn to the potential and sensitivity in going about teaching inherited disorders.

Suggested Resources MRC/NIAS booklet 'Genetic Disease'. *DK GCSE Science Biology has many genetics questions. DK CD-ROM A-Level Biology – for animations on transcription and translation.* For suitable textbooks see Resources list.

Assessment Opportunities *Genetics problems.*

Homework Suggestion

10.2.1 – Controlling Inheritance

Approximate teaching time: 5 hours

Prior learning/context

Selective breeding in agriculture has resulted in varieties of plants and breeds of animals that have increased yields.
The section links very closely with units 10.1 and 10.2.

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
Some of the many ways in which scientists can generate clones of plants, animals and bacteria. Taking cuttings from older plants can produce new plants quickly and cheaply. These new plants are genetically identical to the parent plant.	Take cuttings of common indoor plants. Link this by discussion to asexual reproduction. Relate conditions for survival of the cuttings to transpiration.	Know that cuttings are most likely to grow successfully if they are grown in a damp atmosphere until roots develop.	Care if using hormone rooting powder.
We can use artificial selection to produce new varieties of organisms. We do this by choosing individuals, which have characteristics useful to us and breeding from them.	Start artificial selection by listing the different breeds of dogs. List the characteristics of each breed. Discuss how the breeds might have been produced. Consider what might happen if all breeds bar one were to become extinct. What would we now consider to be a dog? This should lead into an understanding of the reduction in alleles in a population. The idea of a gene pool seems to aid this understanding and could be used at this time.	Understanding the role that artificial selection has played in producing the domesticated plants and animals that we have today is crucial. Some students will see the drawbacks in terms of reduction in the number of alleles and the reduction in the possibilities for future generations.	

10.2.1 – Continued

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
Genes can also be transferred to the cells of animals or plants at an early stage in their development so that they develop with the desired characteristics. The processes involved in modern cloning and genetic engineering.	Examples of artificial selection include cattle, sheep, horses, pigs, pigeons, poultry, wheat, barley, potatoes and cabbages. Consider the advantages of, for example, producing drought resistant wheat. How might this have been achieved – a thousand years ago and today? There is an excellent opportunity to discuss the ethics surrounding this process. At what point does it become unacceptable: plants; frogs; cattle; endangered species or humans? Discuss the importance of rare breed institutions. Questionnaires could be constructed for testing public opinions concerning cloning and genetic engineering.	Be able to make informed judgements on the economic, social and ethical issues involved in cloning and genetic engineering.	

10.3 Variation and inheritance

Approximate teaching time: 5 hours.

Prior learning/context

A knowledge of sexual reproduction.
An awareness of the variation apparent between organisms of the same species.
Laying the foundation for basic Mendelian genetics.
Links with unit 10.1 cell division

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
The relative importance of genetic and environmental causes for the differences in characteristics.	Use the class or small groups to draw up a list of human characteristics. Try to include religion, skin colour, and language spoken as these lead to some very challenging discussions.		
Young plants and animals resemble their parents (have similar characteristics) because of information passed on to them in the sex cells (gametes) from which they developed.	Identify which are genetically determined, environmentally determined or both.		
Genes carry this information. Different genes control the development of different characteristics.	Prepare trays of F1 seeds, grown with light and without light, also F2 seeds grown in light.		
New forms of genes can result from mutations.	Research the work of Mendel. This is an opportunity to develop skills based on Ideas and Evidence. New Discussion of the causes of mutation.		

10.3 – Continued

Learning Objectives	Possible Teaching Activities	Learning Outcomes	Points to Note/ Risk Assessment
The genetic importance of sexual and asexual forms of reproduction. There are two forms of reproduction: Sexual reproduction - which involves the joining (fusion) of male and female gametes; Asexual reproduction - where there is no fusion of cells and only one individual is needed as the single parent. Asexual reproduction gives rise to individuals whose genetic information is identical with that of the parent. These genetically identical individuals are known as clones. Sexual reproduction results in individuals that have a mixture of the genetic information from two parents. These individuals show more variation than offspring from asexual reproduction.	For lower ability students, modelling in some form is essential to establish the basic genetic function of sexual and asexual reproduction. (Card models on which alleles can be written at a later stage are helpful.) Modelling should then be followed with diagrams and then possibly animations or computer simulations. Use of colour coding on the model chromosomes can help in the understanding of why sexual reproduction results in greater variation.	*Know the difference between mitosis and meiosis and know why sexual reproduction gives rise to variation:* □ *the gametes are produced from the parental cells by meiosis* ▶ *when gametes fuse, one of each pair of alleles comes from each parent* ▶ *the alleles in a pair may vary and therefore produce different characteristics.*	

Suggested Resources For suitable textbooks see Resources list.

Assessment Opportunities Throughout the development of these difficult concepts, it is important to allow students the opportunity to discuss in groups and to explain in class what they have learned.

Homework Suggestions Research the life and times of Gregor Mendel. Start a collection for a notice board on any newspaper articles on genetics.

APPENDIX 1B

STRUCTURED TEACHER' S GUIDE

Genetics

Learning Objectives

- Discuss how genetic and environmental factors control life expectancy
- Compare genetic and environmental traits in family members
- Experiment to determine how many people are "tasters"

Concept Map Teaching Strategies

	Poor (2pt)	Satisfactory (3pts)	Good (4pts)	Excellent (5 pts)
Organization	Serious errors in organization, difficult to follow	Some lapses in organization that effect coherence and unity	Organization shows relations of terms, few lapses in organization but overall it is easy to read and understand	Well organized and logical in all areas, map is organized in such a way that concepts and links are easy to follow and understand
Ideas	Ideas are minimal, inappropriate or random	Ideas are somewhat random, minimal, or repetitious	Shows well developed ideas (terms and concepts), enough to establish purpose of concept map	Ideas are pertinent, extensive, establish purpose and show all elements of the topic
Connections	Concept map is mostly linear, with very few multiple connections to relate terms	Concept map is mostly linear, but has some connections that link multiple ideas	Concept map is presented as a web, terms are linked to multiple other terms	Terms and concepts are linked in web form, showing multiple relationships between concepts and ideas
Knowledge	Concept map shows very little overall knowledge of ecology and related terms	Concept map shows some knowledge of ecology and related terms, gaps are evident	Concept map shows a solid knowledge of ecology, and related terms, some minor gaps in knowledge, missing or misconnected terms	Concept map shows extensive knowledge of Ecology - links show an excellent and comprehensive understanding of ecosystems and the interrelatedness of organisms and environment
Items	Less than 10 concepts shown	11-20 items shown	21-30 items shown	30 or more items on concept map
				Total _______ out of 25 (x2)_______ **out of 50**

Work Sample & Commentary: *DNA Concept Map*

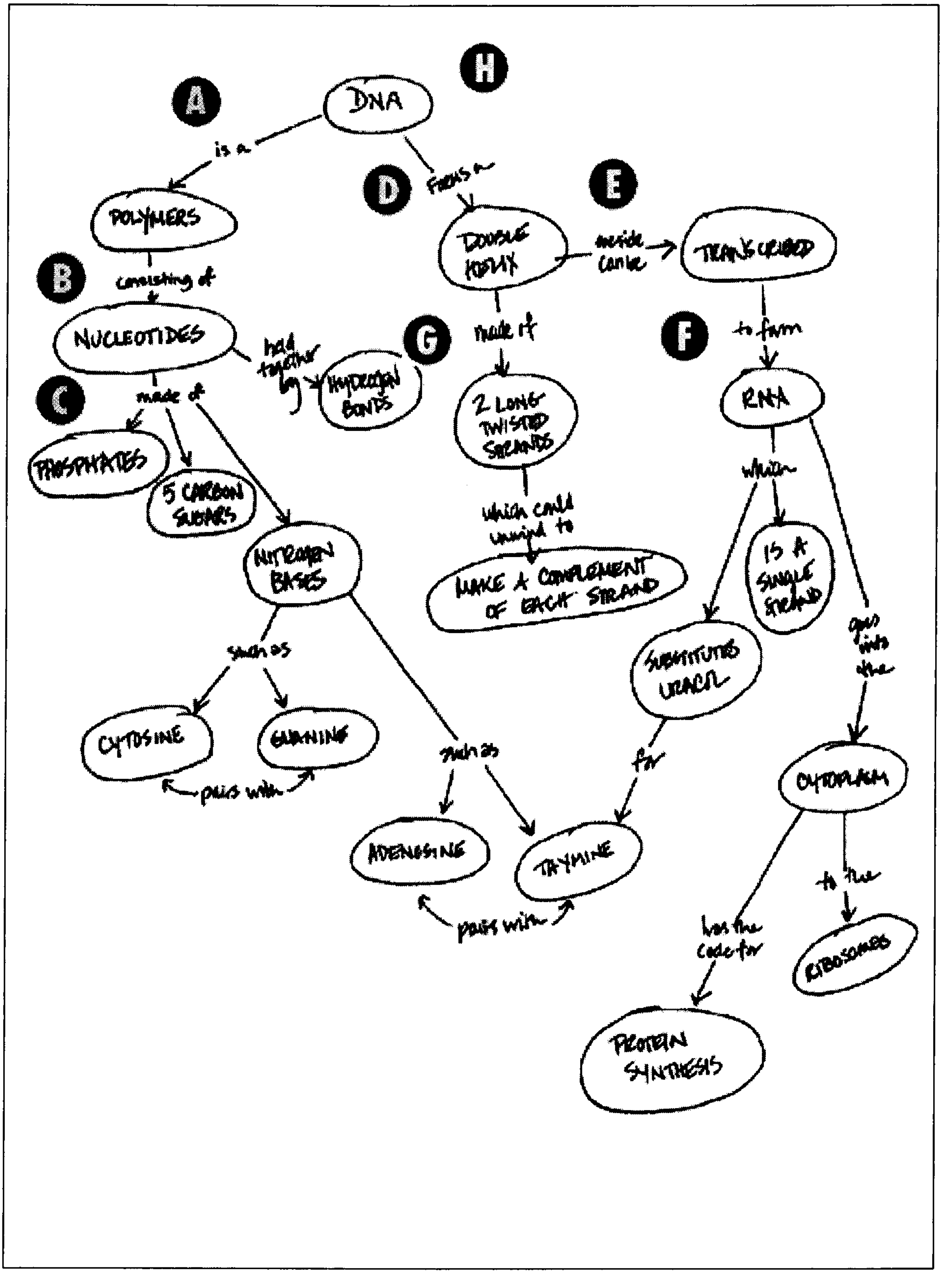
The task

Learners in a high school biology class were asked to create a concept map to show the relationship between DNA, its components and those of RNA. Students had to present their map and defend its structure to the class.

Circumstances of performance

This sample of student work was produced under the following conditions: The work was done in teams of three students.

Alone	**In a group**
In class	As homework
With teacher feedback	With peer feedback
Timed	**Opportunity for revision**



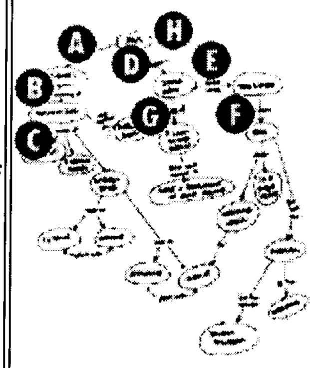
This work sample illustrates a standard-setting performance for the following parts of the standards:

Life Sciences Concepts: The student produces evidence that demonstrates understanding of molecular basis for heredity, such as DNA....

(A)(B)(C) The concept map shows the components of DNA, and the bonds that hold them together. The work shows the role of hydrogen bonds but does not distinguish them as weak, nor does it show location of the bonds. However, the overall organization of the concept map is logical and reasonably accurate.

(D)(E)(F) The concept map also includes key concepts such as formation of a complementary strand, transcription, and RNA.

(F)(G) The organizations of DNA and RNA are shown in terms of double versus single strand; note substitution of uracil for thymine.



Genes and Cell Replication

Announcements:

HOMEWORK: Design a concept map - due Wednesday, August 18 by 10 am.

Individual Assignment: Construct a **concept map** demonstrating your understanding of inheritance, using these terms:

- Gene
- DNA
- Chromosome
- Amino acids
- Protein
- Meiosis
- Mitosis

Objectives today:

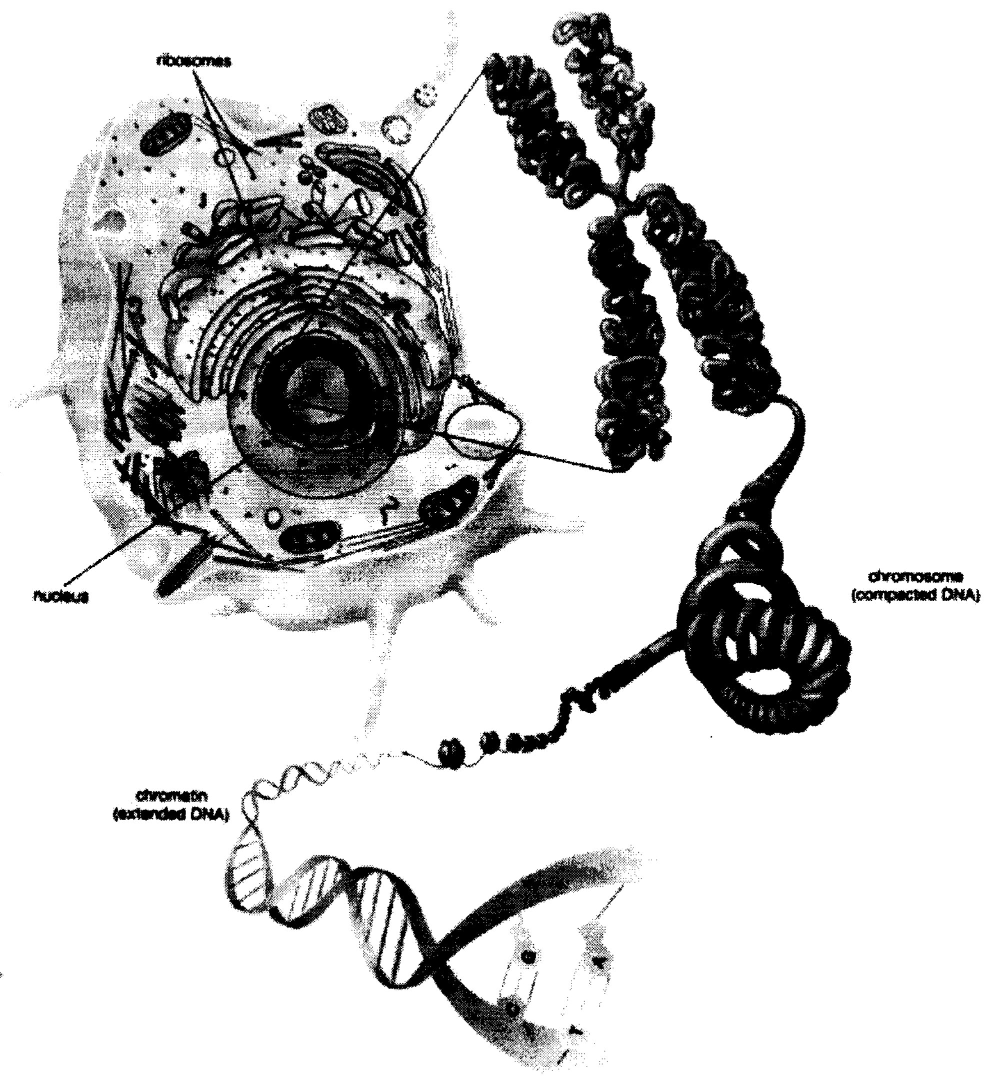
1. Evaluate results from clover experiment
2. Practice making concept maps
3. Understand the relationships among DNA, genes, proteins and traits
4. Explain how traits are passed on and how they are connected to DNA
5. Understand why a change in DNA can result in a change in traits
6. Determine how one parent cell can make **genetically identical** daughter cells by:
    a. Creating a representation of a cell with at least 2 chromosomes and explain how it replicates to get two identical cells (mitosis);
    b. Using your body as a model organism, describe where we would find cells undergoing mitosis and where we would find cells that are not likely to be dividing.

What are genes made of?

Genes are a section of DNA that codes information for making proteins.

Chromosomes are made of DNA

Genes are located on Chromosomes



What are the requirements for genetic material

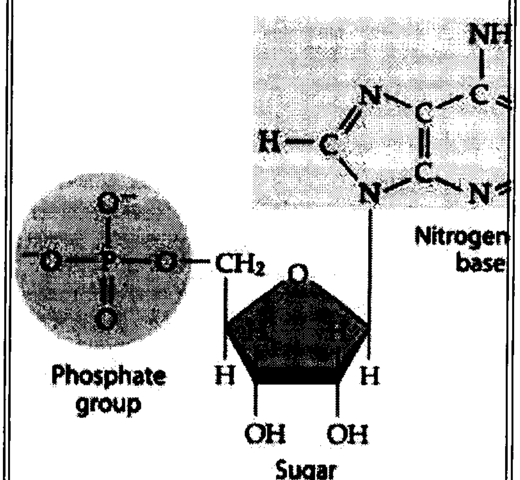
Genetic material

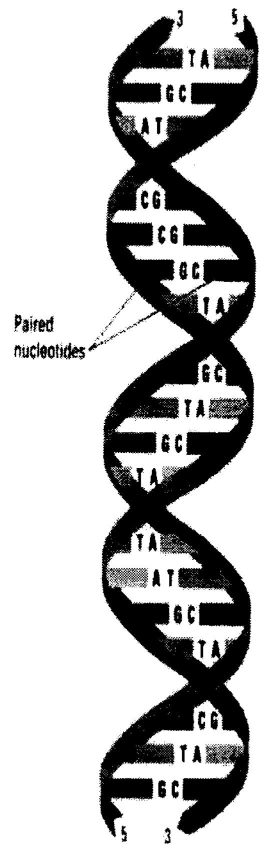
1. Must have variation to code for traits (sequence of 4 base pairs)
2. Must replicate exactly and transfer to daughter cells

What is the structure of DNA?

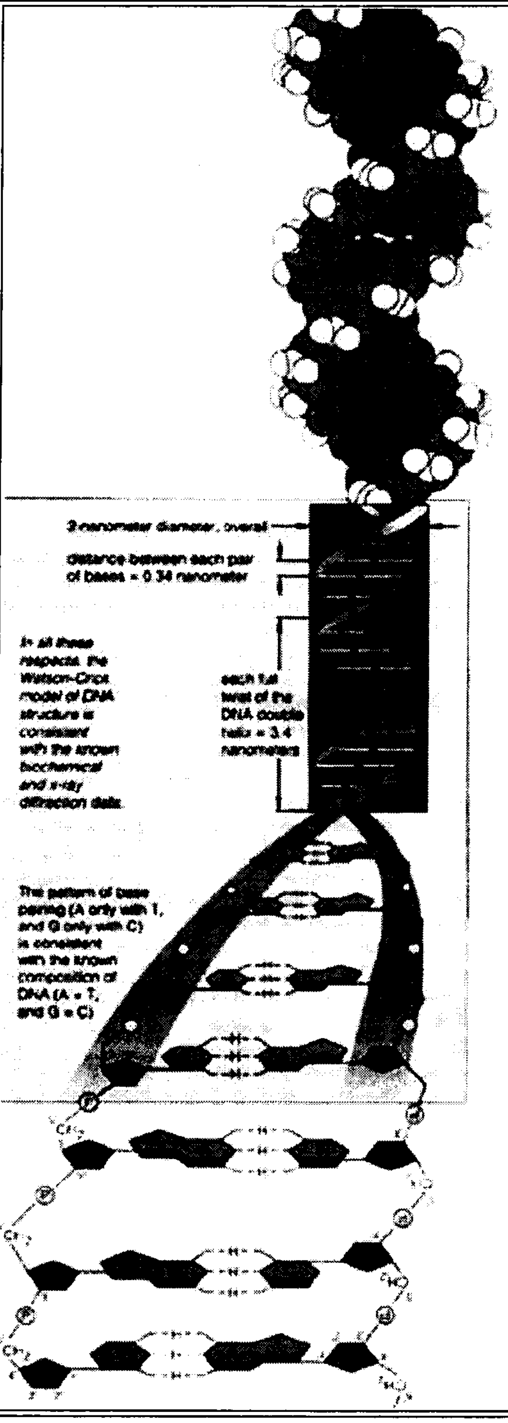
DNA is a nucleic acid made of 4 nucleotides

adenine (A) and guanine (G) (purines)
thymine (T) and cytosine (C) (pyrimidines)

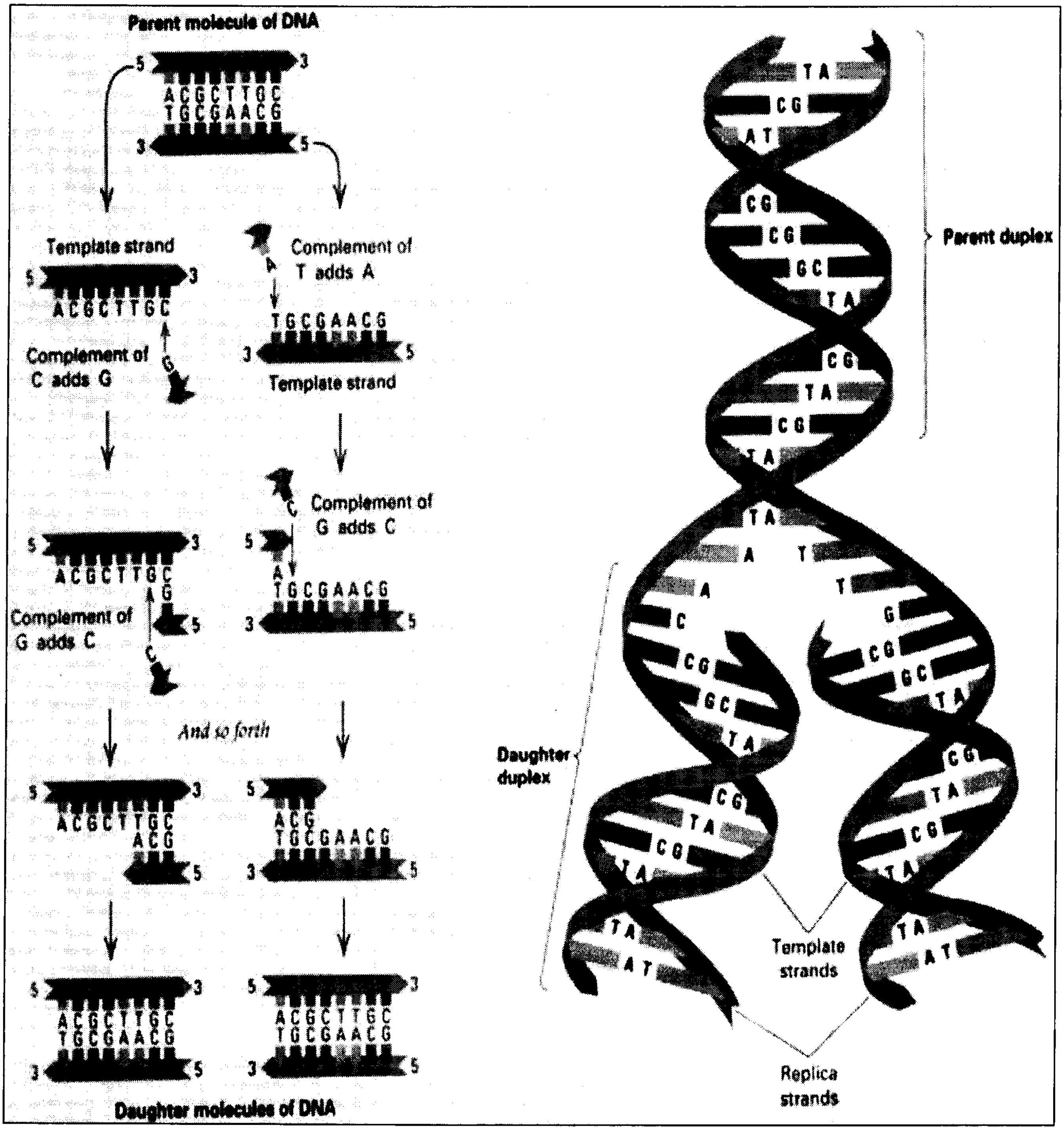




What does DNA look like?

Double helix Adenine->Thymine A-T Guanine->Cytosine G-C By knowing the sequence in one strand can deduce the sequence in the other.	

How does DNA replicate?

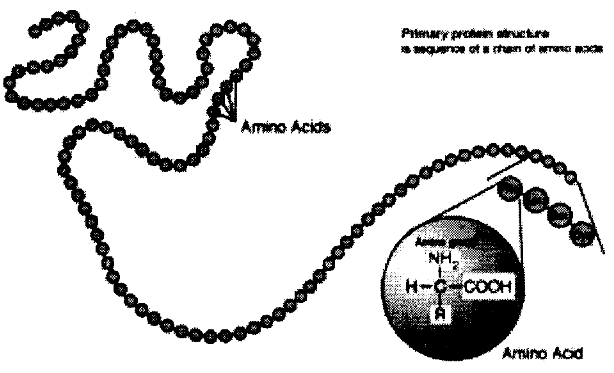
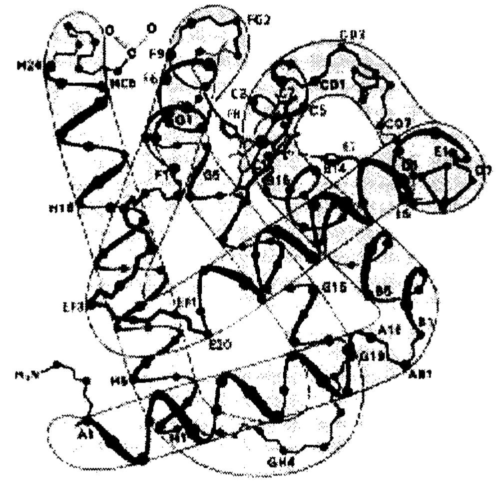
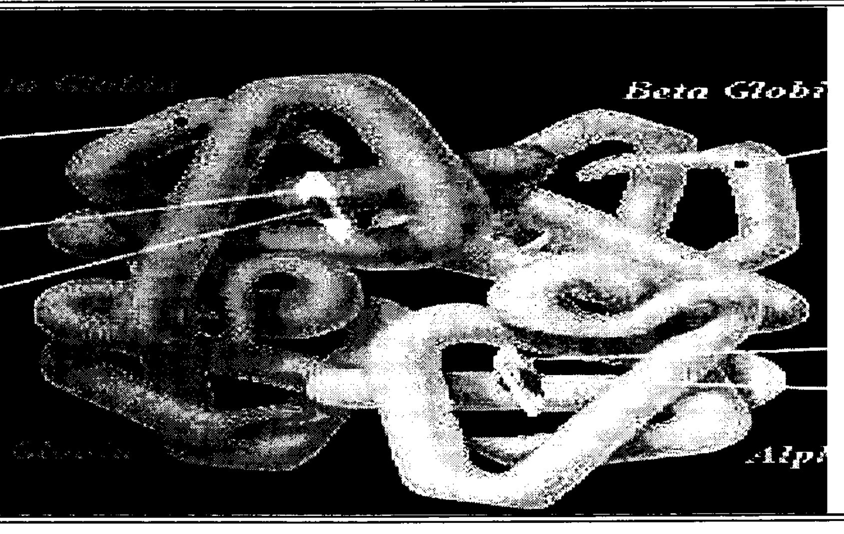


How does DNA code for proteins?

Genes code for proteins via the molecular trilogy:

DNA -> RNA, and -> amino acids

Proteins are made of 20 different amino acids (polypeptide)

<table>
<tr><td>Primary structure</td><td>Protein can then fold into a three dimensional shape</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td colspan="2">Sometimes it is combined with other proteins</td></tr>
<tr><td colspan="2"></td></tr>
</table>

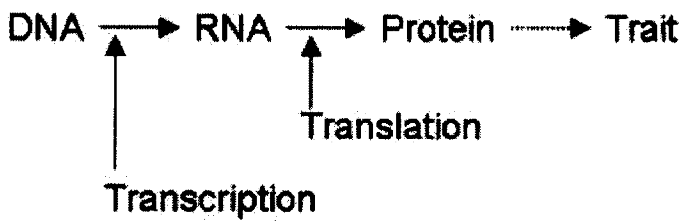
Why should I care about proteins?

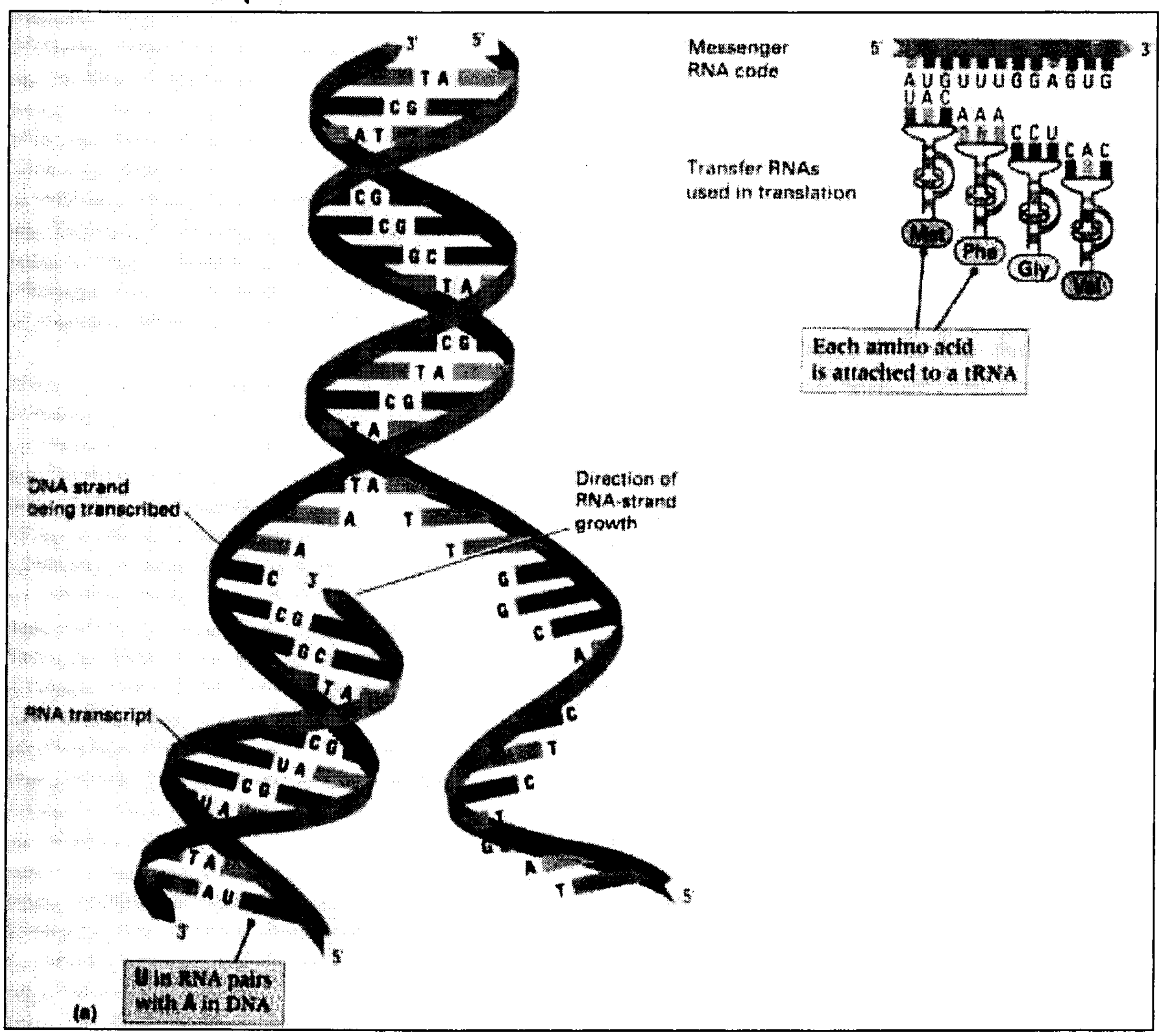
Proteins interact with other molecules as

- regulators of gene activity
- enzymes
- transporters
- structural elements

DNA determines the order of the amino acids in protein
How? **Genetic code**

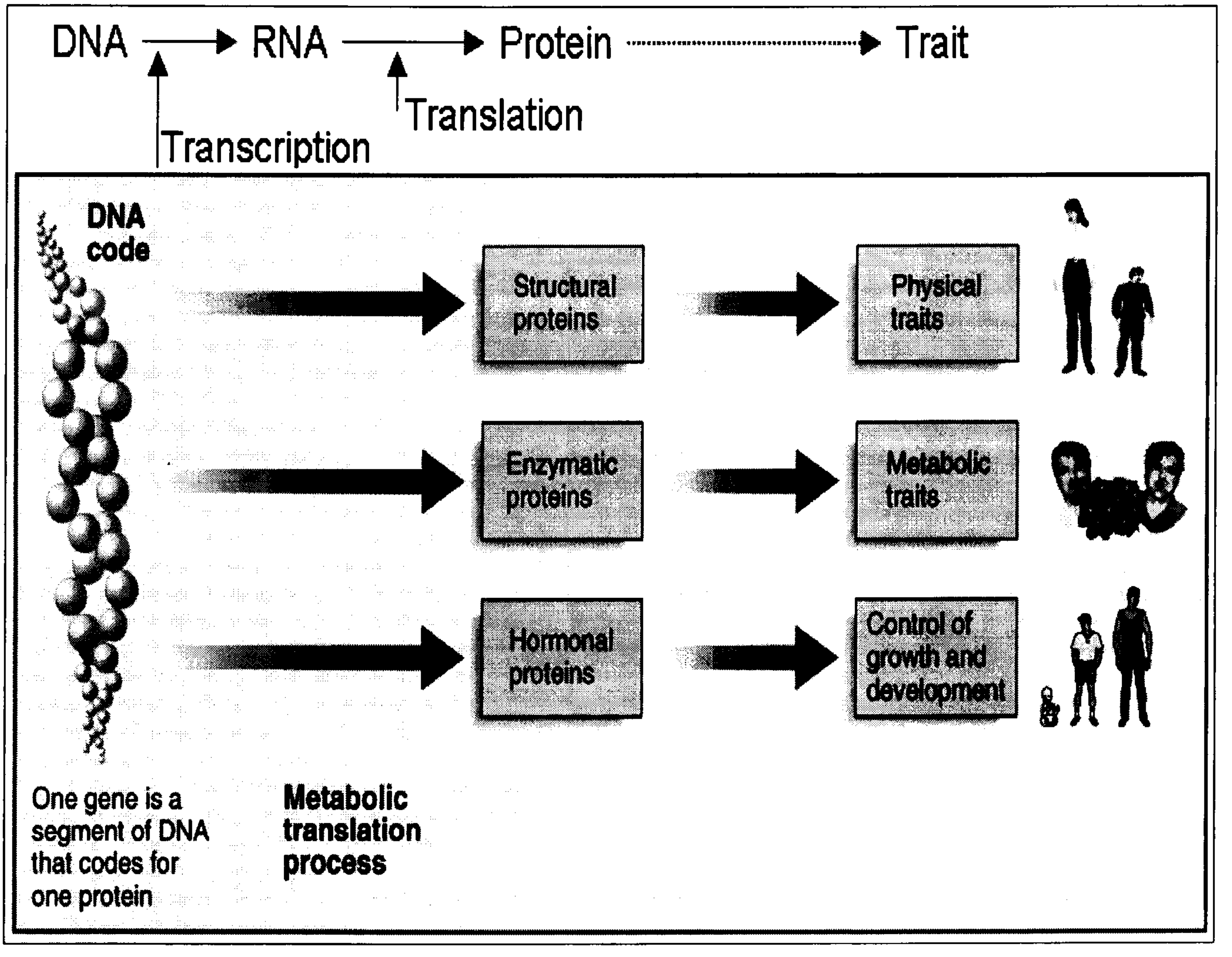
A sequence of 3 nucleotides specify each amino acid, start and stop the same code is used for all organisms





How are traits passed on and how are they connected to DNA?

Traits are characteristics of organisms.



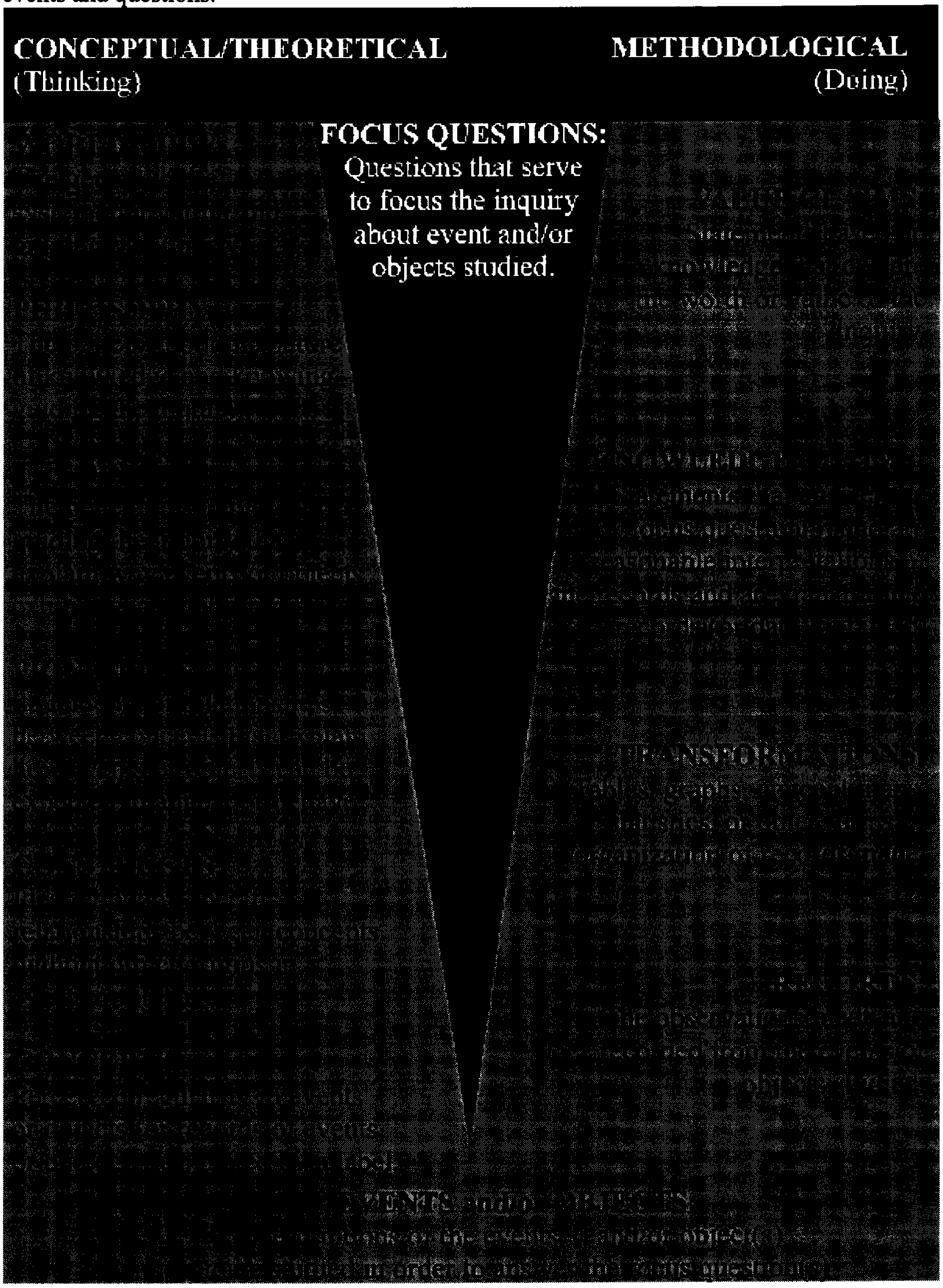
Teaching Strategies

V Diagrams

Bob Gowin developed the vee diagram as a way to aid in the understanding of meaningful relationships between events, processes, or objects. It is a tool that helps in seeing the interplay between what is known and what needs to be known or understood. Upon completion, a **V** diagram is a record of an event that was investigated. The vee diagram has three purposes: (1) planning and carrying out a research project, (2) analyzing a research article, and (3) as a teaching tool. Students in our Explorers of the Universe project primarily use the vee to analyze research articles and to plan and carry out their case-based research.

The **V** is a name derived from the shape of the diagram. A vee diagram is a structured visual means of relating the methodological aspects of an activity to the underlying conceptual aspects. It focuses on the salient role of concepts in learning and retention.

Gowin's Vee showing epistemological elements, which are involved in the construction or description of new kowledge. All elements interacts with one another in the process of constructing new knowledge or value claims, or in seeking understanding of these for any set events and questions.



The Vee diagram has a *conceptual* (thinking) side and a *methodological* (doing) side. Both sides actively interact with each other through the use of the focus or research question(s) that directly relates to the events and/or objects. The point of the **V** contains the events and/or objects that are to be observed.

The conceptual side includes philosophy, theory, principles/conceptual systems (which include developing a concept map), and concepts all of which are related to each other and to the events and/or objects on the methodological side of the Vee. The methodological side includes value claims, knowledge claims, transformations, and records. These records (facts) of events and/or objects consist of various types of data collecting instruments (e.g., log entries, journals, data received from telescopes -- those that are automated and/or equipped with a CCD camera and those that are not. -- use of video tapes to capture related events or objects, interviews, field notes, measurements of time, length, weight, height, temperature, related documents, and so forth). When planning a research investigation, it is important to think about what kinds of instruments you will use to collect data. The data will be transformed into some organized fashion such as tables, graphs, charts, figures, transcribed dialogues, and so forth. These tabulated results enable you to make knowledge and value claims. The knowledge claims answer the questions that were asked. The value claims determine the worth of the investigation (e.g., What good is it? Is this knowledge worth knowing? Does it have any practical or theoretical use? Does it help to better understand the event or object that was studied?). While there is no set way to read a V Diagram (either from left to right or right to left, or anywhere in between), it is advisable to begin with the events at the point of the Vee followed by the focus or research question(s). The reason for such a progression is that the event is paramount in determining the focus or research question(s) for the inquiry and the subsequent interplay among the conceptual and methodological elements. Familiarize yourself with these terms: event, object, and concept. They are described above under Concept Maps and apply to the V Diagram.

Using the Vee to *Plan* a Research Project

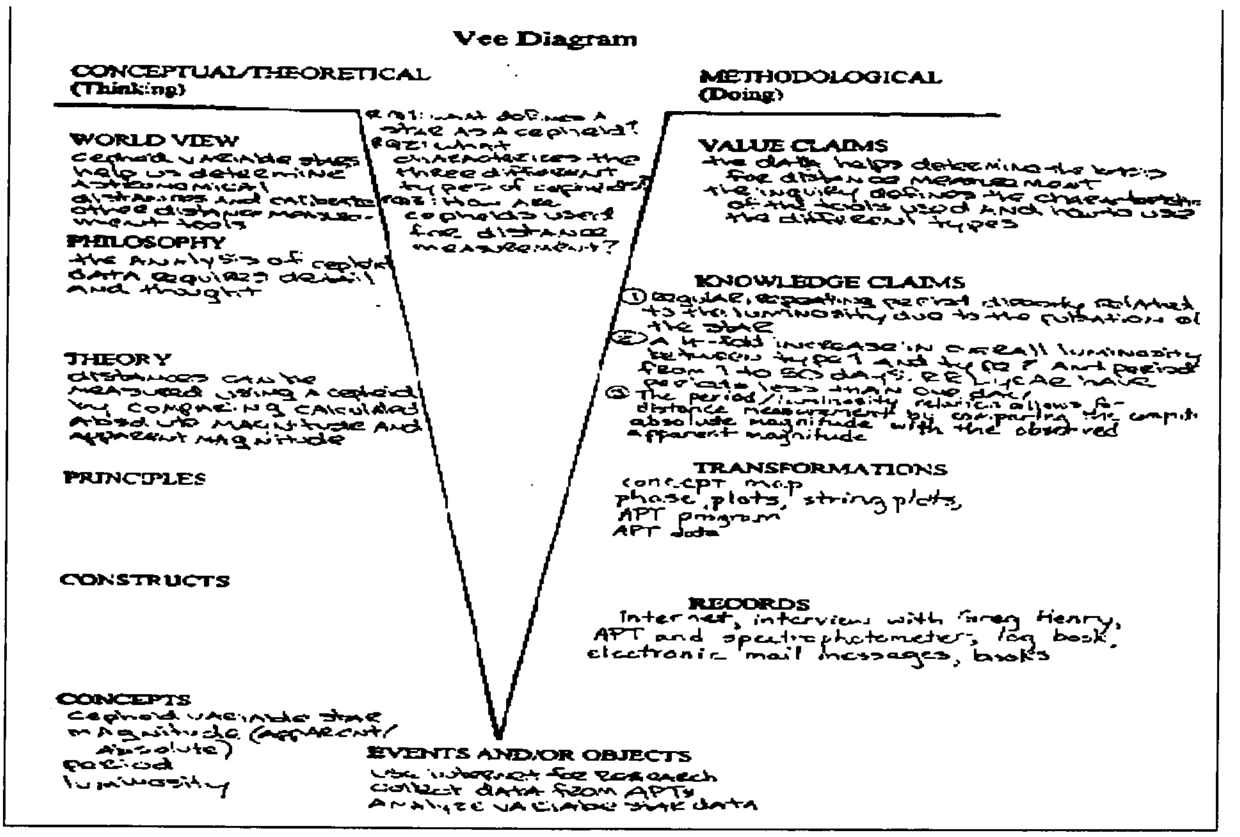
Preparing to engage in your research investigation:

1) Formulate a problem or an idea to study. Refer the figure describing the components of the Vee. Is there a worldview associated with your problem or idea? Is there a philosophy guiding the inquiry?
2) Relate the problem or idea to previous studies (literature review), prior knowledge, and experience. Is there a theory (ies) that you will use to guide your inquiry?
3) Describe the event(s) and/or object(s) to be studied. (Located at the point of the Vee Diagram)
4) Determine the focus of your inquiry. Develop research questions that serve to focus the inquiry about the event(s) and/or object(s) to be studied.
5) Under concepts, list the concepts that need to be operationally defined for your investigation. To make this determination, review your research questions and the events/objects for these concepts.
6) The records portion of the Vee is the facts that are gathered of the events/objects being observed. Under this heading, list the data collection instruments that you plan to use to record the events/objects to be studied.

7) Decide how the information that you collect will be transformed into an organized data set. How do you plan to represent this data (e.g., table, chart, graph, diagram, etc.)?

Your problem or idea is formed. The events/objects to be studied are designed to answer the research question(s) that you have posed. The concepts needed to clarify your research question(s) and events/objects are stated. The records are listed that will be used to collect the data. If there is a world view, a philosophy, and/or a theory that is guiding your inquiry, they are indicated on your Vee. The ways in which you plan to analyze and organize your data are listed under transformations. *You are ready to begin your research investigation.*

A Vee diagram constructed by a team of high school students



Completing the Vee Diagram

Upon completing your data collection, analyzing the dat and representing it in an organized format, you are new ready to finalize the remaining components on the Vee Diagram.

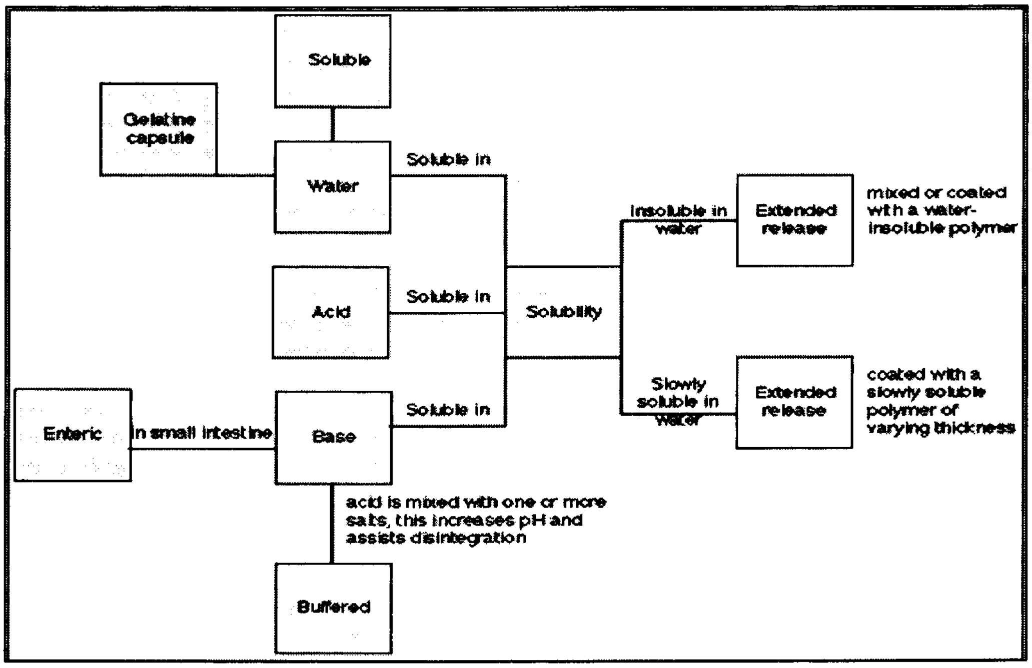
8. Using the information from the transformed data, knowledge claims are constructed to answer the research question(s). These statements are reasonable interpretations of the records and transformed records (or data) obtained from your investigation.

9. Principles and theories follow knowledge claims. Principles tell ***how*** events or objects appear to behave. For example, in an experiment conducted with third graders with sprouting seeds a

principle derived from the outcome is "Plants need air, water, soil, and light to grow." Theories show ***why*** events or objects appear to behave as they do.

10. Value claims are statements of self-worth. It is an expression of feelings about the findings of the inquiry.

These components, once completed, comprise the structure of knowledge of an event or object. Structure refers to the elements and their relation to each other. You are now able to write your research report using the information on the vee diagram. The first part of your report will describe how you prepared and organized your investigation (see 1-6). Your second part will include your entries in response to 8-10. The final part will discuss your findings based on your knowledge claims and value claims and includes implications for future research.



The Improved Vee Heuristic

Background to development

The Vee heuristic in its basic form was developed by Gowin (e.g. Novak and Gowin 1984) and has been strongly improved by Åhlberg (1993, 1996, 1997a and 1997b). In educational situations, both students and tutors are able to use Vee heuristics (Åhlberg and Ahoranta 1999a and 1999b, Alvarez and Risko 1987). Tutors can get useful knowledge about their student's thinking and values and thus the Vee heuristic can be used to improve their teaching and help them better understand and help their students. Students' metacognition clearly improves with use of the improved Vee heuristic (Åhlberg and Ahoranta 1999a and 1999b).

How it is used

An example of an improved Vee heuristic is given below. It contains ten theoretically justified steps to high quality learning and thinking. Working through a process like this is a hard job, and at first people often resist it. But after having done it they almost without exception think that it improves their learning and thinking.

The improved Vee heuristic contains three basic phases of action research and three basic stages of continual quality improvement: planning, implementation and evaluation. The form of the Vee reminds us that we construct knowledge only by making an accurate question and trying to answer it.

In order to construct relevant, deep knowledge of anything of importance, it is necessary to follow all ten steps. The left side of a Vee heuristic should be completed before a learning project and the right side after the project. Issues about values and thinking will be revealed that can subsequently form the basis of student-tutor or group discussion.

An example of use

The Vee heuristic below was produced by Vuokko Ahoranta, Principal of Kangaskylä School in Finland, following professional development work on education for sustainability. She asked what she had learnt from the professional development and how it could be applied to her school and her teaching.

Software counterpart

There is now software counterpart, but facilities in Microsoft Word may be sued to generate Vee heuristics.

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AN ANALYSIS OF ELEMENTARY EDUCATION MAJORS' PROGRESS WITH VEE DIAGRAMMING

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M. Virginia Epps, University of Wisconsin-Whitewater

Research Questions

In this paper, we describe how the vee diagram was used in elementary science methods courses. We used student-centered investigations to provide the context to test the assumption that the vee diagram was a tool to help prospective teachers with their construction and implementation of investigations. The following questions focused the study:

1. Do the prospective teachers show improvement in their use of vee diagrams while designing and implementing investigations?

2. Do the prospective teachers show a reduction in anxiety toward doing investigations, as a result of using vee diagrams while designing and implementing investigations?

3. What patterns are revealed through analysis of pretest and posttest vee diagrams?

Subjects and Instrumentation

Students

Students participating in this study were enrolled in one of three sections of a elementary/middle school science methods course (3 credits). Students in science methods represent one of three programs leading to licensure: 1) pre-school, kindergarten, and elementary school, (preK-6); 2) elementary school, (grades 1-6); and 3) elementary and middle school, (grades 1-9). Just over half of the students were either 1-6 or 1-9 majors. As is typical, the students in these methods courses were female, from rural or suburban schools, and White. Most male students were elementary/middle school majors (1-9 majors).

Prior to enrolment, students completed two years of general studies and a nine semester credit Pre-Professional Program including an eight day urban f~eld experience. Most students completed the mandatory eight semester credit hours of science including a five-semester credit

Laboratory science course and a three-semester credit non-laboratory science course. These courses must be either physical science or life science. Few students choose to complete the 24 credit general science minor that can be elected. None of the students had previous experience with constructing investigations or vee diagramming. Students at the beginning of one methods course were asked to respond to questions about their previous science experiences. The following statements from that open-ended survey are representative: "In middle school my teacher taught science through lectures and movies. I really didn't learn much about science during these years."

"I have not really learned a lot about science during my college years. I've had one biology class where all of the exams were open book."

"[In college] Lectures and lab. Both were interesting, but the lab really caught my attention and was easily remembered, where in lectures there was a lot of memorization."

Anxiety

Zuckerman's instrument (1960) was used to document students' anxiety towards constructing and implementing investigations. Jegede, Alaiyemola, & Okebukola (1990) used this instrument and found gender specific trends (among males) between anxiety reduction and achievement. The instrument has twenty-one adjectives reflective of anxiety embedded in a field of sixty adjectives. Scores lie on a scale of 0-21, 0 indicates no anxiety and 21 indicate high anxiety. A more complete discussion of Zuckerman's anxiety instrument was provided by Jegede et al. (1990).

Vee Diagram

The vee diagram instrument was designed for students to construct responses to capture their investigative operations. This instrument includes a simple description of vee diagrams, a blank vee diagram, graph paper, narrative data, and tabular data. The narrative and tabular data consist of information about Whooping Cranes (Stoker, Agsteribbe, Windsor, & Andrews, 1972). The narrative portion provides a brief description of the Whooping Cranes' migratory pattern, nesting and feeding habits. The tabular set provides data students might modify to answer questions they pose. For example, students can convert snowfall into rainfall then combine rainfall with snowfall. Variables include year of migrating adults, number of migrating adults, number of nests, eggs laid, eggs hatched and precipitation. The graph paper is provided to support students while they search for relationships.

The rubric for scoring vee diagrams provided by Novak & Gowin (1984, p. 71-2) was mod)fied. Table 1 shows the modified scoring scheme with a total possible 18 points. Students were asked to apply the concept of variables in their Focus Question and Principles & Concepts. The Transformations section emphasized skills associated with graphing (McKenzie & Padilla, 1986). Students were not asked to include the following sections of Novak & Gowin's vee diagram: World View, Philosophy, Theory, and Value Claims.

Table 1

Vee Diagram Scoring Rubric Adapted From Novak & Gowin (1984)

Component of Vee Criterion

Focus Question

0 No focus question is present

1 A question is present, but does not suggest variables

2 A focus question is present, but either the dependent or independent variable(s) is/are not suggested by the question

3 A clear focus question is present with specific suggestion of both independent and dependent variables

Principles & Concepts

0 No conceptual side is present

1 A few concepts are identified, but without principle(s)

2 A few concepts are identified and a principle present, but it is the knowledge claim sought in the mvestigation

3 Concepts that are relevant to the investigation and principle(s) are present

4 Concepts are operationalized and principle(s) is/are present

Objects/Events

0 No objects or event s are identified

1 The objects or events are identified, but are/is inconsistent with the focus question

2 The objects or events are identified and are/is consistent with the focus question

Records

0 No records identified

1 Records are identified, but are inconsistent with the focus question or the major event

2 Records are identified, and are consistent with the focus question or the major event

Transformations

0 No transformations are present

1 Processing of raw data (arithmetic manipulations) or graphing is present but is inconsistent with the focus question

2 Processing of raw data (arithmetic manipulations) or graphing is present and is consistent with the focus question, but the graphing is done incorrectly

3 Processing of raw data (arithmetic manipulations) or graphing is present and is consistent with the focus question, and the graphing is done correctly

Knowledge Claims

0 No knowledge claim is present

1 Claim is unrelated to the left-hand side of the Vee or the focus question OR there is simply a statement of data without a generalization present

2 Knowledge claim includes a generalization that is inconsistent with the records and transformations OR claim is not clearly derived from records and transformations

3 Knowledge claim includes the concepts from the focus question and is derived from the records and transformations

4 Same as above, but the knowledge claim leads to a new focus question

Procedures

The study involved three sections of science methods courses taught by two different science educators. In the descriptions that follow, the two method sections are referred two as Group 1 (taught by one investigator) and the third section as Group 2 (taught by the other investigator).

Group 1

Students in the first two sections (n = 51) completed approximately 10 investigations using vee diagrams. As the semesters progressed, the strategy was to shift from investigations initiated by the instructor to those constructed by the students. Butts' (1966) model of inquiry was used to engage students in investigating. Butts suggested that students search information, process data, discover ideas, verify ideas, and transfer ideas as a "cyclic operation" (p. 6). Early in the semester, students were provided data (in tabular form) from which they searched for relationships, or asked a question (e.g., What factors might affect . . .) from which students generated a list of ideas to investigate. Students used science resource books to generate investigations later in the semester.

Early in the semesters, students were introduced to the following ideas: 1) variables (dependent, independent, and controlled), 2) determining ways to control, measure and manipulate variables, and 3) constructing graphs using the variables they tested. Students were then introduced to vee diagramming. Questions that students asked were used to explain the components of the vee using ideas from Tobin & Capie (1980). Table 2 shows how the integrated process skills were related to selected components of the vee diagram. Most instructional time was used to discuss students' ideas for measuring and manipulating both the dependent and independent variables (Concepts) of the investigation.

Table 2

A Comparison Selected Components of the Vee Diagram and the Integrated Process Skills

Selected Components of the Vee Diagram (Novak & Gowin, 1984)	Integrative Process Skills (Tobin & Capie, 1982)
Focus Question	
Principles (Conceptual) variable	Identify variables that may affect the dependent
Concepts (Conceptual)	Identify appropriate procedures for measuring or manipulating the independent variable Identify appropriate procedures for holding identified variables constant Identify appropriate methods of measuring the dependent variable
Objects/Events	Identify the dependent variable Identify the variable to be manipulated Identify the variables to be held constant
Records	Identify data that support an hypothesis
Transformations (Methodological)	Use an appropriate scale for graphical representation of data, Present quantitative data graphically,
Knowledge Claims (Methodological)	Use data to construct or modify an hypothesis

Group 2

Students (n = 27) in this section completed seven investigations and vee diagrams. The first investigation was a demonstration used to introduce two major themes: 1) the process of restructuring "activities" such as those found in popular science resource books as investigations, and 2) vee diagramming as a tool for deriving meaning from the investigation. In this investigation, the instructor established the context (linear inertia) and dependent variable while the students determined the independent variable and its forms, the focus question, method of data collection, data transformation, and knowledge claims.

Following this initial introduction, students located an activity and redesigned it as an investigation, located appropriate materials and equipment, and "taught" their activity to three other members of the class. Each "teacher" was to have his/her "students" construct Vee diagrams for the investigation. The "teacher" then graded the Vee diagrams from his/her "students." Because the students were organized in groups of four, each class member constructed three different Vee diagrams, one for each of three investigations.

Zuckerman's anxiety instrument (Zuckerman, 1960) was used in pretest and posttest fashion to compare 78 preservice elementary/middle school students' anxiety towards investigating. Table *4* shows the comparison between pre-anxiety and post-anxiety mean scores. The pre-anxiety mean score was 13 *(SD* = 3.3) and the post-anxiety mean score was 9.7 *(SD = 1.9)* with a mean difference of 3.3. The t value was 8.39 ($p < .05$). The methods class treatments significantly shifted students anxiety in a positive direction (O - low anxiety). However, no significant correlation was found between investigation anxiety change and vee diagramming change scores ($r = .06$, $p = .22$).

Table 4

A Comparison of Students' Pre-anxiety and Post-anxiety Mean Scores

Test	*N*	*M*	*SD*	*t*
Pretest	78	13.0	3.3	
Posttest	78	9.7	1.9	8.39*

<u>Analysis of the Components of Students' Vee Diagrams</u>

At the beginning of the semesters many students chose not to attempt the Whooping Crane task. The rubric previously discussed was used to reveal strengths and weaknesses in students' investigative skills. Table 5 shows the components of the vee emphasized in the courses and the distribution of students' scores. While the Possible Score shows the score for the criterion of each component, the Percent (Pre-Vee & Post-Vee) shows the proportion of students *(N* = 78) receiving the score.

From pre to post, students showed improvement in constructing all components of the vee diagram. The students achieved the greatest improvement in their focus questions, objects/events and records. On the post-vee, the students received the maximum score for the following:

1. Developing a clear focus question with specific suggestion of both independent and dependent variables (72%, Possible Score = 3),

2. Identifying records consistent with the focus question or major event (83%, Possible Score 2), and

3. Identifying objects/events consistent with the focus question (73%, Possible Score = 2).

Table 5
Scores on Vee Components (N = 78)

Component	Possible Score	Percent Pre-Vee	Percent Post-Vee
Focus Question	0	19	0
	1	32	15
	2	26	13
	3	23	72
Records	0	70	14
	1	3	3
	2	27	83
Objects/Events	0	80	9
	1	8	18
	2	12	73
Knowledge Claims	0	35	1
	1	19	14
	2	27	55
	3	19	28
	4	0	2
Transformations	0	41	5
	1	26	14
	2	22	46
	3	11	35
Principles/Concepts	0	26	10
	1	24	26
	2	32	48
	3	17	13
	4	1	3

Students had more difficulty improving their knowledge claims, transformations and principles/concepts. The greatest percentage of students (35%) did not construct knowledge claims (Possible Score = 0) on their pre-vees. On the post-vee, most students' knowledge claims (55%) included inconsistent generalizations or their claims were not clearly derived from the data (Possible Score = 2). However, 28% of the students constructed post-vee knowledge claims appropriately derived from the records and transformations (Possible Score = 3). In comparison, only 19% of the students constructed knowledge claims appropriately.(Possible Score = 3) on the pre-vee.

Students showed a positive shift in constructing their transformations. While 41% of the students did not construct graphs in their pre-vees (Possible Score = 0), 35% of the students correctly combined data, and correctly made graphs consistent with their focus question (Possible Score = 3) on their post-vees. However, on the post-vees, the greatest proportion of students (46%) correctly processed data (e.g., combined rainfall and snowfall), but their graphs were incorrectly constructed (Possible Score = 2). Two common difficulties emerged from analysis of the students' graphs. Students often placed the independent variable on the y-axis or incorrectly labeled their graphs. Other students tried to show relationships between too many variables. Often times, they made scatter plots in chronological order (x-axis = Year), then plotted number of eggs hatched and precipitation on the y-axis. A clearer approach might have compared precipitation with the number of eggs hatched, by rearranging the data according to the quantity of precipitation.

Students had the most difficulty in constructing their principles/ concepts, with respectively 32% (pre) and 49% (post) of the students identifying concepts and principles sought in the knowledge claim (Possible Score = 2). Few students, on the post-vee, developed non-redundant principles/concepts (13%, Possible Score = 3) and only 3% went one step further by operationalizing the concepts (Possible Score = 4).

Conclusions

When science methods courses emphasize investigations and the processes involved in "doing science," prospective elementary/middle level teachers generally show a significant reduction in anxiety about using investigations in the classroom. In terms of the sections of the vee diagram, the prospective teachers tended to move to maximum scores on the more concrete levels of the vee diagram, objects/events and records, as well as the focus question. The conceptual side of the vee diagram and the more abstract portions of the methodological side of the vee diagram showed the least change. Students continued to show problems in the following more creative aspects of investigating:

- In the principles and concepts, students identified concepts and principles sought in the knowledge claim.
- In the transformations, students need to take the risk and restructure the data in such a way that it clearly answers the focus question.

The often heard rhetoric of "hands-on, minds-on" science is lacking tools to make that connection possible. The vee diagram is just such a tool. In this study, the elementary/middle level methods students showed improvement in the use of this tool and in the willingness to engage in investigations, but they also had difficulty with the "minds-on" portion of the investigation. The challenge is captured by the following statement by Hodson (1992)

> . . . doing science is not just theory-driven, it is *experience driven,* and . . . a major element in a scientist's ability to do science successfully is the steady accumulation of the tacit knowledge that eventually constitutes connoisseurship. It follows that the development of children's tacit knowledge, through experience of holistic investigations, should be a major priority in science education (p. 136).

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The Genetics Concepts

Concept	Keywords
1. Reproduction and Inheritance All living things reproduce. Offspring may closely resemble but are not identical to their parents, from whom they inherit genetic traits. The units of inheritance are called genes and contain the genetic information. Individuals receive two copies of each gene, one from each parent, but the two genes may not be identical. For simple genetic traits, the two inherited copies of a gene determine the phenotype for that trait. Other genetic traits are determined by more than one gene.	Reproduction. The reproductive system. Genotype. Phenotype. Dominant. Recessive. Pedigree analysis. Polygenic trait. Homozygote. Heterozygote.
2. DNA The genetic information is contained in DNA molecules, which have a unique double-helical structure and a four-letter informational code.	DNA structure. Double-stranded helix. Nucleotides. DNA sequencing. Base-pairing. Complementarity.
3. Chromosomes Chromosomes are long pieces of DNA that consist of linear arrangements of genes and other DNA. Sexually reproducing organisms have two sets of chromosomes in most cells of their bodies. Each parent contributes one of each pair of chromosomes to its offspring randomly.	Linkage. Gene mapping. Ploidy. Homologous chromosomes. Segregation. Assortment. Variation. Meiosis. Probability.
4. Genetic and Environmental Determinants Together with the environment, an organism's genes influence its appearance and characteristics.	Genotype gives rise to phenotype. Acquired vs. inherited traits. Environmental factors. Nature vs. Nurture. Penetrance.
5. Proteins The DNA information in genes provides instructions for building proteins. Proteins carry out life functions and are a diverse collection of molecules that includes hormones, enzymes, structural proteins, and antibodies.	Central dogma. The genetic code. Gene expression. RNA. Transcription. Translation. Amino acids.
6. Cells	DNA replication. Cell division. Mitosis

Cells are the building blocks of every organism's body. Each cell of an organism contains the same genetic information, which is passed on faithfully when cells divide. Different types of cells arise because they use different parts of the information, as determined by the cell's history and immediate environment. Different cell types may be functionally organized into tissues and organs.	Differentiation. Gene expression. Cancer.
7. Variation and Evolution There are genetic differences between individuals of the same species. Any one gene can have alternate forms, called alleles. Changes in the DNA, or mutations, cause new alleles to arise. New alleles or new combinations of genes can lead to variation among the individuals within a population. Some variations may confer a survival or reproductive advantage under specific environmental conditions.	Mutagen. Evolution. Species. Biodiversity. Individuality. Genetic disorders.
8. Applications Genetics research has applications in many fields, for example, in medicine, agriculture, biotechnology, and environmental science.	Biotechnology.
9. Ethics Genetics research raises many ethical, legal, and social issues; it is important for everyone to develop skills to address these issues.	Genetic testing. Pre-natal diagnosis. Genetically engineered products. Animal cloning. Genetic privacy. Maintaining biodiversity.

APPENDIX 1C

SAMPLE OF LESSON PLANS

Peninsula High School

Daily lesson Planning

Subject	Syllabus Unit	Date	Grade
Biology	10.1 Cell Division	17 August 2004	11 B

Objective(s)/Expected Outcome(s)
❖ Preliminary insight into the differences between the somatic cell line in a person and the germ cell line and the relationship of the two cell division processes (mitosis and meiosis) with these two lines.
❖ Most learners will not be able yet to correctly connect the mitosis and meiosis with the somatic line and germ line.
❖ Learners realise what they do and do not understand yet or where they get stuck in their reasoning pattern, and get motivated to gain more insight into the two main cell lines and the related cell division processes.

Revision/Assignment at the beginning of the lesson
❖ Whole class discussion and reflection on Learning Activity 1 (LA 1)

Content/Procedure/Planning

Learner activity	Teacher activity
➢ Solving a biological problem (worksheet 1) in groups of four (4) learners: discuss and reason how the hereditary material of a gamete affects the next generation. Discuss and explain their insights into the two lines in their own words to the other learners in the group. ➢ Formulate an answer to the task (problem) they all agree upon. ➢ Discuss the differences in answers and explanations of the group.	✓ Guiding the learners in their group work and discussion on request, but not giving solution to the problems yet ✓ Signalling where the learners get stuck in their in their genetic reasoning pattern and what difficulties they encounter, in order to prepare the subsequent plenary discussion and reflection on this activity. ✓ Guiding the classical discussion aiming at one answer to the assignment, by asking question like: where in your body do you think this process take place? What is the function of that process? What is the difference between a gamete and a somatic cell?

BASIC STRATEGIES

	Lecturing
✓	**Group work**
	Working in pairs
✓	**Discussion**
	Guided Practice
	Project
	Field trip
	Mind Mapping
	Concept Mapping
	Vee Diagramming
	Review test
	Post test
	Other …

MATERIALS NEEDED/TEACHING AIDS
ASSIGNMENT/HOMEWORK

………………………………………..

PRINCIPAL/HOD/SUBJECT HEAD

…………………………………

DATE

Peninsula High School

Daily lesson Planning

Subject	Syllabus Unit	Date	Grade
Biology	DNA Structure and Function	19 August 2004	11 B

Objective:

To understand the structure of DNA and the way in which DNA duplicates by building simple models of DNA and its components.

Apparatus Needed:

Large and small paper clips, 5 cm lengths of coloured pipe cleaners, styrofoam blocks.

Recommended Strategy:

1. Suggested use of materials:

    - Large paper clip to represent deoxyribose sugar
    - Small paper clip to represent phosphate group
    - Yellow pipe cleaner - adenine base
    - White pipe cleaner - thymine base
    - Red pipe cleaner - guanine base
    - Orange pipe cleaner - cytosine base

2. To form a nucleotide, hook a large paper clip to a small paper clip. Then take a short piece of pipe cleaner and fasten it to the center of the large paper clip. Remember what each of these represents.

3. Put half of your nucleotides to one side (two of each colour). These will be used later as your free nucleotides. Line up the remaining nucleotides in one row and write down their order, then determine what the other side of the ladder would have to be to match. Do this about three times to familiarize yourself with the order in which the bases pair.

4. Make a flat model of DNA, using the nucleotides you have before you, hook half the clips together (using one of each colour), making sure the large and small clips alternate to form one side of the ladder. Using the four remaining nucleotides, match the bases in proper order, hook the pipe cleaners together and then hook the clips together to form the sides.

5. To show replication, unhook the pipe cleaner bases from each other to form two chains. Now using your free nucleotides that you put to the side, match them in their proper order and fasten the bases and paper clips together to form two DNA molecules.

6. To make a three-D model, use two pieces of styrofoam and one of the flat DNA models. Straighten out the two paper clips at each end and press them into the styrofoam strips. Hold a

styrofoam strip in each hand, stretch out the model, and twist slightly to give a spiral staircase effect.

Part II: mRNA STRUCTURE and TRANSCRIPTION

Objective

To use the DNA model to build a model of mRNA, which will demonstrate its structure and the way, it is formed by transcription.

Apparatus Needed:

Models from Part 1, the same materials, plus large coloured paper clips to represent ribose, and green pipe cleaners to represent the uracil base.

Recommended Strategy:

1. Use the materials to form nucleotides of mRNA, at least two of each of the four bases.

2. Use the flat model of DNA from Part 1 and your mRNA nucleotides to demonstrate transcription. Unhook your flat molecule at its bases.

Match the mRNA nucleotides in their proper order (keep in mind that thymine is replaced by uracil).

Evaluation

For a follow up assignment write a report describing the structures of DNA and mRNA and the processes of replication and transcription.

....

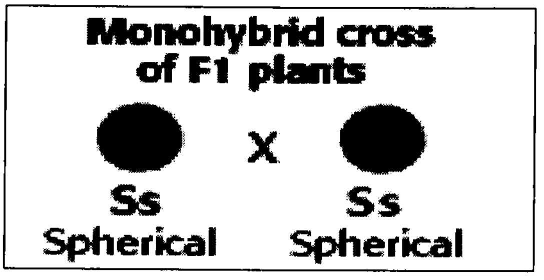
PRINCIPAL/HOD/SUBJECT HEAD DATE

APPENDIX 1D

GENETICS ACHIEVEMENT TEST (GAT)

SECTION A [MULTIPLE CHOICE]

1.1 In pea plants, spherical seeds (S) are dominant while dented seeds (s) are recessive. In the genetic cross of two plants that are heterozygous for the seed shape, what fraction of the offspring do you think will have spherical seeds? [1]



- [ ] A. None
- [ ] B. 1/4
- [ ] C. 1/2
- [ ] D. 3/4
- [ ] E. All.

1.2. Explain in your own words why you think the answer you chose above is the correct one. [3]

2.1 A genetic cross between two F1-hybrid pea plants for spherical seeds will yield what percent of spherical-seeded plants in the F2 generation? (Spherical is dominant over dented) [1]

- ☐ **A.** 100%
- ☐ **B.** 75%
- ☐ **C.** 50%
- ☐ **D.** 25%
- ☐ **E.** 0%

2.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

3.1 In Mendel's experiments, if the gene for tall (T) plants was incompletely dominant over the gene for short (t) plants, what would be the result of crossing two Tt plants? [1]

- ☐ **A.** 1/4 would be tall; 1/2 intermediate height; 1/4 short
- ☐ **B.** 1/2 would be tall; 1/4 intermediate height; 1/4 short.
- ☐ **C.** 1/4 would be tall; 1/4 intermediate height; 1/2 short.
- ☐ **D.** All the offspring would be tall.
- ☐ **E.** All the offspring would be intermediate.

3.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

4.1 Women have sex chromosomes of **XX**, and men have sex chromosomes of **XY**. Which of a woman's grandparents could not be the source of any of the genes on either of her **X**-chromosomes? [1]

- ☐ **A.** Mother's Father
- ☐ **B.** . Father's Mother
- ☐ **C.** Mother's Mother
- ☐ **D.** Father's Father
- ☐ **E.** Mother's Mother and Mother's Father

4.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

5.1 The X and the Y-chromosomes are called sex chromosomes because: [1]

- [ ] **A.** Females have X-chromosomes and males and males have Y-chromosomes
- [ ] **B.** The number of Y-chromosomes determines the sex of the individual
- [ ] **C.** They are present only when cells undergo meiosis
- [ ] **D.** Genes located on these chromosomes play a role in determining the sex of the individual
- [ ] **E.** They are formed only as the result of fertilization

5.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

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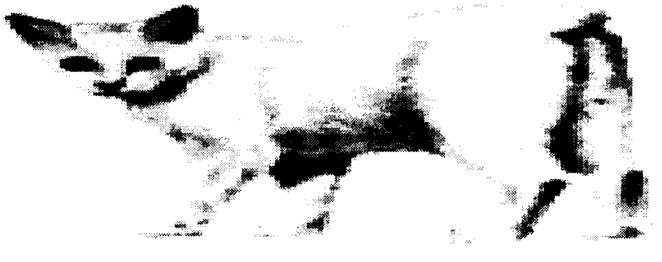
6.1 Manx cats are heterozygous for a dominant mutation that results in no tails (or very short tails), large hind legs, and a distinctive gait. The mating of two Manx cats yields two Manx kittens for each normal, long-tailed kitten, rather than three-to-one as would be predicted from Mendelian genetics. Therefore, the mutation causing the Manx cat phenotype is likely a (n) __________ allele. [1]



- [ ] **A.** Pleiotropic
- [ ] **B.** Co-dominant
- [ ] **C.** Epistatic
- [ ] **D.** Lethal
- [ ] E. Sex-linked

6.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

7.1 A plant with purple flowers is allowed to self-pollinate. Generation after generation, it produces purple flowers. This is an example of: [1]

- ☐ **A.** true-breeding
- ☐ **B.** hybridization
- ☐ **C.** the law of segregation
- ☐ **D.** polygenetics
- ☐ **E.** incomplete dominance

7.2 Explain in your own words why you think the answer you chose above is the correct one. [3]

Section B [Structured Questions]

8. Describe any three applications of genetics you know in agriculture and medicine.

8.1 Agriculture [3]

8.2 Medicine [3]

9. Gregor Mendel never saw a gene, yet he concluded that these "heritable factors" were responsible for inheritance in peas. Is it legitimate (reasonable) science for biologists to claim the existence of things and processes they cannot actually see? Explain. [4]

10. Huntington's disease is a disease of the nervous system, which is caused by the dominant recessive allele that has no observable effect until the individual is 35 to 45 years old. Any child born to a parent who has the disease has a 50% chance of inheriting the allele and the disorder. Imagine that one of your parents suffered from Huntington's disease. Explain in your own words the probability that you too, would someday manifest the disease? [4]

11. There is no cure for Huntington's disease. Would you want to be tested for the Huntington allele? Explain. [4]

12. Chromosomes are largely responsible for the fact that in human populations there are approximately as many men as there are women. Justify this statement. [4]

16. Using a Punnet Square construct crosses for F_1 and F_2 generations for:

P_1: Homozygous RR X **Homozygous rr**

(Round fruit) (Wrinkled fruit)

16.1 F_1 [4]

Gametes		

16.2 F_2 [4]

Gametes		

End of test and good luck!

Total marks: 70

APPENDIX 2A

Scheme of Work

BIOLOGY: GRADE 11

INSTRUCTIONAL OFFERING	BIOLOGY SG
CODE	: 153201509
INSTRUCTIONAL PROGRAMME	: STANDARD 9
CODE	: 609

SYLLABUS

CONTENT		FURTHER ELUCIDATION	PRACTICAL WORK
1.	**A STUDY OF VIRUSES AND BACTERIA**		
1.1	VIRUSES		
1.1.1	Structure	Emphasis on acellular nature only	
1.1.2	Biological importance		
1.2	BACTERIA		
1.2.1	Structure	Prokaryotic organisms	
1.2.2	Reproduction	Binary fission only	
1.2.3	Ecological role	Widespread occurrence. Role as decomposers; in nitrogen cycling; as pathogens; as symbionts	
2.	**A STUDY OF SOME PLANT TYPES**	In making this study, emphasis should be placed on those structural and physiological features of the examples which promote their success in their specific habitats. ***[Taxonomic relationships and general characteristics of groups not required]***	2. Where possible fresh plant material should be used, but care must be taken that the concept of conservation receives prominence. Collecting and preserving should be controlled and limited

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
2.3.2 Structure	Gametophyte: macroscopic and microscopic features noting absence of specialised tissues. Sporophyte: macroscopic and microscopic features noting specialisations for spore dispersal and photosynthesis	2.3.2 Investigation of macroscopic and microscopic structure (L or D)
2.3.3 Nutrition	Gametophyte: autotrophic; photosynthetic. Sporophyte: partially dependent on gametophyte	
2.3.4 Reproduction	***[Schematic and diagrammatic representation of life cycle not required]***	2.3.4 Make use of photomicrograph slides and/or transparencies (D)
2.3.5 Ecological role of bryophytes	Pioneers in succession	
2.4 PTERIDOPHYTES	One example of a fern	
2.4.1 Habitat	Terrestrial, mainly in shaded places	
2.4.2 Structure	Gametophyte: macroscopic and microscopic features including structure and location of sex organs Sporophyte: macroscopic features; microscopic examination of fond only, noting structure of sorus, specialisation of sporangia for spore dispersal an presence of photosynthetic, supporting and conducting tissues	2.4.2 Investigation of *macroscopic* and microscopic structure (L or D). Make use of photomicrographic slides and/or transparencies (D)
2.4.3 Nutrition	Gametophyte: autotrophic Sporophyte: briefly dependent on gametophyte, then autotrophic	
2.4.4 Reproduction	***[Schematic and diagrammatic representation of life cycle not required]***	2.4.4 Make use of photomicrograph slides and/or transparencies (D)
2.4.5 Ecological role of pteridophytes	Role in succession. Form plant cover under certain conditions	

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
(e) Ecological role and economic importance of angiosperms	Importance as producers and in maintenance of oxygen/carbon dioxide balance. Agricultural importance	
3. A STUDY OF SOME INVERTEBRATE TYPES	Throughout the study, an attempt should be made to relate the structural and physiological properties of the animals selected to their efficiency in respect of various activities chosen for consideration. In this regard, mention should be made of the different problems which result from differing habitats and from increasing complexity of body structure. Constant emphasis should be placed upon the relationship between structure, functional efficiency and survival under the relevant environmental conditions. Mention of Mollusca and Echinodermata as other examples of invertebrate animals. <u>(ALTHOUGH THE SYLLABUS PRESENTS THE MATERIAL IN THE FORM OF "TYPE STUDIES" A COMPARATIVE "THEMATIC" APPROACH IS ALSO ACCEPTABLE)</u>	
3.1 PHYLUM: PROTOZOA	*Amoeba* sp. or another protozoan	3.1 *Microscopic examination of pond water or* a mud culture to observe unicellular organisms (L and D)
3.1.1 Habitat		
3.1.2 Structure		
3.1.3 Locomotion		
3.1.4 Nutrition	Nature of food; ingestion; digestion; absorption and egestion	
3.1.5 Gaseous exchange	Diffusion of dissolved oxygen from watery environment through plasmalemma, and of carbon	

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
	the watery environment, or lie very close to it, and can thus each deal with their own needs in terms of gaseous exchanges and excretion of metabolic wastes; translocation of food from endoderm to ectoderm by diffusion across mesoglea	
3.2.6 Reproduction	Budding - the process and its implications; sexual reproduction - location and development of gonads; formation of haploid gametes; fertilisation; dormant zygote stage; significance of asexual and sexual reproduction in the life of *Hydra* sp.	
3.3 PHYLUM: PLATYHELMINTHES	A tapeworm	
3.3.1 Habitat		
3.3.2 Structure	External features. Bilateral symmetry; segmented body with scolex and proglottides. Structure of young and mature proglottid	3.3.2 Because of the danger of contamination, preserved specimens or photomicrograph slides should be observed (*L* or *D*)
3.3.3 Nutrition	Diffusion. Importance of large surface area	
3.3.4 Gaseous exchange and internal transport	Diffusion of dissolved oxygen from watery environment into ectodermal cells, and then from cell to cell through the mesoderm; outward cell-to-cell diffusion of carbon dioxide. Transport of food and gases by diffusion; flattened shape ensure all cells close to ectoderm and branches of gut	
3.3.5 Reproduction and life cycle	Hermaphroditism, self fertilisation. ***[Details of reproductive organs not required]*** Development of uterus with eggs, protection of egg, development and protection of onchosphere, transfer to intermediate and final host, development in hosts	

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
	organs associated with sexual reproduction; mating resulting in mutual exchange of sperm; formation of cocoons, release of ova and external fertilisation in cocoons; nourishment and protection of developing embryos in cocoons; significance of hermaphroditism in the life of earthworms	
3.5 PHYLUM: ARTHROPODA	Mention of the diversity of arthropods Class: Insecta (A locust, cockroach or cricket)	
3.5.1 Habitat		
3.5.2 Structure	External features. Bilateral symmetry. Chitinousexoskeleton protective against mechanical injury and desiccation; mainly firm, but with flexible portions, thus suited to muscle attachment and movement; moulting necessary for growth, triploblasticity	3.5.2 Study of live specimens to identify external features (L)
3.5.3 Locomotion	Walking, jumping, flight	4.5.3 Observation of live specimens (L)
3.5.4 Nutrition	Nature of food; importance of motility and cephalisation; structure and use of biting mouthparts during ingestion; through-gut; egestion via anus	4.5.4 Observation of mouthparts (L)
3.5.5 Gaseous exchange	Spiracles giving access to extensive system of tracheae and tracheoli circulation of air through tracheae; value of chitinous spirals in tracheal walls; pumping mechanism, presence of watery liquid in tips of thin-walled tracheoli; oxygen dissolves in this liquid then diffuses into surrounding tissues. Value of internal location of gaseous exchange surfaces in avoiding excessive loss of water	

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
4.1.6 Reproduction	Sexual; separate sexes [***no study of organs required***]; mating behaviour; external fertilisation; nourishment of embryo [***no study of embryonic development required***]; ovipary and ovovipary	
4.2 A FROG OR TOAD		4.2 Study of a live specimen (D)
4.2.1 Habitat		
4.2.2 External features		
4.2.3 Locomotion	Swimming of tadpole; hopping and swimming of adult	
4.2.4 Nutrition	Change from herbivorous to carnivorous diet in tadpole stage; adults carnivorous; capture of prey [***No study of digestive system required***]	
4.2.5 Gaseous exchange	External, then internal gills of tadpoles; development of simple lungs; ventilation by swallowing; moist skin as an exchange surface; blood for oxygen and carbon dioxide transport	
4.2.6 Reproduction	Sexual; separate sexes [***no study of organs required***], mating in water; external fertilisation; protective jelly around eggs; nourishment of developing embryo by limited amount of yolk [***no study of embryonic development required***]; emergence of larva from egg; metamorphosis with main emphasis placed upon externally visible changes	
4.3 A LIZARD		4.3 Study of a live specimen (D)

CONTENT	FURTHER ELUCIDATION	PRACTICAL WORK
5.3.3 Dominance	Crosses between pure bred (homozygous) animals or plants differing in a pair of contrasting characteristics 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	
5.3.4 Segregation	Contrasting characteristics determined by sets of alleles; segregation of alleles into separate gametes so that each gamete contains only one gene for each particular characteristic; the mechanism of segregation explained in terms of meiosis	
5.3.5 Sex determination	Brief explanation of determination of sex in humans in terms of X and Y chromosomes	
5.3.6 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]***	
6. SOME ASPECTS OF THE ANATOMY AND PHYSIOLOGY OF HUMANS		
6.1 REPRODUCTION		
6.1.1 - Reproductive organs	Their structure and function Male organs: testes, including seminiferous tubules with germinal epithelia and associated cells; scrotum; epididymis; sperm ducts; prostrate gland; seminal vesicles; penis; the main functions of the parts listed	6.1.1 Make use of photomicrograph slides and/or transparencies (D)

APPENDIX 2B

STRUCTURED TEACHER' S GUIDE

To the teacher:

The essential hardware of evolution is the genome. Students can understand change through time, organic evolution, only when they understand the elegance and beauty as well as the utility of DNA, the chemical basis of the gene. Genes drive the production of proteins, the structural and functional building blocks of living organisms.

Cumulative changes in DNA sequences through time, can lead to significant differences in breeding populations, changes which, over vast amounts of time, can lead to speciation. These changes acted on by the environment cause evolution.

In order for students to understand genetics and evolution, they must first know the structure of the DNA molecule. The function of DNA proceeds from its unique structure, a structure beautifully adapted for information storage, transcription, and translation into amino acid sequences, replication, and time travel. This activity illustrates that structure in a simple and colourful way which includes details of the purine and pyrimidine nitrogen bases and the relative positions of the sugar-phosphate backbone. We have included this activity among the ENSI materials to help students master the molecule of change.

To the student:

The real family treasures are not jewels at all they are the DNA molecules that have constructed each member your family. These immortal coils have carried your family's genetic information through vast reaches of time to the present. The digital information encoded within the molecule constructs and orchestrates perfectly formed protein bodies... you! Your protein body, if it is successful, lives, grows, matures and reproduces-- you help make a baby. Next comes the hard part. It takes total commitment to raise your new protein body, your baby. With love, encouragement, education and hard work, your "family treasures" may have the chance to leap into the future! You may see part of your DNA live in your grandchildren and great grandchildren.

DNA stands for Deoxyribose Nucleic Acid. The structure of DNA was unravelled in 1953 in Cambridge, England by two researchers, Francis Crick (English) and James Watson (American). These two men will be honoured in the future for as many centuries as Aristotle and Plato have been in the past. Their contribution to our understanding of life and ourselves is vast and far-reaching. The molecule itself is elegant in its simplicity, and makes great jewellery!

The DNA molecule is composed of four different nucleotide bases. They are Adenine, Guanine, Thymine and Cytosine. The Adenine and Thymine are molecular mates as are the Guanine and Cytosine. These are held in a long helix shape by a backbone of phosphate and deoxyribose sugar. The data contained within the DNA molecule is digital and is processed and passed on from generation to generation with very few errors or changes. The DNA you inherited from your ancestors resides in almost every one of the cells of your body. A "half set" resides in each of your reproductive cells, waiting for a complement, so they may "jump" into the future! We have found this to be a useful project to teach people about the details of the structure of DNA. Middle school students, high school students, and teachers in our workshops have all successfully constructed the molecule. They reinvent the process and make wonderful embellishments. It's an excellent teaching tool and adornment, as well.

SENS ENSI	**Genetic Jewels: Building the DNA Model** Created by Thomas Atkins and Joyce Roderick	**EVOLUTION** **GENETICS** **DNA**

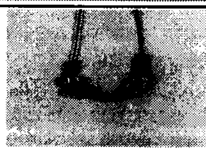
SYNOPSIS	Students build short segments (about 10 base pairs) of DNA, becoming intimately involved in its structure. The materials and final product provide a distinctive and useful piece of jewellery (earrings) that can be worn or given as gifts. The kinaesthetic experience and durable product combine to make a lasting impression, and something useful deeply learned about a seemingly complex topic.
PRINCIPAL CONCEPT	The elegant structure of DNA provides for both continuity and change
ASSOCIATED CONCEPTS	1. DNA provides the machinery for evolution. 2. The sequence of bases in DNA dictates the sequence of amino acids and therefore the functional structure of proteins, which in turn are selected for or against, depending on whether they contribute to survival and reproduction of individuals in their environment.
ASSESSABLE OBJECTIVES **Students will**	1. Recognize the particular pairing of adenine with thymine, guanine with cytosine 2. Create base sequences, which will translate into desired amino acide sequences 3. Translate an unknown sequence into the proper amino acid sequence 4. Create a useful piece of DNA jewellery
MATERIALS	Beads, wire, needle nose pliers
TIME	Two 45 minute periods
STUDENT HANDOUTS	**Genetic Jewels: Building the DNA Model**

TEACHING STRATEGY	1. This activity could fit nicely as part of your introduction to DNA, its structure and function. This is a particularly novel and engaging approach! 2. Alternatively, this activity could be used in your summing up phase, especially if combined with our "Say it with DNA" lesson, from which students can build sequences that code for their initials or 3-letter nickname. 3. Comments to the teacher: setting the tone and context: The essential hardware of evolution is the genome. Students can understand change through time, organic evolution, only when they understand the elegance and beauty as well as the utility of DNA, the chemical basis of the gene. Genes drive the production of proteins, the structural and functional building blocks of living organisms. Cumulative changes in DNA sequences through time, can lead to significant differences in breeding populations, changes which, over vast amounts of time, can lead to speciation. These changes acted on by the environment cause evolution. In order for students to understand genetics and evolution, they must first know the structure of the DNA molecule. The function of DNA proceeds from its unique structure, a structure beautifully adapted for information storage, transcription, and translation into amino acid sequences, replication, and time travel. This activity illustrates that structure in a simple and colourful way, which includes details of the purine and pyramiding nitrogen bases and the relative positions of the sugar-phosphate backbone. We have found this to be a useful project to teach people about the details of the structure of DNA. Middle school students, high school students, and teachers in our workshops have all successfully constructed the molecule. They reinvent the process and make wonderful embellishments. It's an excellent teaching tool and adornment, as well. We have included this activity among the ENSI materials to help students master the molecule of change.
PROCEDURES	1. Print out the steps, or have students access them online. 2. Provide beads, wires, pliers and other materials, and

	time for students to build the models.
ASSESSMENT	1. Ask students to exchange their DNA models, to have them checked to be sure that the base pairs are properly matched (and that they can be translated properly, if such was the intent), or 2. Provide samples of DNA models made by others (or yourself) to check for proper base pair matching, mutation, (and meaningful translation, if that goal was included).
EXTENSIONS AND VARIATIONS	1. If you have a biology or science club, the members might be motivated to make these earrings to order as a fund-raising venture. 2. Consider variations on this activity, making key fobs or wrist-wraps, for example, perhaps using larger beads of different materials. Explore (or have your students explore)... get creative, and share your successes with us.
RESOURCES	See Appendix in the BeadProject collection for possible sources and costs of beads.
ATTRIBUTION Some of the ideas in this lesson may have been adapted from earlier, unacknowledged sources without our knowledge. If the reader believes this to be the case, please let us know, and appropriate corrections will be made. Thanks.	1. **Original Source**:This activity was created and developed by Thomas Atkins and Joyce Roderick (both in ENSI '92) 4. **Edited / Adapted for website** by L. Flammer 1/1/2004

The structure of DNA was unraveled in 1953 in Cambridge, England by two researchers, Francis Crick (English) and James Watson (American). These two men will be honored in the future for as many centuries as Aristotle and Plato have been in the past. Their contribution to our understanding of life and ourselves is vast and far-reaching. The molecule itself is elegant in its simplicity, and makes great jewelry! The DNA molecule is composed of four different nucleotide bases. They are Adenine, Guanine, Thymine and Cytosine. The Adenine and Thymine are molecular mates as are the Guanine and Cytosine. These are held in a long helix shape by a backbone of phosphate and deoxyribose sugar. The data contained within the DNA molecule is digital and is processed and passed on from generation to generation with very few errors or changes. The DNA you inherited from your ancestors resides in almost every one of the cells of your body. A "half set" resides in each of your reproductive cells, waiting for a complement, so they may "jump" into the future!

Genetic Jewellery Project Central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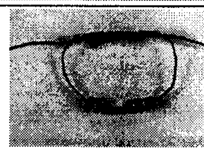
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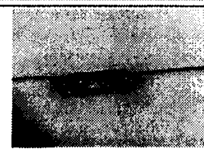
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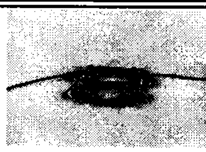
Step Four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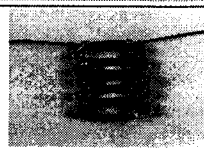
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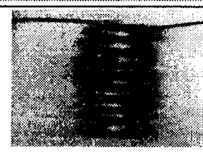
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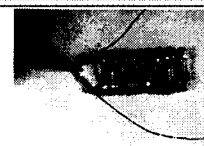
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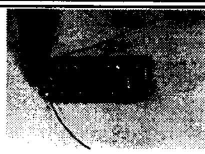
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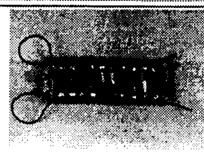
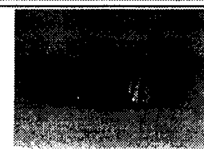

Step Ten


Step Eleven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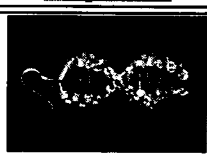
Step Thirteen


Step Fourteen

SAY IT WITH DNA: Protein Synthesis Tutorial

by Larry Flammer

EVOLUTION
GENETICS
DNA

SYNOPSIS	This activity uses the metaphor of decoding a secret message for the Protein Synthesis process. Students teach themselves the sequence of DNA-Translation (DNA-mRNA-tRNA-protein), and practice with DNA codes, which translate into amino acid sequences spelling out meaningful sentences in English! This activity provides practice in base-pair matching and following the sequence as performed by cells. Further practice is provided by requesting students to create new DNA messages which can be "decoded biologically" by others.
PRINCIPAL CONCEPT	Protein Synthesis: DNA makes mRNA, which is read by ribosomes to position tRNA carrying amino acids into a particular sequence forming a particular protein, which in turn (at least as an enzyme) enables (or inhibits) a particular biochemical reaction.
ASSOCIATED CONCEPTS	1. DNA bases match (pair) in specific ways: A with T, C with G, (A with U in RNA) 2. DNA is the central repository of information (in molecular code form), which controls life via protein synthesis. 3. DNA makes RNA makes Protein ("The Central Dogma" of Protein Synthesis, as detailed above)
ASSESSABLE OBJECTIVES Students will....	1. Recognize DNA as a central repository of information (in code form), which controls life via protein synthesis. 2. Know the "Central Dogma": How DNA makes RNA makes Protein, in detail. 3. Know that certain DNA bases match: A & T, C & G, (and A & U in RNA)
MATERIALS	Handouts
TIME	One 45 minute period

STUDENT HANDOUTS	**Protein Synthesis Worksheet** (directions, tutorial, sample message, tRNA dictrionary) **DNA-Decoding Practice Sheet** **DNA Messages** (2 pages, back-to-back on one sheet: 30 to choose from; placed in plastic sleeves) **DNA Message-Maker** **Quick Check** (optional: checks understanding of roles of "players" in protein synthesis).
TEACHING STRATEGY	1. This activity provides a logical activity to use following your Protein Synthesis reading assignment. 2. Be sure that students understand the **significance** of controlling protein production, namely the "One Gene - One Enzyme" concept: each step of a biochemical series of reactions requires a unique enzyme which in turn is the product of one gene. If the gene is there, the enzyme can be produced, and that step of the series can proceed; if the gene is not there (or has mutated), the enzyme may not be produced, and that step may not proceed. This is to some extent a simplification of reality, but should be recognized as a fairly good generalization for understanding how DNA (genes) can control life processes. 3. The one-letter symbols for the amino acids are the standard symbols assigned in molecular biology.
PROCEDURES	1. Hand out the Protein Synthesis Worksheet to every student. 2. Have students read the Worksheet and finish the partially solved message. 3, Meanwhile, hand out the Practice Sheet, and the sheet of 30 DNA Messages. 4. Assign each student one of the practice messages. They can do more, if interested and have the time. To check for accuracy of decoded messages, use the **Messages Key.** 5. Optional: Students can do additional messages for homework. 6. Hand out the DNA Message Maker sheet. 7. Encourage (require?) students to create at least one good message. This could be done for homework. 8. Collect messages and re-distribute for them to be decoded 9. Ask students to do the **Quick Check** measure of their understanding of the functional roles for the real "players" involved in protein synthesis in the cell. (Alternatively, have them do just one of the analogies here, and use the other for assessment, OR, use the Quick Check for assessment only. You could also enlarge the table, place it on an overhead transparency

	and do the Quick Check with the entire class in dialogue/recitation mode. Be sure to cut off the KEY table before using the Quick Check as a master for making handouts.
ASSESSMENT	1. Along with your unit test on the DNA unit, include the "practical" test supplement, requiring students to decipher a short DNA message during a test. Provide the Test Supplement (including tRNA Dictinary), the special answer sheet, and a unique word for each student (on little slips of paper, which you can prepare from the sample sentences provided, or use the 33 3-letter **test words** provided (along with a **test key** for you to use in grading the test.).. Insist that each step be shown and the molecules involved be labeled (DNA, mRNA, tRNA, "protein" (as the "meaningful amino acid sequence"). Include completeness and accuracy in showing these steps and labels in your grading. 2. In addition, you may want to use the "**Quick Check**" here as a measure of understanding of the actual roles for the real "players" in protein synthesis in the cell.
EXTENSIONS **& VARIATIONS**	1. Students can use the DNA Message Maker to create the DNA sequence which would code for their initials or 3-letter name or nickname, then use that code to build DNA jewelry (earrings, etc.) in the **Genetic Jewels** activity. They would have to be sure that the base letters (beads) for the code runs end to end along one strand, and the complementary base letters (beads) run along the connected strand. Such items would have even greater meaning and be uniquely personal, contributing to their retention of understanding. 2. As a special project, a student (or team) could build a large DNA demo model in which the base sequence codes for the name or initials of the school, or the school mascot. Flat rectangular sheets of styrofoam could serve as the base-pair steps; flat pentagonal pieces as deoxyribose sugars, and flat round pieces as the phosphate groups. If interested in trying this, contact the webmaster on this site for templates and other details.
RESOURCES	Protein synthesis section of any good biology textbook. PDF copy of this lesson.
ATTRIBUTION Some of the ideas in this	1. **Original Source**: Larry Flammer, idea developed in 1963 and used in Biology classes ever since, as the finale to a series of Do-It-Yourself DNA Kits (1. DNA

lesson may have been adapted from earlier, unacknowledged sources without our knowledge. If the reader believes this to be the case, please let us know, and appropriate corrections will be made. Thanks.	Structure & Sub Structure, 2. DNA Replication, and 3. Protein Synthesis, all involving manipulation of cutouts, and resulting in the spelling out of a little 3-letter word (meaningful amino acid sequence). 4. **Edited / Adapted for website** by L. Flammer 1/4/2004

APPENDIX 2C

SAMPLE OF LESSON PLANS

Protea High School

Daily lesson Planning 1

Subject	Syllabus Unit	Date	Grade
Biology	Cell Division and Mitosis	18 August 2004	11 A

Objectives:

1. Students will make a slide of onion root tips and observe different phases of mitosis.
2. Students will be able to state why cells divide.
3. Students will draw the different stages of mitosis and try to arrange them in order of division.
4. Students will demonstrate each phase of mitosis and the main characteristics of each.

Materials:

1. Prepared onion root tip mitosis slides.
2. In place of these and to promote interest, students may set up their own slides. Materials needed per slide are: fresh grown onion root tip, 5-10ml distilled water, 5ml 6M HCl, 1 ml Feulgen reagent in a vial, 5 ml 45% acetic acid, dropper pipette per solution, beaker, slide, cover slip, and a pencil with eraser or small cork to squash the slide. Materials needed per class are: 5-10 ml Carnoy's solution (1 glacial acetic acid: 3 absolute alcohol) in vial, 2-3 cups and onions, and toothpicks.
3. A microscope per student or pair.
4. Two different coloured pipe cleaners cut at varied lengths to represent chromosomes for assessment (4 chromosomes per cell). I use 2 long and 2 short blue pipe cleaners and 2 long and 2 short red pipe cleaners connected with beads, which represent the centromeres. This model would use the long pipe cleaners as a homologous pair of chromosomes and the short as another pair. Two pipe cleaners of each size and colour are used to model replication. Each chromosome is composed of two chromatids.

Strategy:

This lesson would be used after cells have been observed with microscopes in the lab. After a review of cell parts, the teacher would exhibit the onion (or prepared slides) and explain that root tips have been cut for the students to observe. Explain that the stain to be used in this preparation is different because something will be noticeable that could not be seen in past labs (chromosomes). Try to have the students guess this by questioning them about the cells they are observing - i.e. dividing cells - and how these are different than previous cells observed. Nuclei were observed before but not the chromosomes.

LAB

Students are more eager to learn how to set up their own slides and observe them than to use a prepared slide with which they may be unfamiliar. Steps 1-8 explain slide preparation. Go to #9 if prepared slides are being used.

1. Advance preparation:
   a) Take an ordinary yellow onion. Cut off any old root growth. Place the onion in a cup of water so that only the root portion is under water. To do this, push toothpicks into the side of the onion which extend outward and hold it on the rim of the cup. New roots should grow within two days.
   b) Cut off .5-1 cm of growth at the root tip - enough for all the students.
   c) Transfer immediately to Carnoy's solution. After 24 hours, roots should be stored in 70% ethanol in a refrigerator. This stops cell division. (Steps 2-9 to be completed by students)

2. Obtain a root tip.
3. After obtaining the root tip, pour off the fixative and replace it with 2-5 ml distilled water. Solutions may be poured into a beaker or down the drain.
4. After 1 minute remove the water with a pipette and add 2-5 ml 6M HCl.
5. After 3 minutes carefully remove the acid and wash tissue off with distilled water. Agitate the vial for 1-2 minutes. Discard the water.
6. Use forceps to transfer the tissue to a vial containing 1-2 ml Feulgen reagent. The reagent may be added to this vial if desired. (CAUTION: this dye will stain hands and clothes permanently.) After 20 minutes use forceps to transfer the tissue to a vial containing 5 ml 45% acetic acid.
7. Place 1-2 drops of acetic acid onto a microscope slide and transfer the tissue to the drop. Using dissecting pins and razor blades tease and macerate the tissue into tiny pieces.
8. Place a cover slip over the macerated tissue trying not to get air bubbles under the cover slip. Press down firmly onto the cover slip with a small cork or pencil eraser to spread the cells in a very thin layer. Push down in a perpendicular direction and the cover slip should not break.
9. Once the slide has been prepared or obtained from the teacher, observe it and draw all the different views of cells present under high power. Be careful to observe the nucleus and chromosomes since this is what was not observed previously.

Discussion

1. During the 20-minute stain time (Step 6) it is important to have the students discuss what the cells are doing. Since these cells are in the root tip, they are rapidly dividing. During normal cell activity the chromosomes are unwound and too thin to be seen. During cell division, chromosomes thicken, take up stain and can be easily observed. The students should also try to come up with reasons why cells divide (possible answers: to grow, to repair or replace damaged cells, to reproduce, or to differentiate in the cell cycle of multicellular organisms). Although it is better to have the students elicit these, it may be necessary to give them some of the reasons since this is an introduction. Also at this time explain what is happening in interphase. Cells need to replicate the chromosomes before dividing to ensure that the newly formed cells contain the same genetic material (chromosomes).

2. What the students are observing is an ordered process by which the cells divide the chromosomes so that one copy of each goes to each new cell. Once they have drawn all the different views of cells they have observed, they should share them with their lab groups, the teacher and perhaps the class. Hopefully all the stages of mitosis have been observed and drawn. These can be put on the board or overhead so that the entire class can see all the phases/views and copy them onto their papers. It is not necessary to name the observed cells with a phase of mitosis, but it may be easier so that students can more easily differentiate them and relate them to a new vocabulary term. Once all the students have drawings of all the phases of mitosis, ask them to arrange the pictures in a way, which would show a logical sequence of cell division.

3. Have one member from each group explain what order they put the drawings and why they did it that way. After all students have explained their process, students may wish to choose the model that they think is best. Students should now look into their textbooks to find out what is happening in each phase and how the text organizes the phases of mitosis.

Assessment:

1. Students are to make a model of a cell, which is in the process of mitosis and cell division. They should draw on their paper the border of a cell, which is dividing. These need to be big enough so that the pipe cleaners can be put inside. There needs to be a cell border for interphase, prophase (perhaps one for early and late prophase), metaphase, a partially dividing cell for anaphase, a nearly totally divided cell for telophase, and two new cells for the daughter cells.

2. Students will take the pipe cleaners and place them in the "cells". They should arrange four "chromosomes" properly in the various phases of mitosis. The pipe cleaners may be taped or glued on the paper and a description written which describes the events occurring within the cell. The pipe cleaners may be manipulated and each phase described to the teacher. Students may work in groups of four and only one student from each group would be tested to save time evaluating the mitosis demonstration.

3. The teacher should determine the grading method, points or letter grade, but a recommended method would be: five (5) for all the phases demonstrated exemplary in proper order with a detailed description of each. Four (4) for correct demonstration of phases and clear description. Three (3) for a generally correct model but lacking some clarity and detail. Two (2) for a partial demonstration, perhaps the phases are out of order or improperly shown and the description is incoherent. One (1) for an incorrect demonstration of model and explanation.

Other notes:

1. For a multicultural emphasis on teaching, students can observe that different organisms have cells, which look very similar. Different races and nationalities of people must have cells, which are not distinguishable from each other.

2. It may not be necessary to use a visible pipe cleaner model to better understand mitosis, but when teaching meiosis the model is very good to demonstrate crossing over and variable gamete formation as well as differences from mitosis.

Protea High School

Daily lesson Planning 5

Subject	Syllabus Unit	Date	Grade
Biology	Cell Structure and Function	23 August 2004	11 A

Objectives:

Discuss scientific advances brought about by the Mars Surveyor Space Program which impact on daily life, especially any animal and plant cell movements. Identify laboratory apparatus like microscopes, slides and cover slips; use the microscopes to view cells and organisms. Learn vocabulary pertaining to cells. Draw and colour what is seen under the microscope.

Vocabulary:

Cell membrane	Endoplasmic reticulum
Cytoplasm	Golgi bodies
Nucleus	Paramecium
Mitochondria	Euglena
Lysosomes	Amoeba

Materials Needed:

Newspaper articles about the Pathfinder landing on Mars. Microscopes, slides and cover slips, flowers and onions, posters of enlarged animal and plant cells, plant and animal cell component labels, cartoon posters of 3 types of cells and various strands of human hair, Elodea specimen and pond water (Elodea is a commercially available alga). This is a list of materials for each student in the class with the exception of microscopes: posters of enlarged animal and plant cells and cartoon posters of Paramecium, Euglena, and Amoeba; lemon gelatin dessert mix; 1 pint (125-ml) reusable plastic bag; quart bowl; large grape.

Strategies:

1. Classroom discussions about the Mars Space Program.
2. Articles on the Mars space program read aloud in class followed by role playing.
3. Locating articles that discuss possible fossils of cells found on Mars.
4. Using a slide to observe Elodea specimen under the microscope.
5. Observing what type of movement the specimen is making.
6. Flagellar, ciliate, and amoeboid motion will be looked for under the microscope.
7. Predict the condition of hair by observing a strand under the microscope.
8. Determine which end of the hair strand was attached to a live cell.
9. Gather some pollen from a flower, place it on a slide, and observe the pollen under the microscope.
10. Draw the cells you see from items 4, 8, and 9 above on a sheet of paper; color the cells.
11. Observe the same slide 30 minutes later or the next day to see what changes occurred.
12. A cooperative team will use a small picture of the animal cell that is labeled with the parts of the cell to identify the same parts on the enlarged poster of the animal cell that is not labelled.

13. The other cooperative group will place and paste the parts of the plantcell on the enlarged poster of the plant cell using the small labeled picture of the plant cell as a guide.
14. Each student will make a World-Class Cell Model.
    a. Have an adult helper mix the ingredients for the gelatin dessert according to the instructions on the box.
    b. Allow the gelatin to cool to room temperature.
    c. Pour the gelatin into the resealable bag, seal the bag, and place it in the bowl.
    d. Set the bowl and bag in the refrigerator and chill until the gelatin is firm (about 3 to 4 hours).
    e. Remove the gelatin from the refrigerator and open the bag.
    f. Using your finger, insert the grape into the center of the gelatin
    g. Reseal the bag.
    h. Place the bag of gelatin on a flat surface such as the kitchen counter. Observe its shape.
    i. Hold the bag over the bowl as you gently squeeze it (the bowl is used in the event that you squeeze too hard and the bag opens). Observe the shape of the bag as you squeeze
15. Thin layers of onion cell skin will be prepared, placed on slides, covered with coverslips, and observed under the microscope.
16. Write a rap or poem concerning the structure and/or movement of cells.

Performance Assessment:

1. Students will share the articles on Mars with role playing.
2. Students will take a multiple choice quiz on the hierarchy of the organizational levels of living things. Below is an example of testing students on knowing the difference between cell, tissue, organ, system and body. You may rewrite it leaving cell off each item.

    Directions: On the quiz below one list would be in a correct order if you were to write organ in the blank. Which list is that?

    a. cell, tissue, system, body, ______
    b. cell, tissue, ______, system, body
    c. ______, cell, tissue, system, body
    d. cell, ______, tissue, body, system

3. The nature of movements of cells in the human body will be discussed.
4. The labeled posters of plant and animal cells will be read aloud.
5. A simple model of a cell with 3 parts will be made.
    a. Each student will understand that the plastic bag represents the embrane of the model cell.
    b. Each student will properly name the pale color of the gelatin dessert as the grayish jellylike material cytoplasm, that fills the cell.
    c. Floating in the gelatin is a grape the represents the nucleus.

APPENDIX 3

GENETICS CLASSROOM INTERACTION OBSERVATION SCHEDULE (GCIOS)

Genetics Classroom Interactions Observation Schedule (GCIOS)

Categories	Tallies
Teacher	
1. Empathises (Introduction)	
2. Gives verbal reward	
3. Accepts and reinforces student's responses	
4. Ignores student's response	
5. Challenges student's response	
6. Lectures	
7. Questions: QR, QP	
8. Responds to question	
9. Directs	
10. Supervises /individual attention	
11. Manipulates apparatus	
12. Rebukes, criticizes, exerts authority	
Student	
13. Responds to question	
14. Question	
15. Initiates talk	
16. Experiments	
17. Read, writes and/ or draws	
18. Non – productive activities	

APPENDIX 4

STUDENT INTERVIEW PROTOCOL (LIP)

CLOZE TEST

Name --

Gender --

Age --

First/Home language -----------------------

MY KNOWLEDGE ABOUT GENETICS

Please read the instructions below carefully and fill the blank spaces in page 2 with the appropriate words in pages 2 and 3. This is not a test, so do not ask others or check in the book, however, try your best and give your best opinion.

INSTRUCTIONS

1. On page 2 there is a passage from the grade 11 biology textbook.
2. Fifty words are deleted from the passage and these are replaced with dotted lines from 1to 50.
3. For each of the 50 spaces four possible words A, B, C and D are given (see the answer sheet provided)
4. Read the whole sentence and try to understand what the author is saying before deciding on the correct word (answer).
5. Choose the best answer and write the letter (A, B, C, or D in the spaces provided.

Example

There are examples of human characteristics, which seem to follow the same pattern as Mendel's peas. One of them is the presence or 1....................of the Rhesus factor on the red 2............. cells.

...........A..........1	A. absence	B. availability	C. absent	D. present
...........C..........2	A. capillaries	B. vein	C. blood	D. artery

Genetic Mechanism

Any mention of sexual reproduction brings to mind the subject of **heredity**, which is the transfer of characteristics of parents to their offsprings. Children tend to resemble their parents, grandparents 1............... other relatives more than they do other 2.............. The same is true of the offspring 3..............every animal and plant. In a group 4............individual of any species variation is apparent. 5...........individual differs from all the other in 6. ....ways. Offspring inherit characteristics from their parents 7........... the sex cells. The hereditary material of 8...........cell (DNA) passes on the information, which ensures 9..........a mating between two goats, say, produces 10...........zygote, which develops into a goat and 11 ...., for example, a dog.

The segregation of 12............which takes place during meiosis, together with 13...........random process of crossing over in which 14................is exchanged between chromatids in the bivalent, 15...............rise to variation. This refers to the 16............between offsprings and their parents and accounts 17............the uniqueness of individuals produced by sexual 18.................

It is important to remember that the 19........... known as gametes, which join together during 20............reproduction will always have a single set 21............chromosomes and that each strand of a 22............... is a DNA molecule. The zygote which 23..........made when the female and male gametes 24................will therefore be provided with a double 25...............of chromosomes—it will be diploid. This 26............set of chromosomes which is the total 27..................make-up of the organism is known as 28.........

The first person to discover the 29.........in which genes are now known to 30.........inherited by a parent's offspring was an 31.................monk called Gregor Johann Mendel (1822—1884). He experimented 32..............the garden pea because there were 33..............number of different pure breeding varieties available. 34..............began by following the inheritance of separate 35............characteristics, often called traits. He grew pure 36..............varieties of the pea with and without 37..........character he was interested in. He then 38.............cross-pollinated the two varieties by removing the 39...............from the variety he was using as 40..........female parent and then hand pollinating them 41.............his male parent variety. In one of 42.........experiments Mendel crossed a pure breeding tall 43.............variety with a pure breeding short growing 44......... When he grew the seeds produced by 45.........cross he found that all the new 46.........were tall plants. This first generation produced 47...............an experimental cross is called first filial 48............. This is usually shortened to F1 generation. 49.............. plants are called hybrids because they are 50...................of parents who have differing genes.

APPENDIX 5

TEACHER INTERVIEW PROTOCOL (TIP)

Teacher Interview Protocol

I appreciate your letting me observe your class. I have some questions I would like to ask you related to this lesson. Would you mind if I taped the interview? It will help me stay focused on our conversation and it will ensure I have an accurate record of what we discussed. Can I have a copy of the instructional materials you used for this lesson?

A. Learning Goals

1. I would like to know a bit more about the students in this class. Tell me about the ability levels of students in this class. How do they compare to students in the school as a whole?

2. Are there any students with special needs in this class? Are there any students for whom English is not their first language? Are there any students with learning disabilities?

3. Please help me understand where this lesson fits in the sequence of the unit you are working on. What have the students experienced prior to today's lesson?

4. How do you feel about how the lesson played out? What do you think the students gained from today's lesson?

B. Content/Topic

5. What led you to teach the genetics topic/concepts/skills in this lesson? Is it included in the provincial/district curriculum/course of study?

6. What process skills do students use to perform genetics tasks?

7. What resources did you use to plan this lesson?

8. How do you feel about teaching this topic? Do you enjoy it?

9. How well prepared do you feel to guide student learning of this content? What opportunities have you had to learn about this particular content area?

10. How comfortable do you feel using the instructional strategies involved in teaching this lesson?

11. What opportunities have you had to learn about using these strategy/strategies?

12. How helpful were these strategy/strategies?

Thank you for your time. If I have any additional questions or need clarification, how and when is it best to contact you?

APPENDIX 6

STUDENT INTERVIEW PROTOCOL (SIP)

Student Interview Protocol

1. Can you describe the genetics lesson of your class? What does the teacher do, what do you do?

2. Do you think that your lesson is an effective way for you to learn genetics? Please explain.

3. Is there any aspect of the lesson that you particularly like or think is particularly effective for you? Can you explain and give an example?

4. Is there any aspect of the lesson that you particularly dislike or think is not effective for you? Can you explain and give an example?

5. Tell me what you think about the participation element of the lesson: when [Teacher X] ask you to either raise your hand and answer a question or discuss the question with your neighbor.

6. How does the participation element of the lesson help you learn genetics?

7. The teacher in this lesson is using what he calls "concept mapping and vee diagramming" to teaching. What do you think of this approach? Are they positive effects for you?

8. Do you notice differences in the teacher's approach that you would like to comment on?

9. What is your reaction to the nature of the teacher's approach?

10. Is there anything else that you can tell us to help us understand your experience in this class?

APPENDIX 7

STUDENT WORKSHEET

Student Worksheet

Name: ---------------------------------- **Date:** -----------------------------------

This is a simple quiz to work out what you know about inheritance before inheritance before you start genetics. It does not count for your assessment.

Term	What do you about these things
Genes	
Chromosomes	
Mutation	
DNA	

APPENDIX 8 & 9

EXAMPLES OF LETTERS SENT TO PRINCIPALS AND PARENTS

University of the Western Cape

Private Bag X17 Bellville 7535 South Africa
Telephone: (021) 959-2788 Fax: (021) 951-2602
SCHOOL OF SCIENCE AND MATHEMATICS EDUCATION

REF: 2444238
Thursdays, July 29, 2004

UNIVERSITY *of the* WESTERN CAPE

The Principal
Hector Peterson Senior Secondary School
60 Boesak Street
Wallacedene
KRAAIFOINTEIN

Dear Sir or Madam:

I have recently been in contact with one of your biology teachers, Mr. Rodney Titus. Mr. Titus has agreed to allow me to visit and observe her grade 11 biology classes for the purpose of collecting data for my master research program. The research involves observing and documenting the ways teachers explain difficult and abstract science concepts in genetics and the way that student understand those explanations. I envisage visiting Mr. Titus and Ms Hazel on several occasions during the next four weeks while she is teaching material pertaining to my research. I will not be interfering with the normal progress of the biology lessons. I may sometimes use an audiotape and video camera in the classroom to help with my data collection.

Part of the data collection will involve individual interviews with about six students from two different classes and learners will write an achievement test. The interview sessions will take about 10-20 minutes and will be conducted at recess or lunchtime so that learners should not miss any important teaching time. The achievement test will not count on their assessment mark and will be entirely used for research purposes only. I have found in the past that these discussions are beneficial to learners because it helps them to reflect on the things they have been learning. Learner participation in the discussion will be voluntary and any learner's wish not be involved will be respected. The data collected from the classroom and student interview will be anonymous and reported in my mini-thesis. The data might also be reported at educational conferences and scholarly journals.

The purpose of this letter is to request your permission to enter your school for this research. I trust this request is satisfactory to you. If you have any difficulties with the request, or would like further information concerning this research study, you can contact me at the University of Western Cape on 959 2788 during office hours from Monday to Friday.

Yours sincerely,

....
Mr. Simasiku Siseho
Master Student

Fairmont High School

Private Bag X11 Durbanville 7551
Medway Durbell Durbanville
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www.fairmont.co.za

2 August 2004

RE: Application for a Research Permit

Mr Simasiku Charles Siseho

Mr Siseho has been granted permission to carry out research on the effects of an instructional strategy on grade (11) eleven learners' understanding of genetics at Fairmont High School for the next five weeks. He is expected in school until September 02, 2004.

He will work in close liaison with me, Mr R Dingley.

I trust that you will find this communiqué in order.

Yours sincerely

R H Dingley
Deputy Principal

APPENDIX 10

EXAMPLES OF RESEARCH CONSENT

RESEARCH CONSENT FORM

The effects of an instructional strategy on grade (11) eleven learners' understanding of genetics

1. Purpose

   I am a Masters Student at the University of the Western Cape (UWC) carrying out a research project for the topic mentioned above. This course requires me to gain experience in designing and conduct research. As such I have designed a research project to investigate the effects of an instructional strategy on grade (11) eleven learners' understanding of genetics.

2. Description

   During this study, you will be asked to write a Genetics Achievement Test (GAT), cloze test and you may be selected for a brief interview concerning your personal experiences in the genetics lessons. You will also be asked for some demographic information (gender, age, language, etc).

3. Potential harm

   There are no known harms associated with your participation in this research.

4. Confidentiality

   All records of participation will be kept strictly confidential, such that only my supervisor and I will have access to the information. The results from this study will be reported in a written research report. Information about the project will not be made public in any way that identifies individual participant.

5. Participation
   Participation is completely voluntary. It may be discontinued at any time for any reason without explanation and without penalty.

6. Consent
   I have read the above form, understand the information read, and understand that I can ask questions or withdraw at any time. I consent to participate in this research study.

____

Participant's signature

____

Investigator's signature

____

Date

APPENDIX 11

Sample transcripts of language switching in learners' discussions

Summary of transcriptions on language and construction of knowledge

Teacher: Apart from textbooks, radio and television most often used. Textbooks are at times perceived to be insufficient or too difficult to follow.

Learner: "I-textbook ityatyadula kakhulu; i-radio iyacacisa kakhulu abasebenzisi amagama amakhulu kakhulu, njenge textbook. Xa sisebenzisa I-textbook, sisoloko sidinga ukujonga I-dictionary."

Teacher: How would you feel about Xhosa being the medium of communication/instruction for education programmes on radio?

Learner: "Andiyithandi loonto ngoba ingasibuyisela muva. I-subjects exinjenge biology asinozivisisa, xazichazwa ngesiXhosa; zinaamagama esingesi afuna ukufundiswa ngololwimi – I-communication yawo yiEnglish. IsiXhosa sinokusi-confusa (confusing)."

I would prefer the medium of instruction for education programmes on the radio not to be Xhosa. We would not be able to understand subjects such as Biology if they were instructed in Xhosa; the terminology used in these subjects is in English and thus requires communication in that language. Communicating such courses in Xhosa would only confuse us.

Learner: "Mna ndibonokokuba kufanele iiSubjects zi-communicathwe (communicate) nge English, izinto ezinzima zichazwe ngesiXhosa ke. Ngolohlobo, sinokwazi ukufunda kwayona I-English eyo siyivisise."

I think that these subjects need to be communicated in English and difficult or complicated aspects explained in Xhosa. That way we will be able to learn English itself and understand things better. Examples of subjects that would be best suited to this approach are **Biology** and Geography.

Learner: "Umangabe kunokuchazwa yonkinto ngesiXhosa, kuzakumoshakala ixesha. Amanye amagama, akanakuchazwa ngesi-Xhosa njengo DNA."

Translating everything into Xhosa would waste a lot of time and anyway, some words/terminology cannot be translated e.g. DNA.

Learner: "Ininzi lwethu sidinga ukuchasiselwa ngesiXhosa, nyani ngoba asivisisi ngesingesi qha; kakhulu amagama amakhulu, siphoswa izinto ezinensi yilonto."

Many of us need things explained to us in our own language to help us understand better because we do not always understand things communicated in English, especially "big words"/complicated terminology; and because of this, we miss out on a lot of things.

Influences on English

Indigenisation or nativization is the process through which a language is accommodated and adapted to its speakers and their circumstances. In a country where English is acquired and used in a variety of different contexts, as in South Africa, the indigenisation of English reflects particular socio-historical processes, which have resulted in the emergence of the varieties discussed above. As in other parts of the globe, therefore, `new Englishes' have come into being in South Africa, reflecting the peculiarities of the South African situation and its people. Consider the following examples illustrating selected grammatical features of various varieties:

General South African English
a) `Busy' as a marker of the progressive: `I'm busy cooking'
b) Reduplication of adverb `now' as `now-now', which denotes either `immediately' or `soon'

African English
a) Use of indefinite article before certain `non-count' nouns: `He was carrying a luggage'.
b) Use of `can be able' for `can': `I can be able to do it' (Gough, 1995)

`Coloured' English
a) Use of `the dative of advantage': `I'm gonna buy me a new car'
b) Use of `do' or `did' in unemphasized statements and questions: `I did tell him to come.' `Who did throw that?' (Mesthrie 1993:31)

South African Indian English
a) Use of `y'all' as second person plural pronoun
b) Retention of ordinary question order in indirect questions with the verb `be': `I don't know what's that.' (Mesthrie 1989:6)