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Comparative effectiveness of Context-based and Traditional teaching approaches in enhancing learner performance in life sciences

by

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CERTIFICATION

This thesis has been examined and approved as meeting the required standard of scholarship for the fulfilment of the Degree of Doctor of Philosophy in Science Education.

Prof. G.O.M. Onwu

.. Date....................................
SUPERVISOR

DECLARATION

I, **Kazeni Mungandi Monde Monica**, hereby declare that this thesis for the Doctor of Philosophy in Science Education degree, at the University of Pretoria hereby submitted by me, is my own work, in design and execution, and it has not been previously submitted for any degree at any other university. To the best of my knowledge this thesis contains no material previously published by me or any other person, and that all references contained herein have been duly acknowledged.

.. **Date: ....**

Kazeni, M.M.M

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ABSTRACT

Young people's interest in the study of science-related courses is declining worldwide. In most developing countries, this waning aspiration has been coupled with reports of poor performance in science subjects. Fading interest and poor performance have led to low enrolment rates in science courses in higher institutions of learning, which pose the potential threat of reduced research activity and economic productivity. The methods usually used to teach science subjects in schools – which often involve the transmission of abstract facts and ideas, that are not explicitly relatable to learners – fail to provide learners with the opportunity to see the relevance of studying science. The failure to see the significance of science education could partly account for the lack of appeal and poor performance in the study of science. This study was an attempt to use contexts as a theoretical framework, and applications of life sciences (biology) to develop and implement 'relevant' curriculum materials as a means of motivating learners and improving performance in genetics, a topic which learners consider difficult to learn. The context-based approach was premised on the use of contexts which learners themselves identified as being relevant, meaningful and interesting in the study of genetics, and a five-phase learning cycle. The relative efficacy of the context-based and traditional approaches to the teaching of genetics in enhancing learner performance was assessed. The study was essentially a quantitative research, involving a quasi-experimental non-equivalent pre-test–post-test control group design. Qualitative data were collected using focus group learner interviews and one-to-one educator interviews to complement and triangulate the quantitative data. The study sample comprised 190 Grade 11 learners and six life sciences educators from six high schools randomly selected from the Tshwane South educational district in Gauteng, South Africa. Five instruments were used to assess learner performance in genetics content knowledge, science inquiry skills, problem-solving and decision-making abilities, and their attitudes towards the study of life sciences. The findings of the study, based on learner performance and perceptions, and their educators' views, revealed that in comparison with traditional teaching approaches, the context-based approach was significantly better in enhancing learner performance in genetics content knowledge ($F = 63.00$; $p = <0.0001$), ability to formulate hypotheses ($F = 33.21$; $p = <0.0001$), ability to draw conclusions from results ($F = 7.70$; $p = 0.0062$), decision-making ability ($F = 17.22$; $p = <0.0001$), problem-solving ability

($F = 16.57$; $p = <0.0001$), and in improving learners' attitude towards the study of life sciences ($F = 25.04$; $p = <0.0001$). The educational implications of the study are discussed.

Key words: context-based teaching, traditional teaching, context, relevance, performance, life sciences, genetics.

DEDICATION

This work is dedicated to my lovely children, Dr. Kazeni Mulai and Given

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LIST OF ACRONYMS

AAAS	American Association for the Advancement of Science
ACS	American Chemistry Society
CDE	Centre for Development and Enterprise
CEI	Centre for Education and Industry
DHA	Department of Home Affairs
DoBE	Department of Basic Education
DoE	Department of Education
DoL	Department of Labour
EC	European Commission
EIRMA	European Industrial Research Management Association
ESRC	Economic and Social Research Council
HSRC	Human Sciences Research Council
IET	Institute of Engineering and Technology
NRF	National Research Foundation
OECD	Organisation for Economic Co-operation and Development
SBP	Small Business Project
SET	Science, Engineering and Technology
TIMSS	Trends in International Mathematics and Science Study

CHAPTER ONE

INTRODUCTION

1.1 ORIENTATION TO THE CHAPTER

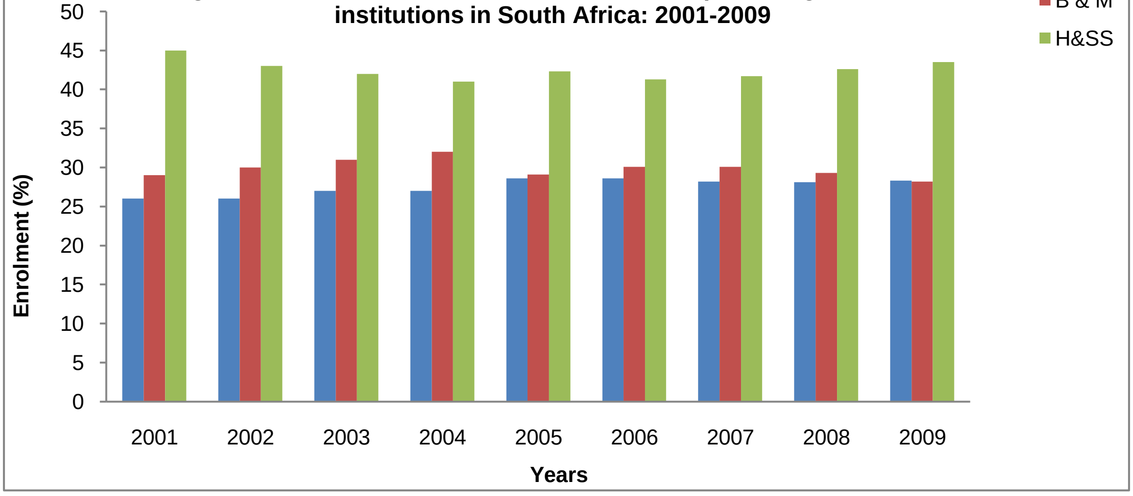
This introductory chapter includes a discussion on declining enrolments in science-related courses and the low uptake of science-related careers worldwide, including South Africa. This is followed by a discussion on young people's loss of interest and poor performance in science subjects as possible determinants of reduced enrolments in science programmes at tertiary level. Further, the effects of traditional and context-based teaching approaches on learner performance are discussed. Thereafter, the problem of the study and consequent research questions and hypotheses are presented. The chapter is concluded with a discussion of the significance and delimitations of the study.

1.2 INTRODUCTION TO THE STUDY

In recent years, one of the most discernible trends in science education worldwide has been the declining numbers of young people taking science-related courses and pursuing science-related careers (Centre for Education and Industry (CEI), 2009; Economic and Social Research Council (ESRC), 2008; European Industrial Research Management Association (EIRMA), 2009; Jenkins & Pell, 2006; The Institute of Engineering and Technology (IET), 2008). To this effect, research findings (Barmby, Kind & Jones, 2008; Jenkins, 2006; Jenkins & Nelson, 2005; Osborne, Simon & Collins, 2003; Sjøberg & Schreiner, 2005) have shown an alarming global decline in young people's interest in the study of science and the consequent uptake of science-related careers. It appears that the youth are losing interest in the pursuance of science.

South Africa has not been an exception to the problem of declining enrolments in science-related courses. For example, in comparison with non-science fields such as business and management, humanities and social sciences, the enrolment of South African learners in science, engineering and technology (SET) in public higher education institutions has been consistently lower over the past decade (Figure 1.1).

Figure. 1.1 Comparison of student enrolment in Science, Business and Management, Humanities, and Social Sciences in public higher education institutions in South Africa: 2001-2009



Key: SET = Science, Engineering and Technology B&M = Business and Management
H&SS = Humanities and Social Sciences, including Education
Source: Data obtained from DoE; Education Statistics 2000–2009:

Low enrolment rates in science-related courses have resulted in the scarcity of personnel in related careers in South Africa. This shortage has been acknowledged in several reports, such as those published by the Human Sciences Research Council (HSRC, 2009). These reports show that the skills of medical practitioners and nurses, engineers and technicians, biotechnologists, and information and communication technology professionals are in short supply. Other publications, including reports by the Department of Home Affairs (DHA, 2006) and the Department of Labour (DoL, 2005), list the skills of science and engineering professionals, science and mathematics educators, health and medical science professionals, and agricultural scientists as critically scarce in South Africa.

In comparison with other countries, South Africa's ratio of scientists and engineers to the population stands at 3.3 per 1000, compared with 21.5 per 1000 and 71.1 per 1000 in the US and Japan respectively (National Research Foundation [NRF] Annual Report, 2005). It would appear that South Africa is among the countries where the youth are increasingly losing interest in pursuing science-related professions. In the South African context, a review of the literature on the uptake of science-related courses seems to show a racial trend. For example, a report by the Small Business Project (SBP, 2011) shows that black learners in South Africa are under-represented in the Science, Engineering and Technology (SET) field of study, as shown in the table below.

Table 1.1 Enrolments in SET studies at higher education institutions by race (2008).

Race	% of the SA population	% of total enrolments in SET
Black	79.2	64.5
Coloured	9.0	5.9
Indian	2.6	6.9
White	9.2	23.1
Total	100	100

Source: SBP report, 14 February 2011 (adapted from HEMIS database and StatsSA, mid-year population estimate, 2008).

Table 1.1 shows that the white population, who made up approximately 9.2% of the total population in South Africa, had 23.1% of SET undergraduate enrolments in 2008, whereas black people, who consisted of about 79.2% of the population, constituted 64.5% of enrolments in SET in the same year. Racial discrepancies in SET enrolments in South Africa have persisted over several years (Department of Education: DoE - education statistics 2000–2009). The challenge of low enrolment rates in science-oriented courses and professions among the black population is one that needs urgent attention. It was therefore deemed necessary in this study to focus on the performance and interest of learners in peri-urban (township) schools where the population predominantly comprises of black people.

Since science has become a fundamental factor in national social and economic progress, low uptake of science subjects and careers is likely to impact negatively on the quality and quantity of scientific research, and national economic development (ESRC, 2008; European Commission (EC), 2007) in developing countries, including South Africa. Science education is seen as a means of producing the scientists and scientifically literate citizenry (Sjøberg & Schreiner, 2005) required for an improved economy and liberation from social ills such as poverty, crime and disease. School science serves as the foundation not only for access to science-oriented courses at tertiary education, but also for the production of skilled personnel in science-related professions, and the creation of scientifically literate citizenry (Centre for Development and Enterprise (CDE), 2010). Unfortunately, school science seems to have failed to excite and attract many learners or enhance their performance in science subjects, and hence has led to a decline in young people's pursuit of science oriented careers. The subsequent section reviews the performance of South African learners in science.

1.2.1 The performance of South African learners in science subjects

A review of the literature shows that the performance of South African learners in local and international assessments in science subjects has been abysmal for several years. For example, the performance of South African primary and high (secondary) school learners in international science and mathematics assessments has been much lower than international average scores in three successive appraisals (Trends in International Mathematics and Science Study - TIMSS reports 1995, 1999, & 2003: Beaton, Martin, Mullis, Gonzalez, Kelly & Smith, 1996; Gonzalez, Guzmán, Partelow, Pahlke, David, Kastberg & Williams, 2004; Mullis, Martin, Fierros, Goldberg, & Stemler, 2000; Reddy, 2006). See table 1.2.

Table. 1.2 TIMSS Average Achievements per Science Content Area (1995, 1999 and 2003)

Year	International average scores	South Africa average scores per science content areas				
		Life science	Earth science	Physics	Chemistry	Environmental science
1995*[1]	56 %	27%	26%	27%	26%	26%
1999*[2]	488	289	248	308	350	350
2003*[2]	474	250	247	244	285	261

*[1] Data reported as average percentage scores. *[2] Data reported as average scale scores

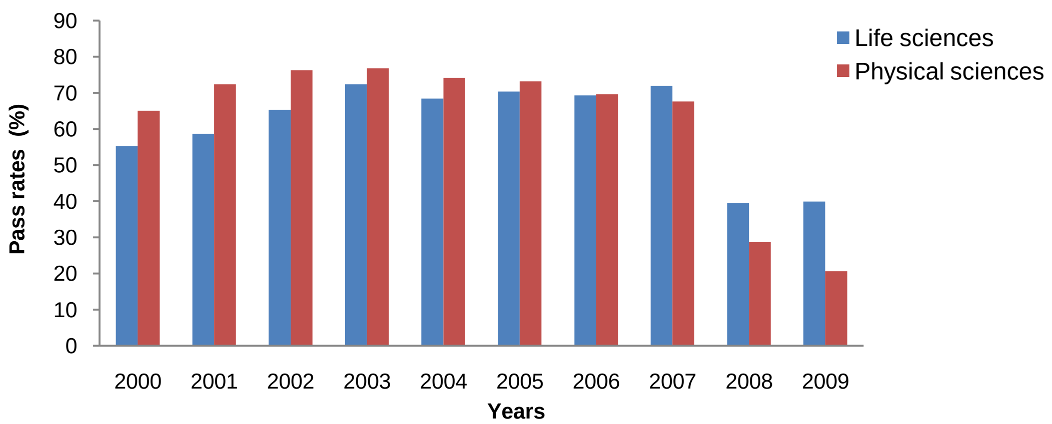
Source: 1995 data - IEA Third International Mathematics and Science Study – TIMSS 1994/95
1999 data - IEA Third International Mathematics and Science Study – TIMSS 1998/99
2003 data - IEA Trends in International Mathematics and Science Study – TIMSS 2003

Table (1.2) shows a comparison of international and South African average scores in three consecutive TIMSS assessment studies (TIMSS 1995, 1999, & 2003: Beaton, et al., 1996; Gonzalez, et al., 2004; Mullis, et al., 2000). In 1995, TIMSS average scores were reported as percentages, whereas in 1999 and 2003, the average scores were reported as scale scores. The international averages for each science content area are scaled to a single figure (the same as the overall international average), as shown in table 1.2. Data from TIMSS reports placed South Africa at the bottom of the participating countries, including African countries such as Morocco, Tunisia, Egypt, Botswana and Ghana, in all the three appraisals.

South African learners' poor performance in science subjects is also evident in the school-leaving National Senior Certificate (NSC) examination results, which, as shown in figure 1.2, have been consistently poor for the decade 2000 to 2009. Figure 1.2 shows a general decline in pass rates in life and physical sciences from

2003 to 2007, with lower pass rates in life sciences. It also shows a dramatic decline in pass rates for the years 2008 and 2009, with pass rates in physical sciences dropping even more significantly.

Figure. 1.2 Pass rates in life sciences and physical sciences, in national senior certificate examinations: 2000-2009



Source: Data from DoE statistics 2000–2009

Pass rates, in figure 1.2, were based on higher grade results in the senior certificate examinations for the years 2000 to 2007. For 2008 and 2009, pass rates were based on an achievement of at least 40% in the new national senior certificate examination whose grading system was different from the previous one. These pass rates were approximations of the basic requirements for entry into science-related programmes at tertiary level. For instance, the minimum entry requirement for science programmes at most universities in South Africa is 50% (Faculty of Natural and Agricultural Sciences, 2010). Therefore access rates into science-oriented programmes at tertiary institutions in South Africa are likely to be much lower than estimated by the above pass rates.

Generally, life sciences have always been assumed to be softer and thus easier sciences for learners to comprehend than physical sciences. However, in the South African context, achievement in life sciences has been as poor as, if not worse than that in physical sciences. For instance, figure 1.2 shows that from 2000 to 2006, the performance of learners in life sciences has been consistently poorer than that in physical science (DoE statistics 2000–2009). Life sciences are becoming increasingly important in understanding prevalent socio-scientific issues, such as

HIV/AIDS, teenage pregnancies, environmental sustainability, pollution, food production, stem cell technology, and genetic engineering. It is therefore important, through meaningful learning of life sciences at school level, that learners are empowered to relate effectively to these issues, and take up life science professions. This study was an attempt to explore ways of achieving better results in life sciences.

The poor level of achievement in life sciences seems to derive, among other things, from specific topics that are considered difficult for educators to teach and for learners to learn. For instance, genetics has been cited by many researchers (Abimbola, 1998; Araz & Sungur, 2007; Dairianathan & Subramaniam, 2011; Furberg & Arnseth, 2009; Kindfield, 1991; Knight & Smith, 2010; Topçu & Sahin-Pekmez, 2009; Tsui & Treagust, 2004, 2007, 2009; Venville & Dawson, 2010) as one of the most difficult topics in life sciences. Genetics concepts and applications are important for understanding other topics in life sciences (for example evolution, animal and plant diversity, and reproduction). Failure to understand genetics is therefore likely to adversely affect overall achievement in life sciences. In this study, an investigation of learner performance in genetics was thus deemed necessary.

In regard to the study of genetics, a review of literature (Dogru-Atay & Tekkaya, 2008; Ibanez-Orcajo & Martinez-Aznar, 2005; Lewis & Kattman, 2004) shows that misconceptions about genetics concepts, domain-specific vocabulary and terminology in genetics, the nature of genetics problems (which require application and reasoning skills), and perceived irrelevance of the study of genetics to learners' daily lives are considered to be determinants of the supposed difficulty of this topic. The factors that may account for the difficulty of genetics in particular and science in general are complex and multifaceted. These factors include both educational and non-educational issues such as infrastructures, teaching and learning resources, quality of educators, instructional approaches, gender, learners' cognitive preferences, learners' attitudes, and influences from role models such as parents, educators and peers (IET, 2008, Mji & Makgatho, 2006). In this study, the focus is on instructional approaches because they seem to play a significant role in learners' comprehension of study materials and the subsequent performance in science. For example, a study conducted by Mji and Makgatho (2006) in South Africa showed that teaching strategies were among the determinants of poor performance in science at high school. Similarly, poor performance in genetics could be a consequence of the instructional approaches that are usually employed by educators to teach the topic. The subsequent section discusses the relationship between the approaches used by educators to teach science, including genetics, and learner performance.

1.2.2 Science teaching and performance in science

Various studies (King, 2007; Kyle, 2006; Onwu, 2000, 2009; Schwartz, 2006; EC, 2007; and Van Aalsvoort, 2004) suggest that the way that science subjects are taught in schools and the learning environment could be major determinants of learner performance. In recent times, the manner in which school science is taught seems to bring about what has been variously described as 'a crisis of relevance' and 'a crisis of misalignment' – science education failing to be relevant in meeting the needs of learners and society in a rapidly changing world (Onwu, 2009; Onwu & Kyle, 2011). Consequently, science is perceived by many learners as an abstract and irrelevant subject (Lyons, 2006), and they therefore feel alienated by it (Carter, 2008; Stears, Malcolm, & Kowlas, 2003).

Several reports and studies (Anderson, 2006; CEI, 2009; EIRMA, 2009; IET, 2008; Jenkins & Pell, 2006; Schayegh, 2007; and Schreiner & Sjøberg, 2004) indicate that learners regard the study of science, including life sciences, as particularly difficult, uninteresting and having no bearing on their aspirations. In South Africa, for example, learners not only perceive some life sciences topics as difficult, but they see the life science curriculum as overloaded and mostly divorced from learners' daily life experiences (De Jager, 2000). For instance, Ferreira (2004) found that the majority of the learners who were surveyed, irrespective of gender or school type, agreed with a questionnaire statement that the life sciences learning programme contains too much information that has to be memorised.

In sum, various researchers (Holbrook, 2005; Onwu, 2009; Onwu & Kyle, 2011) have identified some of the shortcomings of the traditional ways of teaching science, which include the following:

- They do not provide learners with the opportunity to see the link between science education and their day-to-day experiences.
- They make science education unpopular and irrelevant in the eyes of learners.
- They lead to gaps between what learners want and what educators teach.
- They do not promote higher-order thinking skills.
- They do not foster a sense of confidence in learners' ability to solve problems and make informed decisions about their daily experiences and needs.

The traditional ways of teaching science could therefore at least partly account for learners' views of science as being irrelevant, uninteresting and difficult (Anderson, 2006; CEI, 2009; EC, 2007; EIRMA, 2009; Holbrook, 2005; IET, 2008; Jenkins & Pell, 2006; Onwu & Kyle, 2011; Onwu & Stoffels, 2005; Osborne & Collins, 2001; Schayegh, 2007; Schreiner & Sjøberg, 2004; Stears et al., 2003). This perception could have led to poor performance in science and low uptake of science-oriented courses and careers.

The question arises: Would instructional approaches that emphasise the linkage of scientific concepts to learners' daily life experiences enhance the relevance of studying genetics and improve learner performance more than traditional teaching approaches? Some studies (George & Lubben, 2002; Lubben, Campbell & Dlamini, 1996; Suela, Cyril & Said, 2010) have shown that learners like to be able to relate science and scientific principles to their daily lives. Connecting scientific concepts with learners' daily lives entails the notion of 'context-based' teaching (Bennett, 2003; Bennett & Holmann, 2002; Gilbert, 2006), which is discussed below.

1.2.3 Context-based approaches to the teaching of science

A discernible trend in science curriculum development in the past few decades has been the use of context-based teaching approaches to improve learner performance in science. In these approaches, scientific content is embedded in authentic contexts (real-life situations) that show learners the application of scientific concepts and methods in real life (Gilbert, Bulte & Pilot, 2006), and thus the importance and relevance of science education to their lives.

The term 'context' has been various described as a theme, situation, issue, story, practice, application, experience, or a problem (Pilot & Bulte, 2006). In science teaching, 'contexts' have been interpreted in terms of environmental, societal, health, personal, community, economic, nutritional, technological and industrial applications that could be used in developing science curriculum materials (Bennett, 2003). For the purpose of this study, context-based approaches refer to teaching that attempts to develop life science concepts from familiar contexts, such as social issues, which are considered important by learners and are closely related to their needs and situations in which they lead their lives (Bennett & Holman, 2002).

Previously, context-based science curricula at various educational levels, especially primary and secondary level, have almost consistently been developed from contexts that are perceived relevant by educators and curriculum developers, who are adults, and not by the learners themselves (Bennett & Holman 2002; Osborne & Collins, 2001). Curriculum developers and educators seem to assume that learners would be familiar with, and be interested in the same contexts that appeal to them as curriculum designers and educators (Mayoh & Knutton, 1997). As a result, few studies are reported in the literature that focus on discovering directly from the learners the contexts that they find particularly relevant, accessible and interesting in the study of science at high school level.

It is intriguing that learners, whose interest is meant to be aroused by the use of context-based materials, should seldom be given the opportunity to contribute to decisions about the contexts which they consider suitable for science learning. Various authors (for example Cook-Sather, 2005; Jones, 1997) warn that the inability of learners to relate to 'authentic contexts' (as perceived by educators and curriculum developers who are adults) could result in learners being reluctant to engage with the contexts, thus shielding their knowledge and experience from educators. Excluding learners from curriculum decisions in essence negates the whole purpose of incorporating learners' experiences in the curriculum. It would therefore seem essential to involve learners in the choice of contexts to be used in contextualised teaching. One way of achieving this is by finding out from the learners themselves the kinds of contexts which they would value in studying a given topic, particularly one that is considered difficult to learn, such as genetics.

The importance of learners' input into decisions about their own education has been acknowledged by several other researchers (Basu & Barton, 2007; Cox, Dyer, Robinson-Pant & Schweisfurth, 2009; Osborne & Collins, 2001; Rudduck & Flutter, 2000; Sjøberg & Schreiner, 2005). In this study, therefore, it was particularly important to involve learners in the selection of contexts for developing genetics context-based teaching materials. It was also important to implement these materials using a specific context-based approach, designed to fully exploit the potential of the materials to motivate learners and improve their performance in science (De Jong, 2008; Gilbert, 2006).

1.3 THE PROBLEM OF THE STUDY

South African educational institutions have been characterised by poor performance in science and low enrolments in science-related courses for several years (section 1.2.1 and figures 1.1 and 1.2). The way in which science subjects (including life sciences) are taught has been identified by many researchers (EC, 2007; Holton, 1992; King, 2007; Kyle, 2006; Onwu, 2000, 2009; Schwartz, 2006; Van Aalsvoort, 2004) as one of major factors that could affect performance in science.

A review of the literature suggests that science teaching, worldwide, lacks explicit connections of science content with learners' day-to-day experiences (EIRMA, 2009; Kyle, 2006). This could account for the perception of science education by many learners as irrelevant, difficult and uninteresting (Anderson, 2006; CEI, 2009; EIRMA, 2009; IET, 2008; Jenkins & Pell, 2006; Schayegh, 2007). Research findings (George & Lubben, 2002; Lubben et al., 1996; Suela et al., 2010) (see section 1.2.2) suggest that learners appreciate explicit links between the science they learn and their daily life experiences. In addition, anecdotal evidence – for instance the researcher's own observations of first-year university learners – indicates that learners were more interested and performed better in life sciences lessons in which the link between what was learned in class and their day-to-day experiences was clearly discernible. This was particularly true of topics that had direct applications to their own lives and their communities. This evidence necessitated an inquiry into the efficacy of context-based teaching approaches in enhancing learner performance.

Context-based teaching approaches have been used extensively in many countries for learner motivation and improved performance in science (Bennett, 2003). In South Africa, the content and learning outcomes of the former National Curriculum Statement (NSC) and the current Curriculum Assessment Policy Statement (CAPS) for science subjects, including life sciences, promote contextualised teaching and learning (Department of Basic Education [DoBE], 2011; DoE, 2008). However, research findings show that context-based approaches to the teaching of science have not been fully adopted by South African educators (Lubben & Bennett, 2009; Rogan, 2004, 2000).

Lotz-Sisitka (2006) points out that classroom practice in the South African education system is hardly influenced by contexts. This assertion is reiterated by Rogan (2007), who found that the specific outcomes of the South African Curriculum Statement for science subjects that deal with the interface of science and society were largely absent from science lessons, which are dominated by knowledge transmission practices. It could therefore be surmised that although contextualized teaching and learning is encouraged in the South African national science curriculum, its use in schools has not been ascertained.

Although existing literature suggests that context-based approaches have a positive influence on learner motivation (Ramsden, 1998, 1992; Reid & Skryabina, 2002; Yager & Weld, 1999), their effect on conceptual understanding of science has not been unequivocally established. Some studies (Bloom & Harpin, 2003; Gutwill-Wise, 2001; Sutman & Bruce, 1992; Yager & Weld, 1999) have found that context-based approaches enhance conceptual understanding significantly more than traditional teaching approaches do, while others (Barber, 2001; Barker & Millar, 1996; Ramsden, 1997, 1992; Taasoobshirazi & Carr, 2008) found non-significant differences in the conceptual understanding of learners exposed to context-based and traditional teaching approaches. The lack of consensus on the effectiveness of context-based teaching approaches in enhancing learners' comprehension of science concepts calls for further research to gain more insights into the usefulness of these approaches in enhancing achievement.

A variety of factors – such as the use of contexts selected by adults only, to develop learning materials (Bennett & Holman 2002; Osborne & Collins, 2001), and the use of different models of contextualised teaching (Gilbert, 2006) could somewhat explain this lack of consistency in the findings. In this study, contexts identified by learners themselves as relevant, interesting and accessible to the study of genetics were used to develop context-based materials.

Context-based approaches to the teaching of science should emphasise, among other things, the enhancement of science inquiry skills, problem solving and decision-making ability, according to various researchers (Bennett & Holman, 2002; Gilbert, 2006, 2008; Schwartz, 2006). The skills are important, not only for academic achievement, but for the effective and functional existence of the youth in the twenty-first century. The question is: Do researchers, developers and implementers of contextualized teaching take into account the development of higher order thinking skills? Unfortunately, there appears to be a dearth in literature about the effectiveness of context-based approaches in enhancing the acquisition of these skills. Therefore, there was a need to investigate the efficacy of context-based teaching approaches in the development of skills such as integrated science inquiry skills, problem-solving and decision-making ability.

Learner performance in science is known to be influenced by a number of intervening variables, including gender, availability of resources, and cognitive preferences (IET, 2008). For instance, several researchers (Alparslan, Tekkaya, & Geban, 2003; Cavallo, Rozman & Potter, 2004; Osborne, et al., 2003) have acknowledged the global prevalence of gender discrepancies in performance in science subjects. The necessity to find out whether boys and girls would perform differently when exposed to a specific context-based approach became apparent.

‘Cognitive preferences’ refer to the ways in which learners acquire, process, and assimilate information (MacKay, 1975). The traditional ways of teaching science often lead to the memorisation of abstract science concepts (Lyons, 2006; Taasoobshirazi & Carr, 2008), which predispose learners to a recall learning style. It may therefore be assumed that learners who had been exposed to the traditional ways of teaching for a long time would have a predominantly recall cognitive preference. Research evidence reveals the possibility of an interactive influence between learners’ cognitive preferences and instructional approaches on performance in science (McNaught, 1982; Okebukola & Gegede, 1989; Tamir, 1988). The researcher wondered whether the developed context-based teaching approach would have adverse effects on learners with particular cognitive preferences. A review of the literature showed a scarcity of studies that assess the interactive influence of cognitive preferences and context-based teaching on the attainment of learning outcomes. It thus became necessary to explore the possibility of this interaction when assessing the efficacy of the new instructional approach.

1.4 PURPOSE OF THE STUDY

The purpose of the study was to determine the relative effectiveness of context-based and traditional teaching approaches in enhancing Grade 11 learners' attainment of genetics content knowledge, science inquiry skills, and decision-making and problem-solving abilities, and in improving their attitude towards the study of life sciences. The interactive influence of gender and cognitive preferences, and treatment on learners' attainment of the stated learning outcomes, if any, was also measured. In addition, learners' and educators' views on learner performance and the approaches used were determined.

1.5 RESEARCH QUESTIONS

The problem statement gave rise to the following research questions:

1 Would there be any differences in the performance of learners exposed to a context-based teaching approach and those exposed to traditional teaching approaches with respect to:

   i. Achievement in genetics?
   ii. Enhancement of science inquiry skills?
   iii. Enhancement of problem-solving ability?
   iv. Enhancement of decision-making ability?
   v. Improvement of learner attitude towards the study of life sciences?

2 Would there be any interactive influence of gender and cognitive preference, and treatment on learners' attainment of the learning outcomes?

3 What are learners' and educators' views on features of the context-based and traditional teaching approaches that could account for differences, if any, in learner performance on the assessed learning outcomes?

1.6 RESEARCH HYPOTHESES

The null hypotheses tested to answer the first two questions were as follows:

Ho1 There is no significant difference between learners exposed to a context-based teaching approach and those exposed to traditional teaching approaches, in their attainment of genetics content knowledge, science inquiry skills, decision-making and problem-solving ability and their attitude towards the study of life sciences.

Ho2 There is no significant interactive influence of gender and treatment on learners' attainment of genetics content knowledge, science inquiry skills, decision-making and problem-solving ability and their attitude towards the study of life sciences.

Ho3 There is no significant interactive influence of cognitive preferences and treatment on learners' attainment of genetics content knowledge, science inquiry skills, decision-making and problem-solving ability and their attitude towards the study of life sciences.

Ho4 There is no significant interactive influence of cognitive preferences and gender, and treatment on learners' attainment of genetics content knowledge, science inquiry skills, decision-making and problem-solving ability and their attitude towards the study of life sciences.

The third research question was answered using qualitative data obtained from learner and educator interviews.

1.7 SIGNIFICANCE OF THE STUDY – SCIENTIFIC MERIT

This study sought to determine the achievements and experiences of learners who were exposed to context-based and traditional approaches to the teaching of a life sciences topic. Information on the effectiveness of these approaches in enhancing learner performance could provide helpful insights into the use of context-based approaches to teaching life sciences. This is particularly important since the current South African life sciences curriculum emphasises the use of real-life issues in teaching the subject. It is therefore hoped that the outcome of this study will benefit life sciences educators by providing them with a prototype from which future teaching materials could be developed.

The study was premised on the use of contexts identified as relevant, interesting and accessible by the learners themselves to develop context-based materials for teaching genetics. This study is therefore likely to first, provide insights into the contexts that are considered important for studying genetics, by South African learners. Secondly, to provide insights into the effectiveness of teaching materials that are relatable to learners not only in motivating learners, but also in enhancing conceptual understanding and the development of higher order thinking skills.

Lastly, the study sought information on the interactive influence of gender and cognitive preference, and the instructional approaches used, on learners' attainment of the assessed learning outcomes. This knowledge is important in providing insights into whether the developed materials and approach are accessible by both genders and by learners with different cognitive preferences.

1.8 CONTEXT OF THE STUDY

The schools involved in the study were public schools situated in suburban residential areas in Pretoria, South Africa. The schools cater for both General Education and Training (GET) and Further Education and Training (FET) phases (from Grade 8 to 12). The majority of the learners in the schools are 'black Africans', with isolated cases of 'coloured' learners. English is used as the official medium of instruction. However, learners usually use 'seTswana' and 'sePedi' (local languages) outside the classroom, and occasionally during lessons.

Learners in the participating schools come mostly from low to medium socio-economic status groups. Owing to the poor socio-economic status of most of the learners, the schools have feeding schemes where learners are given a meal at lunch time. After lunch, learners in most of the schools attend lessons for about 1 hour 30 minutes, and afterwards engage in extramural activities, such as sport and remedial lessons, or are allowed to go home. The researcher used the time for extramural activities to conduct the study because this was the time recommended by the respective schools and the Department of Education. Participating learners were given an hour to rest and prepare themselves before commencing with the study lessons. All the activities related to the study were done during this duration.

1.9 DELIMITATION OF THE STUDY

The study was conducted with Grade 11 learners from six schools in Pretoria, South Africa. In addition, the materials were based on one life sciences topic – genetics. While the researcher recognises the potential of the materials to enhance performance in a diversity of settings, topics, and subjects, it is acknowledged that the use of more diverse schools and a variety of topics was necessary for generalization of finding from a quantitative study. Care must therefore be taken when applying the findings of this study to other situations, such as a different level of education, and other science topics and subjects.

1.10 MAIN ASSUMPTIONS

It was assumed in this study that the Grade 12 learners who participated in the selection were able to choose contexts that most learners considered relevant, interesting and accessible in studying genetics. It was also assumed that the educators who taught genetics using the traditional approaches would use any teaching approach, which could include the occasional use of contexts.

1.11 SUMMARY

This chapter set out to highlight the global declining intake of learners into science-related courses and the pursuit of science-oriented careers. The poor performance of South African learners in science subjects was acknowledged. Traditional ways of teaching science were identified as a possible determinant of poor performance and low enrolment rates in science programmes. The focus of the chapter was to expound on the need to assess the relative efficacy of context-based and traditional ways of teaching in improving learner performance in genetics, a life science topic which is considered difficult for learners to learn.

More specifically, the chapter explicated the need for using contexts that are identified by learners as relevant, interesting and accessible in the study of genetics to develop context-based materials and to use an appropriate approach to implement them. The chapter included the problem of the study and research questions, as well as the significance, delimitations and assumptions of the study.

1.12 ORIENTATION TO FORTHCOMING CHAPTERS.

The study report is organised in six chapters. The current chapter presents an introduction to the study, followed by Chapter Two, in which literature related to the study and the conceptual framework of the study are discussed. Chapter Three provides a description of the methodology used in the study. This includes a description of the approaches used to develop the teaching materials and the instruments for collecting data. The pilot study, the main study and data analysis procedures are also described in the same chapter. Chapter Four presents the quantitative and qualitative results of the study, which are discussed in Chapter Five. Chapter Six provides the summaries, conclusions, and the educational implications of the study, as well as suggestions for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 ORIENTATION TO THE CHAPTER

In this chapter literature related to the study is reviewed. The literature concerns the use of traditional and context-based approaches to the teaching of science. The review is meant to explore the extent to which traditional and context-based teaching approaches, as well as learning cycles could reasonably motivate learners and improve performance in the study of a life science topic – genetics. This literature is used to explicate the conceptual framework of the study. This followed by a discussion on the assessment of the learning outcomes considered in the study. Finally, some factors that could affect science teaching are examined.

2.2 APPROACHES TO THE TEACHING OF SCIENCE

A myriad factors including lack of resources and of competent science educators, poor infrastructure, the prevalence of large classes, and the types of instructional approaches, could influence the teaching and learning of science (IET, 2008). A review of literature seems to suggest that the approaches educators use to teach science could be a major determinant of learner performance (CEI, 2009; EC, 2007; EIRMA, 2009; Jenkins & Nelson, 2005; Van Aalsvoort, 2004). This is also true for the South African setting where studies and reports (CDE, 2010; Mji and Makgatho, 2006) have shown an association between teaching methods and learner performance in science. The succeeding sections examine the effects of three instructional approaches to science subjects, namely; traditional teaching approaches, contextualized teaching and learning cycles, on learner performance.

2.2.1 Traditional teaching approaches

In the context of this study 'traditional teaching approaches' refer to the usual methods used by educators to teach science subjects, which could involve occasional reference to real-life applications of science. A review of the literature seems to suggest that science teaching methods differ between primary school and high school. Many reports and studies (EC, 2007; IET, 2008; Rennies, Goodrum & Hackling, 2001) imply that at primary school level, science teaching mostly involves pupil-centred and activity-based teaching, entailing frequent practical activities, and providing more freedom for pupil investigations. In contrast, science teaching at high-school level usually involves educator-centred instruction, dominated by ‘chalk and talk’ teaching, lecturing, note copying by learners, factual knowledge, abstract concepts, and ‘cookbook’ practical lessons and demonstrations (EC, 2007; Goodrum, Hackling, & Rennie, 2000; Onwu & Stoffels, 2005; Osborne & Collins, 2001).

In a typical high school science class, the educator provides a few examples or solves a few problems on the board, and in some cases performs experimental demonstrations. Learners in such classes listen to the educator and write notes, but hardly ever ask questions or make remarks (Briscoe & Prayaga, 2004; Kang & Wallace, 2005). For example, a study conducted by Lyons (2006) found that science teaching at high-school level involved the transmission of knowledge from expert sources (educators and text books) to mainly passive recipients (the learners). The following phrases were used by learners who participated in Lyons’ study to describe the presentation of science lessons.

> This is it, this is how it is, this is what you learn; it is like that, learn it because it is right, there is nothing to discuss; it happened, accept it. (Lyons, 2006: 591).

This perception of science lessons seems to imply that learners see science as a body of knowledge to be committed to memory, without understanding or questioning. In addition, a report by the Organization for Economic Cooperation and Development (OECD) Global Science Forum (2006) states that most learners at high-school level are of the view that science teaching lacks a sense of community, does not reflect their experience of the world or contemporary research, involves too much repetition, does not provide a good overview of the subject, and offers little room for discussion. Other researchers (McCarthy & Anderson, 2000) have indicated that the traditional ways of teaching science usually involve little active learning, and frequently cause learners to become disengaged and unmotivated.

Nonetheless, science instruction at high school is not always conducted as depicted above. In some cases, science educators teach effectively, resulting in enhanced learner performance in science subjects, as evident in some high schools that perform consistently well in science (for example, in the South African context, Grey College, King Edward VII School, Hilton College, and St John's College). Despite these high achieving schools, most high schools in South Africa persistently perform poorly, especially in rural schools (Onwu & Stoffels, 2005). The methods used to teach science in such schools could be major determinants of performance.

2.2.1.1 Traditional teaching approaches and learner performance

As stated in Chapter One, for over a decade the performance of many South African learners in science subjects has been poor. In the context of this study, performance is measured in terms of achievement in content knowledge, science inquiry skills, problem-solving and decision-making ability, and learners' attitude towards the study of life sciences. The subsequent sections examine literature on the effects of traditional teaching approaches on the acquisition of these learning outcomes.

- **Traditional teaching and conceptual understanding**

A review of literature suggests that the traditional ways of teaching science often fail to sufficiently develop learners' understanding of scientific concepts (Allen, 2008; Seymour & Hewitt, 1996; Sundberg, Dini & Li, 1994; Taasoobshirazi & Carr, 2008; Wilke, 2003). For instance, Taasoobshirazi and Carr (2008) are of the opinion that traditional ways of teaching science, which usually involve memorization of concepts and computations, often result in learners' failure to comprehend the deeper conceptual connections within the problems. This way of teaching, according to these authors, encourages poor problem-solving approaches and limited comprehension of learned concepts and ideas.

Allen (2008) points out that, in most cases, school science aims to deliver a body of 'right answers', in which currently established theories and concepts are transmitted to learners as if they were absolute irrefutable truths to be learned as examinable facts. This approach to science teaching is likely to encourage learners to memorize and recall scientific concepts for the sake of passing examinations, rather than foster a deep understanding of the concepts. Several other reports and studies (Fonseca & Conboy, 2006; IET, 2008; OECD, 2006; Osborne & Collins 2001; Prokop, Tuncer & Chud'a, 2007) have indicated that most learners find the study of science difficult because science teaching lacks inspiration.

- ***Traditional teaching and conceptual understanding of* genetics**

Many learners find genetics difficult to learn. As indicated in Chapter One, the difficulty in learning genetics and genetics-related concepts seems to derive from aspects such as the prevalence of misconceptions, domain-specific vocabulary and terminology, problems that require application and reasoning skills, and instructional approaches that do not foster meaningful learning (Dogru-Atay & Tekkaya, 2008; Ibanez-Orcajo & Martinez-Aznar, 2005; Lewis & Kattmann, 2004).

Several researchers (Seymour & Hewitt, 1996; Sundberg et al., 1994; Wilke, 2003) have associated the difficulty in learning certain life science topics, such as genetics, with ineffective instructional methods. In consequence, recent studies (Araz & Sungur, 2007; Dairianathan & Subramaniam, 2011; Furberg & Arnseth, 2009; Kindfield, 2009) have explored various ways of teaching genetics, such as the use of out-of-school settings, collaborative activities, socio-cognitive approaches and problem-based learning, in an attempt to improve performance. These approaches are aimed mostly at increasing the relevance of learning genetics, with the hope of improving conceptual understanding of the topic. The approach developed in this study focuses on the use of; materials that are relatable to learners, minds-on and hands-on activities, and applications of scientific concepts to enhance learner performance in genetics.

Despite assertions that traditional teaching methods are often un-motivational and do not foster conceptual understanding, some learners exposed to these teaching methods perform well, as indicated earlier in this section. It was therefore deemed necessary in this study to compare the effectiveness of traditional teaching and the developed context-based teaching approach, in enhancing learner achievement in genetics.

- **Traditional teaching and the development of science inquiry skills, problem solving, and decision-making ability**

Science is regarded by many people as a discipline based on practical and analytical activity. Instructional approaches in science are therefore expected to be premised on hands-on and minds-on tasks (EIRMA, 2009; IET, 2008; Lyons, 2006; Rennies et al., 2001). Such approaches are envisaged as enhancing the development of critical and analytical thinking skills, including science inquiry, problem solving and decision-making ability. However, while most of the science education community consent to the use of pedagogical practices based on inquiry-based methods, the reality of classroom practices is that science teaching is rarely inquiry based, especially at high school level (Allen, 2008; EC, 2007). Similarly, other higher order thinking skills such as decision-making and critical thinking are seldom developed.

Most high school educators, particularly in developing countries, present science as a theoretical body of knowledge characterized by facts, concepts and theories, with minimal or no practical work (Barmby et al., 2008; EC, 2007; Lyons, 2006; OECD, 2006; Onwu & Stoffels, 2005). In cases where practical experiments are conducted, learners usually follow stringent instructions from the educator or a practical manual in order to carry out an experiment to confirm results that are already known (EC, 2007; Kang & Wallace, 2005; Lyons, 2006; OECD, 2006).

The problem of lack of practical and analytical activity in science classrooms is more profound in rural areas, where there are large under-resourced classes. For instance, in South African rural schools, practical experiments are often performed as demonstrations by educators, partly owing to large classes and insufficient resources (Onwu & Stoffels, 2005). During educator presentations, the educator conducts an experiment, and learners are expected to follow the procedure closely, while the educator occasionally asks them questions related to the experiment. At the end of the demonstration, worksheets are usually handed out to learners to complete in class or as homework (Onwu & Stoffels, 2005).

This approach to conducting experiments deprives learners of minds-on and hands-on experiences that could enhance learner creativity and the development of higher-order thinking skills, such as science inquiry skills, decision-making and problem solving ability. This deprivation is acknowledged by Klassen (2006: 48) who argues that “school science lacks the vitality of investigation, discovery, and creative inventions that often accompany science-in-the-making”.

In spite of the described practical activity in traditional teaching, some educators frequently expose their learners to experimental work, probably through improvisation or other means, and manage to develop higher order thinking skills in the learners. It was therefore considered important in this study to determine the relative effectiveness of traditional and context-based teaching approaches in enhancing the acquisition of science inquiry skills, problem-solving and decision-making abilities. This comparison was particularly necessary because of the emphasis on inquiry skills, problem solving, and decision-making skills in the South African life sciences curriculum (DoE, 2008), and the importance attached to the development of these skills for personal benefit, academic success, and effective participation in contemporary society.

- **Traditional teaching and learners' attitude towards the study of science**

One of the objectives of science education is to motivate learners to study science and to pursue science related careers. The concept of motivation is difficult to define because it is multi-faceted and it is affected by a variety of factors. Nonetheless, Brophy (2004) defines motivation as "a theoretical construct used to explain the initiations, direction, intensity, persistence and quantity of behaviour". In relation to learning, Petrides (2006) argues that learner motivation can be viewed in relation to two factors: the needs of the learners and their attitudes towards a subject. In a similar vein, Gardner (1995) asserts that motivation constitutes three elements: effort, desire to achieve a goal, and attitudes.

From these definitions, it appears that motivation is a composite of a number of notions, which include attitudes. In this study, the focus was on the attitude aspect of motivation. The notion of attitude is complex and has been variously defined by researchers. Of the numerous definitions of attitude towards science, the definition that comes closest to the perception of attitude in this study, is one given by (Osborne et al., 2003: 1053), who defines attitude towards science as "The feelings, beliefs and values held about science, including perceptions about the science educator, anxiety towards science, the value of science, self-esteem at the study of science, motivation towards science, enjoyment of science lessons, achievement in science, and fear of failure in a (science) course".

The importance of learners' attitude in learning, particularly in science education, has been acknowledged by several researchers (OECD, 2006; Papanastasiou & Papanastasiou, 2002; Papanastasiou & Zembylas, 2002). A review of literature

(Barber, 2001; EC, 2007; King, 2008; Papanastasiou & Zembylas, 2002; Papanastasiou & Papanastasiou, 2002; Rollnick, Green, White, Mumba & Bennett, 2001; Schwartz, 2006) suggests a strong relationship between learners' attitude and achievement in science.

A report by the OECD Global Science Forum (2006) on the 'Evolution of learner interest in sciences', states that learners' perception of the quality of education, and the consequent motivation to study a subject, is determined to a large extent by what educators do in the classroom. Instructional approaches could therefore be determinants of learners' attitudes towards the study of science, including life sciences, which could in turn affect their achievement. Several researchers (Rigden & Tobias, 1991; Seymour & Hewitt, 1996; Trafil & Hazen, 1995) have acknowledged the relationship between instructional approaches and learner attitude towards the study of science. What needs clarification is: How do traditional teaching approaches influence high-school learners' attitudes towards the study of science?

A study conducted by Osborne and Collins (2001), which involved teaching science to learners enrolled for science subjects and others who were enrolled for non-science subjects, found that the non-science group pointed out that, the study of science did not have room for learners to contribute anything, in contrast with other subjects in which they could use their imagination. These learners (from the non-science group) described school science as "consisting of facts to be learnt, which you have got to 'print it into your brain', or learning 'straight facts', which you have to repeat in the exam" (Osborne & Collins, 2001: 452). The study revealed discontentment among learners about practices in science education, citing mostly lack of relevance and of autonomy in science classes as reasons for their dissatisfaction (Osborne & Collins, 2001). This perception of science could affect learners' attitude towards the study of science.

Various other studies (Anderson, 2006; Barmby et al., 2008; Driver, Leach, Millar & Scott, 1996; Ebenezer & Zoller, 1993; Jenkins & Pell, 2006; Schayegh, 2007; Schreiner & Sjøberg 2004) have indicated that a substantial proportion of learners do not see the significance of science education in their lives, which makes them lose interest in the subject. Other studies (EIRMA, 2009; IET, 2008; Prokop et al., 2007;

OECD, 2006; Lewis & Kattmann, 2004) have shown that learners perceive the study of sciences as difficult and boring.

Learners' perception of science education as irrelevant and difficult is often associated with their failure to make effective links between what they learn in science classes and their real-life experiences. A recent study conducted by Barmby et al. (2008), entitled 'Examining changing attitudes in secondary school science', showed that learners were unable to make connections between school science and everyday life, and hence could not appreciate the study of science. The concern is, what is it about traditional teaching that prevents learners from making these connections? In this regard, the OECD (2006) report states that the way science is normally taught does not make the relevance of science education visible to learners because science education is disconnected from cutting-edge science and contemporary applications of science and technology.

Other reports and researchers (EIRMA, 2009; Kyle, 2006; Onwu, 2000) have acknowledged the failure of traditional teaching methods to link the study of science to learners' day-to-day experiences. If learners are unable to see the relevance of what they study in science classrooms, they are likely to develop negative attitudes towards the subject.

In summary, the literature on traditional teaching approaches and learner performance seems to suggest that:

- The traditional ways of teaching science often make the study of science appear to learners as a catalogue of abstract facts, with little scope for discussion, thus making science appear difficult.
- They might not encourage hands-on and minds-on activities, which are necessary for the development of higher-order thinking skills.
- They might not sustain young people's sense of curiosity about the natural world.
- They may not always relate science lessons to learners' real-life experiences, which could make the study of sciences seem irrelevant and uninteresting to learners.

In some instances, traditional approaches to the teaching of science somewhat appear to be effective in fostering positive attitudes towards the study of science and in enhancing achievement, in some learners, judging from the number of learners exposed to these approaches who opt to pursue science-related careers and succeed. What needs to be explored is whether the use of context-based approaches to the teaching of science, which tend to place more emphasis on the linkage of science learning with learners' daily life experiences, would be more facilitative than is currently achieved in most traditional classrooms? In this study therefore, it became necessary to determine the relative effectiveness of traditional teaching approaches and a context-based approach in improving learners' attitude towards the study of life sciences. The following section reviews literature on the use of context-based approaches to teaching science.

2.2.2 Context-based teaching approaches

The term 'context' is commonly used in everyday language, and has a variety of interpretations (see section 1.2.3). For example, Oxford dictionaries (Pearsall, 1999) define contexts as: "the circumstances that form a setting for an event, statement, or idea, and the terms in which it can be fully understood". In relation to education, two usages of the term 'context' are evident in the following quotation.

> The term context has different and somewhat conflicting meanings. Some proponents use context to denote domain specificity. Performance in this context would presumably show deep expertise. On the other hand, context has been used to signal tasks with authenticity for the learner. The adjective authentic is used to denote tasks that contain true-to-life problems that can embed … skills in applied contexts (Baker, O'Neil & Linn, 1994: 335).

Bennett and Holman (2002) highlight examples of contexts with reference to chemistry teaching, which include economic, social, personal, technological and industrial applications of chemistry (science). In a similar vein, De Jong (2008) has attempted to clarify the meaning of contexts for science teaching and learning by identifying four domains as the origin of contexts. These are personal, social and society, professional practice, and scientific and technological domains. De Jong (2008) describes these domains as follows:

- Personal domain refers to contexts relating to learners' personal lives, such as personal health and needs (food, clothing, etc.).
- Social and societal domain refers to contexts that involve community and environmental issues such as crime, climatic changes, and the effect of acid rain.
- Professional practice domain refers to contexts that are career related.
- Scientific and technological domain refers to contexts involving scientific and technological discoveries and innovations.

From these descriptions of domains of contexts and existing literature, it appears that issues related to real-life experiences, situations or applications on which the meaning of a given phenomenon or concept may be understood could denote the notion of contexts. Based on this understanding, context-based teaching approaches would signify instructional practices that relate learning to real-life situations, experiences and activities. To this effect, the Queensland Studies Authority (2004: 11) defines 'context-based teaching' as "a group of learning experiences that encourage learners to transfer their understanding of key concepts to situations that mirror real life". Similarly, Taylor and Mulhall (1997, 2001) assert that contextualization of learning takes place when the learning materials and instructional methods are explicitly linked to the experiences and environment of the learners. Bennett, Lubben and Hogarth (2006: 348) define context-based approaches to science teaching as "approaches adopted in science teaching where contexts and applications of science are used as the starting point for the development of scientific ideas".

Based on Bennett., et al (2006)'s definition and the need to address learners' views, context-based teaching is defined in this study as "approaches adopted in science teaching and learning where contexts determined by learners themselves and applications of science in familiar situations and experiences are used as starting points for developing scientific concepts and ideas, and for improving motivation".

The aims underpinning the development and use of context-based materials have evolved from highlighting the relevance of science education, increasing enrolments in science programs, and providing appropriate science courses for non-science specialists (Bennett, 2003), to include effective learning of science ideas, motivation of learners, and the provision of hands-on and minds-on experiences of science phenomena, including the development of analytical and inquiry skills (Gilbert, 2006, 2008; Schwartz, 2006). Context-based materials are therefore developed and designed to address some or all of these aims.

According to Gilbert (2006: 960-966), the development of effective context-based teaching materials should be guided by the following principles:

1. Context-based materials should provide a setting (social setting) in which learners may engage in mental encounters with events on which attention is focused.
2. The environment in which the mental encounters take place must be of genuine inquiry, which reflects the conditions under which scientists operate.
3. The way of talking within the environment should be developed by the learners.
4. Preconceptions of learners must be used, and their explanatory adequacy explored.

Despite these guiding principles, various models of context-based teaching materials and approaches exist. These models are based on different aspects of contextualized teaching, which include; the kind of contexts used to develop teaching materials, the extent to which the materials integrate the principles of contextualized teaching, the order of presentation of teaching materials, and function of the contexts in the teaching and learning process. Gilbert (2006) and De Jong (2008) have categorized these models into what the researcher perceives to be models for developing and implementing context-based materials respectively, as discussed below.

2.2.2.1 Models for developing context-based materials

Gilbert (2006) synthesized the models for developing context-based materials into four classes, based on the kind of ‘contexts’ that explicitly underpin the materials (that is, based on social, environmental or personal domains) and the extent to which they meet the principles that guide the development of context-based materials. These models are discussed below.

Model 1: Context as the direct application of concepts

This model involves a "one-directional and rigid relationship between concepts and applications", where "applications are tagged onto the end of a theoretical treatment of concepts as an afterthought" (Gilbert, 2006: 966). For instance, an educator could give an example of an albino as an application of the effects of mutation, after teaching abstract concepts of mutation. Usually, "no social setting is provided for mental engagement with the contexts. The model evokes little background knowledge. And it focuses on the abstract learning of specific concepts, without framing the social setting and behavioural environment in advance" (Gilbert, 2006: 966). This model therefore lacks a social setting, and does not provide high-quality learning tasks and opportunities for learners to acquire a "coherent use of specific scientific language" (Gilbert, 2006: 967). These limitations made the model inappropriate for this study.

Model 2: Context as reciprocity between concepts and applications

The second model involves context-based materials that relate concepts to their application in such a way that "those applications affect the meanings attributed to the concepts. The context is formed by juxta-positioning concepts and applications in learners' cognitive structures" (Gilbert, 2006: 967). Within this model, several "sub-groups of contexts can be distinguished", such that a "shift between the sub-groups can imply a different meaning for a concept, which could lead to confusion by both educators and learners" (Gilbert, 2006: 967). This model does provide opportunities for learners "to acquire a coherent use of a specific scientific language" (Gilbert, 2006: 968).

In this model, learners are enabled to relate learned materials to their own preconceptions. However, the model does not emphasize the need for learners to value the social settings in which learners and educators may operate (Gilbert, 2006). For these reasons the model was not selected for use in this study.

Model 3: Context provided by personal mental activity

The third model involves the use of historical narratives to provide a social setting for the teaching and learning of scientific concepts and ideas. In other words, narratives of historical events are linked to a scientific theme for the purpose of illustrating and explaining the concepts within the theme. The model thus provides a social setting, and a specific scientific language could be effectively developed. The model also draws on learners' background knowledge. An example of this model was devised by Stocklmayer and Gilbert (2002), who identified examples of historical events or situations from sources, such as books, which were intended to provide informal science education. These examples were 'woven' into stories or narratives that could be interpreted in terms of 'contexts'.

The challenge that could arise from this model is that the use of historical events may require a great deal of background information and preparation for learners to accurately picture the situation as it occurred, and to value it. There is therefore the possibility of learners not recognizing the relevance or value of the narrative, as they might not be able to access the required background knowledge (Gilbert, 2006). Even if they did, learners might not empathize with the issues being depicted or described because the importance and significance of the contexts could be outmoded as far as the learners are concerned (Pilot & Bulte, 2006). The social dimension of contextualized teaching is therefore essentially missing from this model (Gilbert, 2006). As a result of this challenge, the model was considered inappropriate for this study.

Model 4: Context as social circumstances

In this model the social aspect of a context is emphasized, and contexts represent real-life issues occurring in the society in which learners live their daily lives. The model relates science concepts and "people's activities that are considered of importance to the lives of communities in the society" (Gilbert, 2006: 969). In other words, the context provides a clear setting for what happens in the community. The model is therefore "based on situated learning and activity theory" (Gilbert, 2006: 970), whereby educators and learners see themselves as participants in a 'community of practice', defined by Greeno (1998: 6) as "regular patterns of activity in a community, in which individuals participate".

Learning in this model is primarily activity-oriented, "based on sustained inquiry in a substantial setting" (Gilbert, 2006: 970), in which the context shapes the meaning of the content, and vice versa. Learning tasks in this model are based on clear illustrations of important science concepts "to enable learners to develop a coherent use of specific scientific language" (Gilbert, 2006: 970).

It is clear that the fourth model embraces the principles for developing context-based materials for teaching science (the provision of a social setting valued by learners, in which they may engage in mental encounters with focal events; the use of learning tasks that "bring a specifically designed behavioural environment into focus" [that is, the types of activities engaged in frame the talk that takes place] (Gilbert, 2006: 965); through the talk associated with the focal event, learners are enabled to reach an understanding of the concepts involved, thus "enabling them to develop a coherent use of specific scientific language" (Gilbert, 2006: 966). The model also involves genuine inquiry, and it emphasizes active participation of learners in the learning process. Consequently, the fourth model was used as the basis for developing the materials used in this study.

2.2.2.2 Development of context-based teaching materials

The development of context-based materials usually involves the selection of contexts and content, and the creation of learning and assessment activities.

- ***Selection of contexts for development of context-based materials***

Contexts used to develop context-based materials are commonly selected by curriculum developers and implementers, to the exclusion of the learners (Bennett, 2003). For example, contexts used to develop materials in large-scale context-based projects such as Salters Projects (Bennett & Lubben, 2006), Chemie in Kontext (Parchmann, Gräsel, Baer, Nentwig, Demuth, Ralle, 2006) and ChemCom (American Chemistry Society, 2002), were chosen mostly by curriculum developers.

Often, curriculum developers create teaching materials and supply them to educators. In other cases, educators are encouraged to collaborate with university experts in developing the materials (Parchmann et al., 2006; Pilot & Bulte, 2006). With regard to small-scale context-based projects such as Matsapha in Swaziland (Lubben, et al., 1996) and MASTEP in Namibia (Kasanda, Lubben, Gaoseb-Marenga, Kapenda and Campbell, 2005), contexts for developing teaching materials are usually determined by educators (see section 2.2.2.4).

It appears that the views and aspirations of learners for their learning are seldom considered in the development of either large-scale or small-scale context-based materials. The exclusion of learners from decisions involving their learning materials could create a mismatch between contexts that are used in teaching materials and those considered relevant, meaningful and appealing by the learners themselves. Many researchers (Gomez, Pozo & Sanz, 1995; Harp & Mayer, 1998; Shiu-sing, 2005) have raised similar concerns about the selection of contexts solely by adults. Inclusion of learners' perceptions and wishes when choosing contexts would seem appropriate in the development of context-based materials.

- ***Development of learning activities***

The next stage in the development of the materials involves the incorporation of contexts and content into learning activities. In most cases, these activities are designed to encourage the development of critical and analytical thinking skills. Such activities include small group discussions, group and individual decision-making and problem-solving activities, investigations, and role-play exercises (Bennett & Holman, 2002). These activities are meant to be intellectually stimulating to elicit learner motivation and conceptual understanding. They are also envisaged to be effective in fostering several learning skills, provide a considerable degree of learner autonomy over the learning process, and be less threatening to learners than educator-talk activities (Bennett, 2003). In accordance with these aspirations, the materials developed in this study consisted of teaching and learning activities involving hands-on and minds-on tasks.

- ***Development of assessment tasks***

The final stage in the development of context-based materials is the construction of tasks for assessing learners' understanding and ability. The ideal approach would be to use tasks that are context-based. Such an assessment would have the advantage of measuring learners' ability, scientific knowledge and understanding in relevant and unfamiliar contexts (Bennett, 2003). In most cases however, assessment tasks in contextualized teaching focus on measuring learners' understanding, application and evaluation of abstract scientific ideas (Bennett, 2003). The emphasis on the assessment of conceptual understanding is probably the result of influences from examination boards and entry requirements at tertiary educational institutions whose aims and specifications for assessment may differ from those of contextualized teaching and learning. In developing the materials used in this study, assessment tasks were designed to measure learners' understanding, application and evaluation of scientific concepts in relation to day-to-day experiences.

2.2.2.3 Approaches for implementation of context-based materials

A typical context-based lesson involves the presentation of contexts and content in varying proportions, at different stages of a learning sequence. The successive stages of context-based lessons vary, depending on the model used. Recently De Jong (2008) argued that variations in the order of presentation of contexts (the stage at which the context is located) and related concepts can lead to differences in the function (purpose) of the contexts in contextualized teaching. To this effect, he identified three approaches for implementing context-based materials, based on the presentation and function of the context:

Model 1: Traditional context-based teaching approaches

In these approaches scientific concepts are taught first, followed by applicable contexts. The contexts are used to illustrate the concepts that have been taught, and to offer learners the opportunity to apply the concepts (De Jong, 2008).

Model 2: More modern context-based teaching approaches

The second category involves a discussion on a particular context, given before the related scientific concepts are introduced. Contexts are used as rationale or starting-points for teaching concepts, and to enhance motivation for learning new scientific concepts (De Jong, 2008).

Model 3: Recent context-based teaching approaches

The third category involves approaches in which contexts is exposed to learners before the introduction of content. After the introduction of scientific concepts, learners are exposed to other contexts. In these approaches, the contexts introduced before the concepts serve as rationale for teaching scientific concepts and motivation for learning new concepts, whereas those introduced after the concepts serve the purposes of illustrating and applying the scientific concepts (De Jong, 2008).

The context-based approach used in this study was based on the third category of context-based approaches. By following this approach, we took into account all four functions of contexts: rationale for teaching scientific concepts, motivation for learning new concepts, illustration and application of scientific concepts, as suggested by De Jong (2008). Other workers (Campbell, Lubben & Dlamini, 2000) have recommended context-based teaching approaches similar to De Jong's third approach.

2.2.2.4 Implementation of context-based teaching materials in school science

A common trend in implementing typical context-based materials is to introduce content (scientific concepts, ideas and principles) on a 'need to know' basis. That is, science ideas, concepts and principles are introduced only when they help to explain or enrich understanding of the particular context being used (Bennett & Holman, 2002). By so doing, scientific ideas and concepts may be re-visited again and again in a 'drip feed' (in small manageable quantities) or 'spiral' approach as they are needed to elucidate the contexts in subsequent themes (Bennett & Lubben, 2006).

A variety of learning activities are usually used to make the links between contexts and content, for enhanced relevance, understanding and transferability of learning materials. Such activities include scientific inquiry, experiments, discussions, debates, class presentations, simulations, problem-solving and decision-making activities, as well as field trips (Bennett & Lubben, 2006; Parchmann, et al., 2006; Schwartz, 2006). These activities are perceived to elicit and sustain learner motivation, and to develop a wide range of skills, including cognitive skills perceived to be relevant to science generalists and science specialists (Gilbert, 2006; Bennett, 2003).

Context-based teaching approaches have been used extensively throughout the world (Bennett, 2003; Jenkins, 2006; Osborne, et al., 2003; Sjøberg & Schreiner, 2005), especially in Western countries where there have been alarming declines in learners' interest in the study of science subjects and courses (EIRMA, 2009; Jenkins & Pell, 2006). Different models and principles of implementing context-based materials have been adopted in various educational settings. The next section examines examples of context-based projects around the world in order to illuminate the designs used and the effect they have had on learner performance.

➢ ***Studies involving context context-based science teaching***

Context-based materials developed for use in Western countries include large-scale projects such as the Salters Projects in the UK (University of York Science Education group – Bennett & Lubben, 2006); Chemie in Kontext [Parchmann, et al, 2006]); Supported Learning in Physics Projects (SLIPP) (Whitelegg & Edwards, 2001); and ChemCom (American Chemistry Society, 2002) in the USA. In Africa, context-based interventions have mostly been small-scale, short-term projects, developed about specific contexts and applications. Examples of African context-based projects include Matsapha in Swaziland (Lubben, et al, 1996), MASTEP in Namibia (Kasanda, et al., 2005), Namutamba Basic Education Integrated Rural Development (BEIRD) in Uganda (Kiyimba & Sentamu, 1988), and SHAPE in Zambia (Chelu & Mbulwe, 1994). A few of these context-based projects are described in the following passages to illuminate their design.

- ***Salters' Projects***

Salters' study units are context-based materials developed by researchers from the University of York Science Education Group (1990–1992: Bennett & Holman, 2002; Bennett & Lubben, 2006). In Salters' units, scientific concepts are developed from familiar contexts, such as food, clothes, and transport (Bennett & Holman, 2002).

At the beginning of each unit, contexts are introduced to learners in form of storylines. As the storyline progresses, aspects (sub-contexts) of the story are highlighted and used to bring in new scientific concepts. This process continues until all the relevant sub-contexts within the storyline have been used to introduce applicable scientific concepts.

As evident from the above description of Salters' study materials, learners are enabled to access different aspects of science content on a 'need to know' basis as the storyline progresses. The 'drip feeding' of concepts allows learners to access new scientific ideas only as they need them to understand the contexts under consideration. By the end of a storyline, learners would have been exposed to a range of scientific concepts, some of which they would have encountered in previous stories (and sub-contexts), and others that are new to the specific story.

Introduction of scientific concepts and ideas in Salters involves the use of active learning approaches such as discussions, presentations, simulations, and decision-making exercises (Bennett & Holman, 2002), as well as problem-solving, practical activities, and paper-based activities, that are designed to support their learning and to develop a wide range of skills. During individual investigations, learners are encouraged to pose a question about a science-related phenomenon and subsequently plan practical work in order to answer that question (Bennett & Holman, 2002). The approach is therefore learner centered and encourages the construction of knowledge by the learners themselves, with guidance from educators.

The implementation of 'Chemie in Kontext' (Parchmann, et al., 2006) and ChemCom (ACS, 2002) is more or less similar to the Salters' approach, although Chemie in Kontext does not necessarily stress the reciprocity between concepts and applications. In all these approaches, contexts form the basis of lessons, while relevant scientific concepts are introduced to learners in small manageable amounts.

Although the Salters' approach to context-based teaching has been found to have motivational effects on learners (Ramsden, 1992, 1997), their effectiveness in enhancing conceptual understanding remains a matter of speculation. A possible challenge with the Salters' approach and most other context-based materials could lie in the selection of learning materials by adults only (Bennett & Holmann, 2002). In these approaches, curriculum developers produce a variety of resources such as support packs and textbooks to support the teaching and learning process, while educators simply implement them according to stipulations. Literature on salters' approach does not reveal learner involvement at any stage of materials development. Contexts chosen by adults might not be appreciated by learners, or be effective in enhancing their conceptual understanding. Involvement of learners in the selection of contexts, as pointed out earlier (section 1.3) could shed light on contexts that are relevant to them, and thus effective in enhancing conceptual understanding.

Another possible challenge with Salters' materials could be the lack of systematic learning phases, where learners could engage in cerebral activities such as the eliciting of prior knowledge, exploration of contexts, explicit linkages of content and contexts, and transfer of learned knowledge to other situations, as an intrinsic part of the teaching approach. The occasional discussions and inquiry activities which do not follow a specific sequence might not have significant impact on learners' intellectual engagement with the materials (Allard & Barman, 1994; Stiles, 2006). Lack of an explicit learning sequence for learners' cerebral engagement could limit conceptual understanding and the development of higher order thinking skills. The use of a systematic learning cycle in contextualized teaching might nullify this possibility.

Further, the approaches used in Salters' Projects and Chemie in Kontext involve the introduction of a broad (big) societal or environmental issue (such as global warming) - the storyline. The storyline is subsequently narrowed down to specific aspects (e.g., pollution, ozone layer, deforestation, acid rain) of the broad issue, upon which the introduction of scientific concepts or ideas is based. The challenge here is that learners may not be able to make coherent connections among the specific sub-contexts of the storyline, in order for them to have a logical understanding of the relationships between the sub-contexts and the broad issue. This could confuse learners (Gilbert, 2006) and in consequent lead to limited conceptual understanding. A learning sequence that directly relates scientific concepts to a specific context in a particular learning cycle (ie. one context per learning cycle) might negate this problem.

- ***Supported Learning in Physics Projects***

Supported Learning in Physics Projects (SLIPP) is a collaborative project led by the Open University staff (Whitelegg & Edwards, 2001). SLIPP learning units are designed to introduce physics content through case studies that are based on real-life situations (context-based). The structure of SLIPP involves an initial engagement of learners in activities that involve finding information about a particular context, for example, learners may be required to find information on car safety features, from sources such as manufacturers' brochures, TV advertisements and physical examination of cars. This activity provides opportunities for discussions among learners and with educators. The discussions are usually open ended and learner centred. Educators facilitate rather than direct the discussions (Whitelegg & Edwards, 2001).

Following the discussions, learners are provided with learning materials to study the physics concepts and mathematics involved in the solution of particular problems. This activity is meant to develop learners' knowledge and understanding of the issues under consideration. Learners are therefore responsible for planning what they need to know in order to effectively address a particular problem. The learning units also incorporate the use of other learning resources such as commercially available CD-ROM and video material, and other resources that educators may select to support their learners' use of SLIPP materials, if they wish. In this way educators structure the learning process by providing the learners with assistance when it is required, then withdrawing to allow learners to learn the study materials at their own pace. As the learners progress through the study texts, they are exposed to several learning activities and self-assessment questions for them to evaluate their own understanding of the learning materials. Solutions to the questions are given at the end of each section.

The early introduction of contexts for learning in SLIPP is envisaged as increasing learner interest in studying the materials, and as encouraging independent learning of science concepts based on real-life situations. Situating learning in real-life contexts as done in SLIPP is important in developing learners' interests in science (Whitelegg & Edwards, 2001). In addition, allowing learners to have control over their own learning is far more likely to make them enjoy the learning experience than limiting their control of what they learn and how they learn it (Whitelegg & Edwards, 2001). Similarly, allowing learners to choose the contexts used in contextualized teaching of science might enhance their enjoyment of the learning experience and their conceptual understanding of the subject. A limitation of this approach lies in the possibility of learners' inability to find relevant information about a particular context, and lack of opportunities for learners to apply learnt concepts to novel situations.

- ***Context-based teaching in Africa.***

A review of context-based interventions in Africa (Chelu & Mbulwe, 1994; Kasanda, et al., 2005; Kiyimba & Sentamu, 1988; Lubben, et al, 1996) reveals unstructured approaches to context-based teaching. In these approaches, contexts which are mostly determined by educators are occasionally incorporated into science lessons in an unsystematic way. For instance, an investigation of the pedagogical approaches used by educators in a Mathematics and Science Teacher Extension Program (MASTEP) which was aimed at improving contextualized teaching, among other things, revealed four approaches to context-based teaching (Kasanda, et al., 2005). The first involved the initial introduction of context by the educator before the exposition of content, or the introduction of contexts only when motivated by the failure of a traditional teaching approach. In the second approach, contexts are used as part of a question or an answer provided by an educator or a learner during a lesson. The educator may then elaborate on the emergent context.

In the third approach, contexts may form a setting for an assessment task (such as class tasks, or examination and test questions), where the stem of a problem would contain some context. Educators or learners would use the contexts only to the extent that the necessary information for solving the problem demanded. Thereafter, no reference is made to the contexts, and even the solution to the problem would normally be stated in an abstract manner. According to the researchers of the MASTEP program (Kasanda, et al., 2005), most contexts were used in assessments in the described manner. Lastly, everyday contexts may be used while practicing a particular skill (Kasanda, et al., 2005).

The researchers of the MASTEP program also stated that among the observed lessons, only the introduction of learners' experiences in the class signified learner-centered learning. There was little evidence of small group work or project work that would imply more advanced approaches to learner-centered teaching. The implementation of other context-based programs in Africa (Matsapha in Swaziland, Lubben, et al, 1996; Namutamba BEIRD in Uganda, Kiyimba & Sentamu, 1988; SHAPE in Zambia, Chelu & Mbulwe, 1994) show similar trends regarding contextualized teaching. One is therefore tempted to believe that context-based teaching approaches in most African educational innovations lack detailed systematic structure, and features that could significantly enhance conceptual understanding and skills development.

Further, the reviewed literature does not have indications of learner involvement in the choice of contexts for contextualized teaching, except in situations where learners would ask a question or give an answer which involves some context (Kasanda, et al., 2005).

Regardless of the unstructured nature of contextualized teaching in Africa, a longitudinal evaluation of the effectiveness of a context-based project called Matsapha in Swaziland shed some light on contexts which could be useful in contextualized teaching in Africa. In the study, three categories of contexts were identified as possible determinants of learner interest and participation in science lessons (Lubben, et al., 1996). These categories are: contexts to which learners relate to, contexts in which learners have strong experience and contexts that are contentious and provocative. It could therefore be helpful to find out from the learners themselves, the contexts which they consider to meet these requirements.

2.2.2.5 Context-based teaching approaches and learner performance

This section reviews literature on the effect of context-based teaching approaches on the acquisition of content knowledge, science inquiry skills, problem-solving and decision-making abilities, and learners' attitudes towards the study of science.

- **Context-based teaching and conceptual understanding**

A review of literature on the effect of context-based teaching on conceptual understanding shows inconsistencies in learner achievement. For example, some researchers (Bloom & Harpin, 2003; Gutwill-Wise, 2001; Sutman & Bruce, 1992; Yager & Weld, 1999) found that learners exposed to context-based teaching approaches achieved better conceptual understanding than those exposed to traditional approaches. Other researchers (Barber, 2001; Barker & Millar, 1996; Bennett & Holmann, 2002; Ramsden, 1992, 1997, 1998; Taasoobshirazi & Carr, 2008) found no significant differences between the conceptual understandings of the two groups of learners.

Various factors could account for the inconsistencies in research findings regarding the effect of context-based teaching on conceptual understanding. These factors may include variations in the design and implementation of teaching materials (as discussed in sections 2.2.2.1, 2.2.2.2 and 2.2.2.3). Specifically, the nature (De Jong, 2008; Taasoobshirazi & Carr, 2008) and source (Bennett & Holman, 2002) of the contexts used to develop teaching materials; the models used to develop and implement the materials (Gilbert 2006); educator competence and attitude in designing and implementing context-based materials, could partly account for the inconclusive findings regarding the effect of the approaches on conceptual achievement (see section 2.2.2.6 for further elucidation of these factors).

In their synthesis of the research evidence on the effects of context-based and Science, Technology and Society - STS approaches to science teaching, Bennett, et al., (2006) found a dearth of research focusing on the contextual teaching of biology (life sciences). It is therefore difficult to make conclusive assertions on the effect context-based teaching on learners' conceptual understanding of life sciences concepts, including genetics.

Given their motivational effect on learners, context-based approaches if well designed and implemented could enhance learner achievement in science subjects, including life sciences. It was therefore considered necessary in this study to explore the effectiveness of a carefully designed context-based approach in enhancing learners' conceptual understanding of a life sciences topic - genetics.

- **Context-based teaching and the development of science inquiry skills, problem-solving and decision-making abilities**

The learning activities involved in context-based teaching approaches are envisaged as developing higher-order thinking skills in learners, including science inquiry skills, decision-making and problem-solving ability (Bennett & Holman, 2002; Gilbert, 2006, 2008; Schwartz, 2006). However, literature about the effectiveness of these approaches in developing these skills is sparse (refer to section 1.3).

Nonetheless, a few studies attempted to measure directly the effects of context-based teaching on the development of inquiry-related skills. These include a study conducted by Campbell et al. (2000), in which learners exposed to contextualized teaching were asked to provide written explanations, which included their ability in designing an experiment to solve an everyday dilemma. The results of the study showed that only a few of the respondents (about 37%) showed some proficiency in experimental design.

Another study conducted by Yager and Weld (1999) used questionnaires to measure, among other things, learners' views on science processes and creativity. They found that learners in the Scope, Sequence and Coordination - SS&C project, which involved context-based courses, achieved better results in the enhancement of science process skills and creativity than those in traditional text-based courses. An earlier study conducted by Wierstra (1984) used a five-point scale questionnaire and achievement tests to assess learners' perceptions of actual and preferred learning environments. The results of the study showed that there was considerably more inquiry learning in context-based classes than in control classes.

None of the studies reviewed attempted to measure the effect of context-based teaching on learners' decision-making and problem-solving ability, which are assumed to be developed during contextualized teaching. Owing to the dearth of literature on the efficacy of context-based approaches on the development of several higher order thinking skills, it is difficult to ascertain the effect of these approaches on the development of these skills. This study attempted to investigate the efficacy of context-based and traditional teaching approaches in enhancing the development of science inquiry skills, problem solving and decision making abilities.

- **Context-based teaching and learners' attitude towards the study of science**

Several studies (Campbell et al., 2000; Kaschalk, 2002; Ramsden, 1997; Rayner, 2005; Yager & Weld, 1999) have shown that context-based teaching approaches have motivational effects on learners. For instance, Smith and Mathews (2000) used a questionnaire to assess perceptions of school science by learners that were exposed to context-based and traditional teaching approaches. They found that learners from the experimental group (context-based) developed more positive perceptions of school science than those in the control group (traditional teaching).

Bennett et al. (2006), in their synthesis of the research evidence on the effect of context-based and STS approaches to science teaching, reveal that almost all the studies reported improvements in learner attitude towards the study of science. Research evidence therefore seems to suggest that context-based teaching approaches are effective in improving learners' attitudes towards the study of science. Most of these studies on the motivational effect of context-based approaches were conducted outside South Africa. It therefore becomes important to determine whether the use of these approaches in the South African setting would also be more effective in improving learners' attitudes towards the study of science, specifically life sciences, than the approaches currently used in schools.

2.2.2.6 Factors affecting the efficacy of context-based approaches in enhancing performance in science

The lack of consensus on the effect of context-based approaches on conceptual understanding and the development of higher order thinking skills could be attributed to a number of factors as such as; the origin and nature of contexts used to develop materials; the models used to develop and implement the materials; and educators' competence in developing and developing materials, as indicated in section 2.2.2.5 (Taasoobshirazi & Carr, 2008). In the following texts, an attempt is made to explicate these factors.

➢ Selection of contexts

The actual contexts used to develop context-based materials are critical to their efficacy (Taasoobshirazi & Carr, 2008). De Jong (2008) is of the opinion that a weak relationship between contexts and relevant concepts in the perception of learners and educators could affect the attainment of envisaged learning outcomes. According to Pilot & Bulte (2006), the relevance of contexts can be influenced by time and regional priorities. Contexts perceived to be relevant and meaningful at a given time may not be regarded in the same way at another time, owing to changes in circumstances. Similarly, contexts considered significant in a particular country or region might be considered unimportant in other areas or cultures (Pilot & Bulte, 2006), because people from these regions and cultures have different aspirations and preferences.

Further, from the learners' perspective, contexts used in context-based teaching materials may not always be relevant and accessible to them. De Jong (2008) identified four difficulties that could be encountered by learners exposed to context-based materials. First, contexts may not really be relevant to learners and will therefore fail to motivate them. Second, contexts may be too complicated for learners to make proper links with scientific concepts. Third, contexts may confuse the learners because everyday life meanings of certain concepts do not always correspond with scientific meanings. Fourth, contexts may be so interesting that learners are distracted from learning the envisaged scientific concepts.

It appears that contexts used to develop context-based materials need to be carefully selected for specific learner populations in order to meet time and regional priorities, as well as the perceptions, aspirations, inclinations and needs of the learners. A review of the literature seems to suggest that learners' interest and participation in science lessons are enhanced to a large extent by lessons which have personal useful applications of science (Lubben and Campbell, 2000). One way of knowing learners' perceptions, inclinations and desires regarding contexts is by finding out from them, the contexts that they think would be helpful in making a topic more relevant, meaningful, interesting and accessible to them. To this effect, Whitelegg and Parry (1999) contend that by using contexts that are accessible or relatable to learners, or building on contexts suggested by the learners themselves in context-based teaching, learners become empowered to negotiate the process of learning, so that it meets their social needs.

The involvement of learners in some curriculum decisions is supported by several researchers (Basu & Barton, 2007; Osborne & Collins, 2001; Sjøberg & Schreiner, 2005), who argue for the incorporation into curriculum materials of some aspects of science that are experienced, valued and used by learners. In this regard, Osborne and Collins (2001) warn that the exclusion of learners from curriculum development decisions could partly account for learners' disenchantment with the science curricula. Many researchers (Gomez, Pozo, et al., 1995; Harp & Mayer, 1998; Shiu-sing, 2005) have raised similar concerns regarding the exclusion of learners from decisions regarding curriculum materials. It was from this premise that contexts that the learners themselves considered important and interesting in learning genetics were used to develop genetics contexts-based teaching materials.

- **Design of context-based materials**

Another factor that could affect the efficacy of context-based teaching approaches is the design of the teaching material. In sections 2.2.2.1 and 2.2.2.3, various models of material development and implementation were discussed. Some of these models have inherent limitations (section 2.2.2.1) which could affect their efficacy in enhancing learner performance. These limitations include the degree to which the principles for developing effective context-based teaching are addressed (Gilbert, 2006), and the type of learning sequences and activities employed. Careful selection of an appropriate context-based model that meets the requirements of effective context-based materials, and addresses the specific objectives of the approach may therefore be crucial in contextualized teaching. The teaching materials developed in this study incorporated the principles for effective context-based materials (Gilbert, 2006), and elements for enhancing conceptual understanding and the development of higher order thinking skills (see section, 3.7).

- **Educator competence in context-based teaching**

The efficacy of context-based teaching could be affected by the accuracy and effectiveness with which the materials are implemented by educators (De Jong, 2008). The attitudes and competencies of educators who implement context-based materials play a vital role in the success of the instructional innovation in improving learner performance (Gilbert, 2006). Five educator competencies for effective contextualized teaching have been identified. These are: context-handling, regulation of learning, emphasis, design and school innovation (Stolk, Bulte, De Jong, & Pilot, 2009; Vos, Taconis, Jochems & Pilot, 2010). Of these five competencies, only context-handling, regulation of learning and emphasis relate to what occurs in the classroom, which is the interest of this study. The following discussion will therefore focus of the three educator competencies.

Context-handling

Context-handling refers to educators' ability to use contexts to enhance learner performance, and it requires educators to be competent in:

- Bringing together the socially accepted features of a context and the attributes of a context to the extent that these are familiar from the perspectives of the learners (Gilbert, 2006)
- Establishing scientific knowledge through contextualized teaching (Parchmann et al., 2006)
- Helping learners transfer concepts to other contexts (Van Oers, 1998)

Regulation of learning

Regulation of learning entails educators' ability to guide the learning process instead of controlling it, which is a requirement of the constructivist nature of context-based teaching. In constructivism, knowledge is believed to be constructed by a learner, either individually or through social interactions (von Glasersfeld, 1989). The educators' role is to facilitate the knowledge construction process (Labudde, 2008). Constructivism learning therefore requires educators to be competent in regulating the learning process so that learners are provided with the opportunity and learning environment to construct their own meaning of learning materials.

Emphasis

Curriculum emphasis signifies the importance an educator places on particular aspects of the curriculum. According to Robert (1982: 245), curriculum emphasis is:

> a coherent set of messages to the learners about science… Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself – objectives which provide answers to the learner question of: Why am I learning this?

The following science curriculum emphases have been identified: “Fundamental Science Emphasis (FSE), where theoretical notions are accentuated”; “Knowledge Development in Science (KDS) emphasis, which stresses how scientific knowledge is developed in a socio-historical contexts in order to present science as a culturally determined system of knowledge”; and “Science Technology and Society (STS) where learners are encouraged to communicate and make decisions about socio-scientific issues” (Roberts, 1982). The KDS and STS curriculum emphases are particularly relevant in context-based teaching approaches (Gilbert, 2006).

Educators’ lack of competence in context-handling, regulation of learning and curriculum emphasis could affect the effectiveness of context-based approaches in improving learner performance. In consequence, the educators involved in implementing the context-based materials developed in the present study were trained on how to handle contexts, regulate the learning process and how to emphasize the development of scientific knowledge and the development of Higher Order Thinking Skills (HOTS), such as decision-making, problem-solving and science inquiry skills.

In spite of the challenges of context-based teaching approaches and the lack of consensus among researchers on the effects of the approaches on learner performance, the approaches seem to have the potential to significantly enhance learner performance if designed and implemented effectively, as demonstrated by the few studies that found enhanced learner performance (Bloom & Harpin, 2003; Gutwill-Wise, 2001; Sutman & Bruce, 1992; Yager & Weld, 1999). De Jong (2008) suggests the following ideas for improving contextualized teaching in order to enhance learner performance in chemistry (and science in general).

- Use of carefully selected contexts that are well known and relevant to learners, do not distract learners’ attention from related concepts, and are not too complicated or confusing for the learners

- Helping educators to undertake context-based teaching in a successful way, which involves offering an introductory context, collecting and adapting learners' questions, restructuring textbook content and offering follow-up inquiry contexts
- The development of science curricula that place context in a more dominant central position, and incorporate it in testing and assessment.

In light of the suggested principles for developing effective context-based teaching materials (Gilbert, 2006), the identified challenges of contextualized teaching (section 2.2.2.6), and the suggested ideas for improving contextualized teaching (De Jong, 2008), the use of contexts selected by learners to develop context-based teaching materials, and a learning cycle to implement them seem to be a realistic and appropriate way of addressing most of the issues. The following sections examine the nature and educational implications of learning cycles.

2.2.3 Learning cycle instructional approaches

Learning cycles are controlled instructional methods for introducing learners to scientific discovery or inquiry-based learning experiences (Dogru-Atay & Tekkaya., 2008). The main thesis of the learning cycle is the creation of a situation that allows learners to examine the adequacy of prior knowledge and beliefs (or conceptions), and forces them to argue about, and test these preconceptions (Dogru-Atay & Tekkaya, 2008).

The original learning cycle, conceived by Karplus and Their (1967), separates instruction into three phases: exploration; invention (later referred to as concept introduction); and discovery (later known as concept application). The three-phase learning cycle has since been modified into different models, including a five-phase (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook & Landes, 2006) and seven-phase (Eisenkfraft, 2003) learning cycles, by extending or clarifying the phases of the cycle. Nonetheless, each new version of the learning cycle has retained the essence of the original cycle (exploration, concept introduction and application phases), including the specific sequence of the phases.

The 5E version of the learning cycle was popularized by the Biological Sciences Curriculum Study (BSCS) in which numerous teaching materials based on the model were developed for high-school learners (Bybee et al., 2006). The model extends the three-phase cycle by including an engagement phase at the beginning and an evaluation phase at the end of the sequence. The 5E cycle thus consists of the elements: **E**ngage, **E**xplore, **E**xplain, **E**laborate, and **E**valuate. The Explore, Explain and Elaborate phases have essentially the same purpose as the exploration, invention and discovery phases of the original model.

The engage phase involves short activities that assess learners' prior knowledge and help them become engaged in a new concept. The phase is designed to initiate learning, capture learners' attention and uncover learners' current knowledge (Brown & Abell, 2007; Bybee, et al., 2006). In the explore phase, learners gain experience with the phenomena or the event under consideration, based on their own ideas and prior experiences. The explain phase allows learners to gain content knowledge from the educators and their own inferences, which is necessary for a deeper understanding of the phenomena. The elaborate phase allows learners to apply their understandings to new situations or contexts. The evaluate phase provides an opportunity for educators to assess learners' progress and for learners to reflect on their new understandings (Bybee, et al., 2006).

Eisenkraft (2003) extended the 5E learning cycle into a seven-element (7E) model, which includes the **E**licit and **E**xtend phases at the beginning and the end of the learning cycle, respectively. The adoption of the 7E learning cycle was meant to give emphasis to eliciting prior knowledge and transferring learning to other contexts (Eisenkfraft, 2003).

It has been shown that learners benefit more from the use of the learning cycle when the three phases of the cycle are used in the correct order (Lawson, 2001). Several researchers (Allard & Barman, 1994; Stiles, 2006) have found that correct use of the learning cycle in science classes is an effective way of making the study of science more enjoyable, understandable and applicable to authentic situations. Researchers (Eisenkfraft, 2003; Lawson, 2001) contend that learning cycle instructional approaches are effective in enhancing learner performance. Other studies involving the use of the learning cycle have shown that instruction based on learning cycle approaches could enhance both conceptual understanding and skills development (Musheno & Lawson, 1999).

- **Principles underpinning learning cycle instructional approaches**

The learning cycle instructional approach capitalizes on principles of what is known about how people learn. Specifically, learning cycles embody principles of Herbart's effective instruction model (Bybee, et al, 2006), Dewey's model of reflective experience (Bybee, et al, 2006) and Piaget's mental function model (Abraham & Renner, 1986), as well as constructivism learning (von Glasersfeld, 1989), as explained below.

Herbart's instruction model

The three original phases of a learning cycle are analogous with the steps in Herbart's effective instruction model, which was summarized by Bybee, et al., (2006, 4-5) as follows:

> We begin with the current knowledge and experiences of the learners, and the new ideas related to the concepts the learners already have. Introducing new ideas that connect with the extant ideas would slowly form concepts. The next step involves direct instruction, where the teacher systematically explains ideas that the learners could not be expected to discover independently. In the final step, the teacher asks learners to demonstrate their understanding by applying the concepts to new situations.

The features stated in the quotation above reflect the learning activities involved in the various phases of learning cycles.

Dewey's models of reflective experience

Learning cycles also exploit principles of reflective experience as suggested by Dewey. Bybee et al. (2006: 5), describe the general features of Dewey's reflective experience model as involving:

> (i) perplexity, confusion and doubt due to the fact that one is implicated in an incomplete situation whose full character is not yet determined; (ii) a conjectural anticipation – a tentative interpretation of the given elements, attributing to them a tendency to affect certain consequences; (iii) a careful survey (examination, inspection, exploration, analysis) of all attainable considerations which will define and clarify the problem at hand;

> (iv) a consequent elaboration of the tentative hypothesis to make it more precise and more consistent; (v) taking one stand upon the project hypothesis as a plan of action which is applied to the existing state of affairs; (vi) doing something overtly to bring about the anticipated result, thereby testing the hypothesis (p.50).

In sum, Dewey's model for reflective experience advocated for both hands-on and minds-on experiences. Similarly, during the phases of learning cycles, learners engage in hands-on and minds-on activities as they become aware of their prior conceptions, relate them to new knowledge, and reflect on the appropriateness of their prior knowledge in light of new information, in order to formulate possible explanations to situations, and to gain new knowledge (Bybee et al. (2006).

Piaget's mental function model

Abraham and Renner (1986) contend that the phases of the learning cycle comprise features which correspond to the features of the Piaget's mental function model. They explain that the exploration phase for instance permits learners to assimilate the essence of the science concept through direct experience (as in Piaget's model). They further explain that as learners attempt to examine a new concept through an exploration, their new experiences cause them to reconsider their past experiences. If the two domains of knowledge (past and current knowledge) are in conflict, disequilibrium is created in the learner's cognitive structures. The learner may attempt to resolve the conflict to various degrees by seeking relationships between the conflicting domains (Stears, et al, 2003), and thus incorporate the new concept to attain equilibration (an element of Piaget's model).

Likewise, learning cycles make learners aware of their own reasoning by encouraging them to reflect on their previous conceptions, activities or experiences as they seek to attain cognitive equilibrium (Dogru-Atay & Tekkaya, 2008), as envisaged in Piaget's mental function model. Further, the concept application phase of the learning cycle provides learners with opportunities to relate the newly learned science concepts to everyday applications through a cognitive process known as 'organization' in Piaget's mental function model (Abraham & Renner, 1986).

Constructivism

Learning cycles are underpinned by the notion of constructivism learning as is evident from the activities involved in their phases. Constructivism as stated earlier refers to the idea that learners construct knowledge and meaning from their own experiences either individually or socially (von Glasersfeld, 1989) through a variety of learning activities and interactions. In the same vein, researchers (Dogru-Atay & Tekkaya, 2008) assert that the main role of the learning cycle is to assist learners construct new knowledge by forming conceptual change through interactions with the social and natural world.

In the study reported here, a five-phase learning cycle was used to implement context-based materials on genetics. A five-phase learning cycle was considered appropriate for use in the study because the activities involved in the five phases of the learning cycle encompass the principles suggested for effective instructional and learning models (Herbart's effective instructional model, Dewey's reflective experience and Piaget's mental function model). The principles recommended in these models are necessary for enhancing learner performance, including the development of the analytical skills of problem-solving, decision-making and science inquiry skills which were assessed in this study.

The five phases of the learning cycle used in this study are introduction of contexts, interrogation of contexts, introduction of content, linkage of content and context, and assessment of learning (see section 3.7 for a description of the phases). The developed learning cycle has commonalities with a four-phase learning sequence described by Wieringa, Janssen, Van Driel (2011) which is frequently used in contextualized teaching of life sciences. Nevertheless, the activities in some of the phases of the learning sequence described by Wieringa, et al., differ from those in corresponding phases of the five-phase learning cycle used in the present study (see section 3.7.1 for details).

2.3 CONCEPTUAL FRAMEWORK FOR THE STUDY

The conceptual framework of this study was derived in part from Hung's (2006) 3C3R (3C - Content, Context, Connections, and 3R - Researching, Reasoning and

Reflecting) model for designing problems in Problem-Based Learning (PBL). The elements of the 3C3R model are categorised into a core component, comprising the 3Cs, and a process component involving the 3Rs. Hung's model was considered useful in providing an appropriate framework for addressing the research questions, because the focus of this intervention study was on implementing a context-based course for enhancing the learning of concepts and development of higher order thinking skills, similar to those stated in Hung's model. For the purpose of this study, the 3C3R model was adapted to comprise three classes of components: the core component, process component, and a learning cycle. Each of these three components consists of various elements, as discussed in the subsequent texts.

(i) Core component

The core component of the conceptual framework of the present study consists of the content, context and linkages. The content element involves the genetics concepts, ideas, principles and theories to be taught. The contexts involve the situations and experiences identified by the learners themselves (personal, societal, environmental, and science and technological issues), through which the content was taught. While the linkages entail the interconnections between the contexts and content (that is, contexts were based on the genetics concepts to be studied, and the content was integrated into these contexts).

The content element of the core component is meant to address the need for learners' content knowledge proficiency. In prevailing schooling systems, content knowledge is necessary for learners to obtain competitive scores in national examinations that are used to validate learners' achievements. In these examinations learners are judged according to achievement standards set before the examinations (Hoffman & Ritchie, 1997). The need to emphasize content proficiency in educational innovation is particularly important in context-based approaches to the teaching of science where there have been assertions of limited content depth and coverage (Bennett et al., 2006).

The context element serves to motivate learners and situate learning. Biggs (1989) suggests that learners would try to optimize their understanding of subject matter when they have intrinsic motivation, such as when fulfilling a curiosity or interest about the subject, or when an instantaneous threat is imminent. Several other researchers (Brown, Collins & Duguid, 1989; Godden & Baddeley, 1975) assert that when content is learned in situations that are similar to the contexts in which they will be used, the learning materials and skills will be remembered and retained more easily. Further, Prawat (1989) suggests that lack of contextual knowledge may explain learners' difficulties in applying learned concepts to real-life situations. The context element was therefore used to enhance the relevance of the teaching and learning materials for motivation and improved performance.

The third element of the core component involves the formation of connections between concepts and contexts. In this study, linkages of learned materials were made in two ways. First, connections were made among concepts, through the use of various concepts to study a particular situation (context), so that learners might appreciate the interconnectedness of different concepts. Second, links were made between concepts and contexts through the use of the same concepts again and again in different contexts, to help learners to realize the applicability of concepts to different situations in real-life.

In sum, the three elements (context, content, and linkages) of the core component were meant to enhance conceptual understanding, contextualize learnt content, and guide learners to form integrated mental conceptual and contextual frameworks. These three elements were used in the development of materials, implementation of the materials and the assessment of learning (see sections 3.6 and 3.7).

(ii) Process component

The process component involved learners' reasoning and reflections around the study materials. It was therefore concerned with the teaching and learning activities of the materials. The activities often involved addressing questions about issues, and the interaction between the contexts and content. These learning activities, included debates, question and answer sessions, brainstorming sessions, and role plays.

The reasoning element is critical to understanding the core component of the framework, and to helping learners to construct knowledge and develop analytical skills (Hung, 2006). In this study, learners were required to make logical links (reasoning) between the contexts under consideration and content taught. The cognitive activity for making these links included higher-order thinking skills, such as problem-solving, decision-making, analytical and critical thinking, hypotheses formulation and interpretation of data.

Learner reflections were concerned with the evaluation of pre-conceptions about a given situation, in the light of new information gained during the lessons, and an examination of the adequacy of those pre-conceptions. This approach to learning is affirmed by researchers (Andre, 1986; Duell, 1986) who contend that learning can be enhanced through learners' self-evaluation of their problem-solving and decision-making strategies, exploration of situations, and examination of alternative hypotheses and solutions.

The process component further involved investigations (research) in which learners embarked on, as they explored the practical aspects of the concepts and contexts under consideration. The process component was therefore concerned with learners' attempts to gain an understanding of the contexts using the content provided, through reasoning, reflections and investigations (research).

(iii) Learning cycle

Some authors (Gilbert, 2006) have pointed out that researchers or practitioners generally do not implement all the suggested principles of context-based teaching in a systematic and organised way, for the enhancement of meaningful learning and improved performance, as originally envisioned. In order to address some of these criticisms, the learning cycle was introduced as an important aspect of the conceptual framework for this study. A five-phase learning cycle adapted from the five-phase Biological Sciences Curriculum Studies (BSCS 5E) Instructional Model (Bybee, et al., 2006) was used in this study. The elements of the BSCS 5E model, as described in section 2.2.3, are **E**ngage, **E**xplore, **E**xplain, **E**laborate and **E**valuate. The learning cycle used in this study also comprised five phases, namely the introduction of contexts; interrogation of contexts; introduction of content; linkages of content and contexts; and assessment of learning (see section 3.7 for details).

The phases in the BSCS 5E model and the five-phase learning cycle used in this study have some similarities. However, the learning sequence, teaching and learning activities, the focus, and the purposes of the phases of the two learning cycles are not necessarily the same (see section 3.7.1 for an explanation of the differences between the two learning cycle approaches).

The main thesis of the learning cycle developed for this study was the creation of; opportunities to situate learning in specific contexts or situations that allow learners to expose their preconceptions, conditions for educators to identify learners' alternative conceptions and to remedy them, chances for learners to examine the adequacy of prior knowledge and beliefs (preconceptions), and to enable learners to argue about these preconceptions and to test them (Dogru-Atay & Tekkaya, 2008). Further the learning cycle was meant to provide opportunities for educators to assess learners' understating of contexts and content. The teaching and learning activities were expected to enhance learner participation during lessons, conceptual understanding, and the development of higher-order thinking skills, such as inquiry skills, analytical skills, and problem-solving and decision-making ability.

In conclusion, the conceptual framework for this study consisted of three classes of components: the core component, process component, and the learning cycle. The core component provided the content and structure of the learning materials. The process component was concerned with the teaching and learning activities in which learners were engaged, while the five-phase learning cycle was used to expose learners' prior knowledge, enable them to re-organize and probably change their pre-conceptions through interactions among themselves and with the educator, and to enable the educator to address learners' pre-conceptions and to assess their learning.

2.4 ASSESSMENT OF SKILLS ACQUISITION AND LEARNER ATTITUDE

Varying techniques have been used to assess learners' acquisition of science inquiry skills, problem-solving and decision-making abilities, and learner attitude towards the study of a given subject. The ensuing sections review some of these assessment techniques, with a view to provide a background for the manner in which these skills and abilities were assessed in this study.

2.4.1 Assessment of science inquiry skills

Science inquiry skills are variously referred to, by some researchers, as the scientific method or science process skills, while others distinguish among the concepts. Regardless of the terminology used, science inquiry skills refer to a group of mostly transferable abilities, applicable to many science disciplines and indicative of the behaviour of scientists (Padilla, 1990). Inquiry skills are hierarchically organized, ranging from the simplest to more complex ones (Dillashaw & Okey, 1980). This hierarchy has been broadly divided into two categories, namely the primary (basic) science inquiry skills, and the integrated science inquiry skills (Dillashaw & Okey, 1980; Padilla, 1990).

Integrated science inquiry skills are higher-order thinking skills that are usually used by scientists when designing and conducting investigations (Rezba, Sprague, Fiel, Funk, Okey & Jaus, 1995). They include the ability to formulate hypotheses, identify, control and manipulate variables, operationally define variables, design and conduct experiments, collect and interpret data, solve problems, make rational decisions, and draw conclusions (Dillashaw & Okey, 1980; Padilla, 1990; The American Association for the Advancement of Science (AAAS), 1998). In this study, learners' acquisition of some integrated science inquiry skills was assessed.

Typically, the assessment of competence in practical skills, such as integrated science inquiry skills, requires learners to demonstrate competence through practical activity (Dillashaw & Okey, 1980). However, using hands-on procedures to assess skills acquisition in a study could be an expensive and burdensome task, particularly in quantitative studies such as described in this dissertation, given the large number of participants involved in quantitative research. The paper and pencil group-testing format is therefore frequently used as an alternative assessment practice when dealing with large numbers of learners.

Items in paper and pencil tests for assessing competence in inquiry skills are usually referenced to a specific set of objectives, associated with planning investigations and analysing results from the investigations (Dillashaw & Okey, 1980; Onwu & Mozube, 1992). Likewise, in this study, the comparative effectiveness of traditional approaches and the developed context-based approach in enhancing the acquisition of the integrated inquiry skills of formulating hypotheses, identifying variables, designing experiments, displaying and drawing conclusions from results (interpreting data) were assessed using a paper and pencil test (see section 3.7.2).

2.4.2 Assessment of problem-solving ability

Problem-solving skills have been vital for the survival of humankind from time immemorial. These skills have become increasingly important in contemporary life, especially with advances in science and technology. Successful survival in contemporary life requires the ability to solve personal, societal and environmental problems. In this study therefore, it was deemed necessary to assess the relative effectiveness of traditional and context-based approaches in developing problem-solving skills in learners.

A problem is defined by Charles and Lester (1982: 5) as “a task for which the person confronting it wants or needs to find a solution, the person has no readily available procedure for finding the solution, and the person must make an attempt to find a solution to the task”. Similarly, Rey, Suydam and Lindquist (1992: 28), define a problem as “a situation, quantitative or otherwise, that confronts an individual or a group of individuals, that requires resolution, and for which no path to the answer is known”. From these definitions, a problem appears to have three features: a situation for which a solution is required; there is no immediate solution or a readily available way to the solution; and an individual or a group of people need to find a solution to the situation.

Problems are characterized by various features reflecting domains such as theoretical, academic or real-world contexts (Reeff, Zabal & Blech, 2006). Problem-solving can therefore be a complex cognitive process with many intricate facets.

Nonetheless, the following definition of problem-solving synthesizes several views, and elucidates the use of the phrase 'problem-solving' in this study.

> …a process by which the problem-solver, consciously or unconsciously, moves systematically or randomly through a series of operations using thinking skills appropriate to the problem being solved, gathers more information as needed, makes choices, and selects priorities to arrive at one or several solutions (Sorenson, Buckmaster, Francis & Knauf, 1996: 6).

The procedure for assessing competence in problem-solving that was used in this study was guided by this definition and suggestions from the literature (Mourtos, DeJong Okamoto & Rhee, 2004; OECD, 2004; Polya, 1946; Sorenson et al., 1996). The literature shows that the process of problem-solving often involves an understanding of the problem (clarify, describe, define or state the problem), an exploration of the problem (identify and consider the variables and their interrelationships), planning a solution to the problem, implementing the plan, and reflecting on the solution (evaluate the solution). These steps were deemed testable and appropriate in the procedure used to assess competence in problem-solving in this study (section 3.7.4).

2.4.3 Assessment of decision-making ability

Decision making is a type of problem-solving that involves choosing among alternatives under constraints (OECD, 2004). People always make decisions on various aspects of life, based on past knowledge, intuition, or analysis of benefits, costs and risks (Saaty, 1994). The modern world, however, requires citizens who can analyse evidence effectively and make rational choices, in order to arrive at viable personal and policy decisions (Burden, 1998). The challenge is how to prepare young people, who are the future leaders, to be able to make rational decisions on issues that affect them and society at large. The question that was explored in this study was: how effective are the two contending teaching approaches in enhancing learners' decision-making ability?

The assessment of decision-making competence presents a challenge, because decision-making ability, like problem-solving, is complex and multifaceted. Several researchers (Byrnes, 1998; Halpern-Felsher & Cauffman, 2001; Hong & Chang, 2004; Ratcliffe, 1997) have developed and used specific criteria for assessing decision-making competence. These criteria are; the ability to state the problem in a given situation, the ability to identify alternative options, the ability to use facts to evaluate and eliminate options, and select a viable option, and the consideration of stakeholders during the decision-making process. This set of criteria was used to assess decision-making competence in this study (section 3.7.3).

2.4.4 Assessment of learners' attitude

Several researchers (Campbell, et al., 2000; Reid & Skryabina, 2002; Yager & Weld, 1999) have used learners' attitudes to investigate the motivational effects of contextualized teaching on learners. Similarly, in the present study, the motivational effect of the instructional approaches used, was determined using learners' attitudes. Attitudes, according to researchers (Allport, 1935; Gardner, 1996), are dynamic and directional in nature. Allport for instance stated that attitude is "a mental and neural state of readiness to respond, organized through experience, *and* exerting a direction and/or dynamic influence on behaviour" (1935; 850 [*italic* researcher's emphasis]). Based on this view of attitudes and other definitions of attitude that imply a directional propensity (Brophy, 2004**)**, attitudes in this study were measured in terms of learners' directional attitudinal inclinations (i.e, either positive or negative attitudes) towards the study of life sciences.

In order to determine learners' directional attitudinal inclinations towards a given subject, valid and reliable assessment instruments are required. However, there seems to be considerable controversy over the measurement of attitudes (Reid, 2006). Despite this controversy, several researchers (Beaton et al., 1996; Meyer & Koehler, 1990; Oliver & Simpson, 1988; Papanastasiou & Zembylas, 2002; Reid, 2006; Simpson & Oliver, 1985) have attempted to measure learners' attitudes towards science using self-reporting methods such as; written reports, interviews and questionnaire surveys. Likewise in this study, learners' directional attitudinal predispositions towards life sciences were measured using a three-point Likert-type questionnaire and interviews.

2.5 SOME FACTORS AFFECTING PERFORMANCE IN SCHOOL SCIENCE

Science learning is influenced by a number of factors, which may be external and internal, such as resources, infrastructures, quality of educators, gender, learners' cognitive preferences, learners' attitudes and influences from role models such as parents, educators and peers (IET, 2008), as stated in Chapter one. A review of literature on all the factors that could affect science learning is beyond the scope of this dissertation. Nonetheless, studies (Chung, Yang & Kim 1995; Krause, Burrows, Sutor & Carlson, 2007) have shown some interactions between gender and instructional methods. In addition, some researchers (Atwood & Stevens, 1978; McNaught, 1982; Okebukola & Jegede, 1989; Tamir, 1975, 1988) have indicated that cognitive preferences could influence learner performance in science. Given that South African learners have been exposed to traditional teaching approaches for a long time, it is possible that they could be predisposed to a particular cognitive preference. This study therefore explored the interactive influences of gender and cognitive preferences, and the teaching approaches used, on the attainment of the learning outcomes assessed in this study.

2.5.1 Gender and achievement in science

Gender discrepancies in learners' achievement in science subjects have been documented worldwide (Alparslan, et al., 2003; Cavallo et al., 2004; Howie & Hughes, 1998; Osborne, et al., 2003). For instance, in the international mathematics and science assessment project (TIMSS), it was reported that in numerous countries, boys performed better than girls in mathematics and science (Howie & Hughes, 1998).

In the South African context, researchers (Arnott et al., 1997; Howie & Hughes, 1998) have reported that boys usually perform better than girls in physical science, whereas girls perform better than boys in life sciences. However, contrary to these reports, the South African educational statistics (DoE, 2001–2009) show that although the enrolment of girls in life sciences has been higher than that of boys, boys have been consistently performing better than girls in the subject.

The conflicting research outcomes concerning the achievement of girls and boys in science are not restricted to South Africa. Studies conducted in other places around the world have revealed similar inconsistencies in results. While some researchers (Dogru-Atay & Tekkaya, 2008; Hupper, Lomask & Lazarowitz, 2002; Thompson & Soyibo, 2002; Ugwu & Soyibo, 2004) have indicated non-significant difference between boys and girls in science achievement, others (Alparslan, et al., 2003; Cavallo, et al., 2004; Soyibo, 1999) have reported significant gender differences. For example, in a study conducted by Ugwu and Soyibo (2004), they found no significant gender differences in the achievement of Jamaican 8th-grade learners in nutrition and plant reproduction concepts. Dogru-Atay & Tekkaya (2008) also found no significant differences in the achievement of boys and girls in genetics. On the contrary, Alparslan et al (2003) found a significant difference between girls' and boys' achievement in respiration, in favour of the girls.

It seems that the issue of gender discrepancies in science achievement has not been conclusive, and thus requires further investigations, especially when exposing learners to new instructional innovations, such as the one developed in this study. The need to investigate the interactive influence of gender and the instructional approaches used in this study was also informed by studies (Chung, et al., 1995; Krause et al., 2007) which reported significant interactive influences of gender and instructional strategies in the attainment of learning outcomes in science.

2.5.2 Learners' cognitive preferences and achievement in science

Cognitive preferences are defined as "self-consistent, stable individual differences between learners' typical modes of cognitive organization and function in the acquisition, processing and transmission of information" (MacKay, 1975: 50). The conceptualization of the phrase 'cognitive preference' was introduced by Heath (1964) as an innovative means to measure and evaluate the effectiveness of new curriculum reforms. Heath identified four cognitive reference modes which he described as follows (Tamir, 1988: 202):

- Acceptance of information for its own sake, without considering its implications, application, or limitations (**Recall mode, R**).

- Acceptance of information because it exemplifies or explains some fundamental principle or relationship (**Principle mode, P**).
- Critical questioning of information as regards its completeness, general validity or limitations (**Questioning mode, Q**).
- Acceptance of information in view of its usefulness and applicability in general, social, or scientific context (**Application mode, A**).

Several researchers (Atwood & Stevens, 1978; McNaught, 1982; Okebukola & Jegede, 1989; Tamir, 1988) have suggested the possibility of interactive influences of cognitive preferences and teaching approaches on the attainment of learning outcomes. Tamir (1975) advises that in attempts to assess the effectiveness of any new curriculum (or teaching materials) on learner performance, it is important to examine the interactive influence of cognitive preferences or changes that occur in the cognitive styles of learners.

Several tests have been developed to determine learners' cognitive preferences. The general format of the items in these tests is an initial presentation of limited information of a scientific nature (the stem). This is followed by four correct statements (options) related to the initial statement (the stem), each of which correspond closely to the four cognitive preference modes described above.

Learners' cognitive preferences are determined using normative or ipsative measurement procedures. In the normative procedure, learners are required to select one option from the four (correct) options allocated to the stem statement that appeals to them most. By choosing the most appealing statement (which corresponds to a specific cognitive preference mode), the learner is assumed to exhibit his or her own cognitive preference. The cognitive preference of a learner is inferred from the overall response pattern in the test (Tamir & Kempa, 1976). The ipsative procedure uses a graded rating of options to determine learners' cognitive preferences. This approach requires learners to rate the options according to their preference. The learner's cognitive preference is represented by the cognitive preference mode with the highest total score out of all the items of the test (Tamir & Lunetta, 1977).

Many researchers (Kempa & Dube, 1973; Tamir & Lunetta, 1977) are of the view that the normative procedure does not conform to the original aim of identifying cognitive preferences, since, according to them, preference is ipsative by definition. The researchers argue that the use of normative procedures may obscure the differences among relative levels of preference towards each of the four cognitive modes, as learners are required to express a single generalized preferred level of response. Based on these suggestions, the current study employed the ipsative procedure to determine learners' cognitive preferences.

2.6 CHAPTER SUMMARY.

The literature reviewed showed that the ways science is usually taught (traditional teaching approaches) make science subjects appear irrelevant, uninteresting and difficult to learners. These perceptions could account for the despondency and poor performance apparent in science education. With respect to context-based teaching approaches, the literature suggests that while researchers agree on the motivational effect of these approaches, their effect on learners' conceptual understanding and skills development has not been indisputably established. The literature also revealed that the source and type of contexts used to develop materials, the models and approaches used to develop and implement materials, and the competence of educators in contextualized teaching could be possible determinants of the efficacy of context-based approaches in enhancing learner performance. The context-based projects reviewed seem to suggest lack of learner involvement in the selection of contexts, and the use of unsystematic ways to expose study materials to learners.

A conceptual framework consisting of three classes of components - the core, process, and learning cycle – was discussed. The framework is based on the use of context determined by learners to teach content, linkages between content and contexts, and the use of minds-on and hands-on activities in science classrooms. In addition, assessment techniques used to measure competence in science inquiry skills, problem-solving, decision-making abilities, and learners' attitude towards the study of life sciences were discussed. Finally, the intervening variables of gender and cognitive preferences were discussed. The following chapter presents a discussion of the methodology used in the study to collect and analyse data.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter presents a discussion of the research procedure that was followed in the study. It includes the research method and design, study sample and sampling procedures, development and validation of research instruments, and data analysis procedures. The ethical issues considered in the study are also discussed.

3.2 RESEARCH METHOD

The study adopted a sequential mixed-method research approach (QUAN/Qual: Creswell, 2009), in which the primary data were quantitative. Qualitative approaches played a supportive role in augmenting and triangulating aspects of the quantitative data, and provided greater insight into the results. Mixed-method research is defined by Johnson, Onwuegbuzie & Turner, 2007: 123) as:

> The type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration.

A predominantly quantitative research approach was necessary for the study because it was consistent with the nature of the main research questions. A quantitative research approach also provided the advantage of being able to measure and compare the performance of a large number of learners in grade 11 classes, and still be able to present the findings in a succinct and economical manner (Patton, 2002). At the same time, qualitative information on the intervention, based on the views of participating learners and educators, was required to elucidate the quantitative data. A mixed-method research was therefore adopted, so that the numerical data from the quantitative approach and the narratives from the qualitative approach could complement each other for greater insight into, and for better understanding of the results.

3.2.1 Quantitative research design

In this study, a quasi-experimental non-equivalent pre-test–post-test control group design (Campbell & Stanley, 1966; Gall & Borg, 2007) was used to compare the performances of learners who had been exposed to a context-based teaching approach with those who had experienced traditional teaching approaches, in the acquisition of genetic content knowledge, science inquiry skills, decision-making and problem-solving abilities, as well as their attitudes towards the study of life sciences.

The use of a non-equivalent quasi-experimental design in this study was necessitated by the difficulty of randomly assigning subjects to the control and experimental groups, which is inherent in a school setting (Campbell & Stanley, 1966; Gall & Borg, 2007; Shadish, Cook & Campbell, 2002). According to Babbie (2011), a non-equivalent quasi-experimental design involves the use of an existing control group that is similar to the experimental group, but is not created by random assignment of subjects to groups. Figure 3.1 below shows the symbolic representation of the quantitative research design used in this study.

Figure 3.1 Symbolic representation of the research design

Experimental group	O_1	X	O_2
Control group	O_1		O_2

Key to the symbols

O_1 and O_2 - represent pre-test and post-test measurements respectively.

X - represents an intervention (exposure to treatment).

___ - (horizontal line) represents non-random assignment of participants to the experimental and control groups.

The methodological shortcomings of a non-equivalent quasi-experimental design are acknowledged in the study. These include the difficulty of controlling extraneous variables, and the statistical complications of comparing non-equivalent groups resulting from non-random assignment of participants to the control and experimental groups (Trochim, 2006). Consequently, several measures were taken, as an attempt to minimize the effect of variations in the two groups. First, participating schools were selected based on a set of criteria designed to equalize the two groups. Second, pre-tests were administered to both groups in order to compare their competencies on the assessed learning outcomes before the intervention (Creswell, 2009). Third, an analysis of covariance (ANCOVA), which reduces the extraneous variability of post-test scores (Creswell, 2009; Field, 2009; Trochim, 2006) was used to analyse post-test scores. Lastly, qualitative data were collected to complement and triangulate the quantitative data.

3.2.2 Qualitative research method

Semi-structured focus group interviews were used to collect qualitative data from learners regarding their views and opinions on the intervention. Morgan (1997: 18) defines focus group interviews as "carefully planned discussions designed to obtain perceptions in a defined area of interest in a permissive, non-threatening environment". Focus group interviews are believed to elicit cooperative reasoning, which could enhance the quality of learner responses, as well as activate forgotten details (Maree, 2007). They are also known to provide a diversified range of responses (Merton, Fiske & Kendall, 1990) that could enrich the findings of the study.

Further, focus group interviews are likely to provide ample information within a short period, while avoiding one-to-one soliciting of information, which could be intimidating to some learners. A possible shortcoming of focus group interviews in the context of this study might have been what is referred to as the 'groupthink' phenomenon, in which individual views are not easily discernible (Janis, 1982). This shortcoming, however, had little impact on the results of this study, since the researcher was interested in the collective views of the groups.

One-to-one semi-structured interviews were used to collect in-depth information on the intervention from individual educators who participated in the study. A one-to-one interview involves a discussion in which the interviewer determines the general direction, and follows specific topics addressed by the respondent (Babbie, 2011). Information from these interviews was necessary for corroborating learners' responses from the focus group interviews and for triangulating the quantitative data on the effectiveness of context-based and traditional teaching approaches in enhancing learner performance.

3.3 STUDY VARIABLES

Table 3.1 shows the variables that were addressed in the study.

Table 3.1 Study variables

	Type of variable	Variables
1	Independent variables	1.1 Context-based teaching approach 1.2 Traditional teaching approach
2	Dependent variables (also referred to as 'learning outcomes')	2.1 Life science content knowledge 2.2 Competence in inquiry skills 2.3 Decision-making ability 2.4 Problem-solving ability 2.5 Learners' attitude towards life sciences
3	Intervening variables	3.1 Gender 3.2 Learners' cognitive preferences

3.4 POPULATION AND SAMPLING PROCEDURES

The population of the study comprised all Grade 11 learners in government schools in Tshwane south educational district in Pretoria, South Africa. The district was chosen for the study because it has a wide spectrum of schools, including high- and low-performing schools, and urban and rural schools. It also has many peri-urban (township) schools, in which performance in science has been consistently poor.

A random stratified sampling technique was used to select schools and subjects for participation in the study. Initially a list of all government high schools in the Tshwane south educational district was drawn. Twenty-one schools that met the following selection criteria were chosen from the list for possible participation in the study:

1 Schools are in a peri-urban area (township).
2 Schools have been teaching life sciences (formerly known as biology) for at least five years.
3 Schools have qualified life science educators with a minimum of eight years teaching experience at Further Education and Training (FET) level.
4 Schools are co-educational, to ensure similar learning environments for participating boys and girls.
5 Schools have at least one functional science laboratory at FET level, to minimize infrastructure and resources discrepancies.
6 Schools are not involved in any other major research activities.

To select the schools that participated in the main study, 15 high schools were randomly sampled from the 21 qualifying schools, from which 11 life sciences educators from different schools volunteered to take part in the study. Of these 11 educators, three of them opted to teach genetics in their own schools as the control group. The remaining eight educators agreed to participate in a workshop for implementing context-based teaching materials. At the end of the workshop, three of the eight educators were chosen according to ratings from judges (university science education lecturers) to implement genetics context-based materials in their schools as the experimental group. Therefore, six schools (3 experimental and 3 control schools) and six educators were selected for participation in the study.

The six educators who took part in the study comprised two males and one female for the experimental schools, and two females and one male for the control schools. All six educators were qualified to teach life sciences at FET level, with academic qualifications ranging from bachelor’s degrees (BEd) to honours degrees (BEd Hon). All had at least eight years of life sciences teaching experience.

Eighty-seven (55 girls and 32 boys) Grade 11 learners from the three experimental high schools volunteered to participate in the study, while 103 (54 girls and 49 boys) Grade 11 learners from control high schools offered to take part. In total, the participants of the main study comprised six life sciences educators and 190 (that is, 87 experimental and 103 control learners) Grade 11 learners. Grade 11 learners were considered suitable for exposure to genetics materials because genetics is taught in Grade 12 in the South African life sciences curriculum. It was therefore assumed that learners in Grade 11 had minimal genetics knowledge, since they had not yet studied the topic. Further, Grade 11 learners do not write national examinations at the end of the academic year. The provincial department of education therefore permitted them to participate in the research. The 190 Grade 11 learners who comprised the experimental and control groups were aged between 15 and 20 years.

After the intervention, 58 learners (37 girls and 21 boys), consisting of 25 from the control group and 33 from the experimental group, offered to participate in focus group interviews. Nine groups, consisting of at least five learners per group, took part in the interviews. Allocation of learners to the focus groups was based on preference. The six educators who taught the experimental and control classes also participated in one-to-one interviews after the intervention.

3.5 SUMMARY OF JUSTIFICATIONS FOR THE DESIGN OF THE CONTEXT-BASED TEACHING APPROACH USED IN THE STUDY

Current major challenges in science education include the following (Gilbert, Bulte & Pilot, 2011; Wieringa, et al, 2011):

- Curriculum overload, where too much content (concepts, facts and ideas) is included in science curricula for learners to conceptualize and make sense of
- Lack of coherence within and between concepts and contexts, which leads to the inability of learners to construct worthwhile mental maps
- Inability of learners to transfer learnt knowledge to situations outside the classroom
- Irrelevance of science curricula to learners' everyday lives
- Confusion about the reasons for learning science

These educational challenges could partly account for learners' loss of interest in the study of science subjects (Barmby, et al., 2008; Jenkins, 2006; Jenkins & Nelson, 2005; Osborne et al., 2003; Sjøberg & Schreiner, 2005), the perception of science subjects as difficult to study (Anderson, 2006; CEI, 2009; EIRMA, 2009; IET, 2008; Jenkins & Pell, 2006; Schayegh, 2007; Schreiner & Sjøberg, 2004), and learners' inability to develop analytical thinking skills, including problem-solving, decision-making and science inquiry skills.

Context-based teaching approaches are envisaged as enhancing learner's conceptual knowledge, motivating learners to study science, increasing coherence within and between concepts and contexts, developing higher order thinking skills, and increasing the relevance of science curricula (Wieringa, et al., 2011). These features of context-based teaching seem to address some of the above stated challenges in science education. It was therefore considered necessary to investigate the efficacy of these approaches in enhancing learner performance in life sciences, particularly in genetics where the stated educational challenges are prevalent.

Review of literature (Bennett & Holman, 2002; De Jong, 2008; Gilbert 2006; Pilot & Bulte, 2006; Taasoobshirazi & Carr, 2008) on the efficacy of context-based teaching approaches in enhancing achievement, as pointed out in section 2.2.2.5, reveals inconsistencies. These inconsistencies could be associated with weaknesses in the design (including the selection of contexts by adults only) and implementation of teaching materials (section 2.2.2.6), which this study addresses.

It was assumed in this study that the use of contexts that are selected solely by curriculum developers and educators to develop teaching materials (Bennett & Holman, 2002; Taasoobshirazi & Carr, 2008) could account for insignificant improvements in the achievement of learners exposed to context-based materials. The assumption was based on assertions by researchers (De Jong 2008; Pilot & Bulte, 2006) that learners could experience difficulties with contexts which do not meet their needs, aspirations, expectations, as well as time and regional priorities. Reviewed literature (Basu & Barton, 2007; Osborne & Collins, 2001; Sjøberg & Schreiner, 2005) seem to promote the involvement of learners in curriculum decisions for effective learning. Therefore, the contexts used to develop learning materials for this study were selected by the learners themselves, to limit the difficulties which could be experienced by learners exposed to the materials (De Jong, 2008), to meet the time and regional priorities (Pilot & Bulte, 2006), to make the learning materials more relatable to learners (Lubben, et al, 1996), and to empower learners (Whitelegg & Parry, 1999).

Review of relevant literature showed that most context-based materials are not based on all the principles suggested for developing effective teaching materials (see Gilbert, 2006), and they do not systematically incorporate learning activities which promote effective learning and the development of higher order thinking skills (ref. section 2.2.2.4). It was therefore presumed that failure to adhere to the principles for developing effective context-based materials (Gilbert, 2006) and non-systematic organization of learning activities might also explain the limited success of context-based approaches in improving learner performance.

Instructional and learning theorists (Herbart's instructional model, Piaget's mental function model, and von Glasersfeld's constructivism learning) seem to recommend the use of learners' experiences, active discussions, self-reflections on preconceptions, and applications of learned materials for effective learning. These learning activities also appear to provide opportunities for incorporating the principles for developing effective context-based materials (Gilbert 2006). Learning cycles could provide learning the necessary learning environments for engaging learners in these activities in a systematic manner. Further, learning cycles introduce learners to discovery or inquiry-based learning (Dogru-Atay et al., 2008) which is consistent with context-based teaching (De Jong, 2008). Consequently, a five phase learning cycle, which was envisioned to promote coherence within and between concepts and contexts, encourage the transfer of learnt knowledge to novel situations, and enhance the relevance of science curricula to learners' everyday lives was used to implement the context-based materials developed in this study.

Descriptions, explanations and justifications of the phases and activities of the five-phase learning cycle are given in section 3.7. The subsequent section provides a description of the development of the teaching materials used in the study.

3.6 DEVELOPMENT OF CONTEXT-BASED GENETICS MATERIALS

The development and implementation of the context-based materials used in this study were guided by the conceptual framework of the study, which as explained in section 2.3 involves a core component (content, context and linkages), process component (reasoning, reflections and research), and a five-phase learning cycle component (introduction of context, interrogation of context, introductions of content, linkage of content and contexts, and assessment of learning). In order to address the components of the framework, the development of the context-based teaching materials involved selection of a study topic (which provided the content), selection of contexts, and organization of content and context into learning activities (linkages). These steps are discussed in the succeeding sections, while the implementation of the materials (the context-based approach), which further involved linkages of contexts and content, and reasoning and reflections around them, is discussed in section 3.7.

3.6.1 Criterion for selecting a topic for use in the study

To adequately assess the comparative efficacy of the context-based approach and of traditional approaches in enhancing learner performance, it was considered necessary to use a topic that was considered predominantly difficult from the learners' and educators' perspectives. In order to select the study topic, thirteen high schools that were not chosen for participation in the main study were randomly sampled from Pretoria to participate in a survey for selecting a life sciences topic considered difficult for learners to learn. Ten educators from ten of these schools volunteered to take part in the selection of a difficult topic. Two of the ten schools, from which educators had volunteered to participate in the survey, allowed their Grade 12 learners to take part. Sixty seven learners from these two schools participated. Grade 12 learners were considered suitable for the survey because they had already studied most of the life sciences topics in the South African national curriculum statement, and were therefore in a better position to make informed decisions about the difficulty of topics.

A list of life sciences concepts, such as gaseous exchange, human diseases, excretion in humans, chromosomes, DNA and gene structure and function, and genetic code, was compiled from the South African life sciences national curriculum statement (DoE 2008). Participating learners and educators were required to select from the list, ten concepts that they considered most difficult for learners to learn. Table 3.2 displays the ranking of the ten most difficult concepts (see appendix III for a complete list of ranked concepts).

Table 3.2 Ranking of the top ten most difficult life science concepts

Life science concepts	Percentage of respondents					Rank
	Educators		Learners		Average %	
	Number	%	Number	%		
Chromosomes, DNA, and gene structure and function	7	70	46	69	69.5	1
Genetic code	6	60	49	73	66.5	2
Cellular respiration	6	60	46	69	64.5	3
Human nervous system	6	60	45	67	63.5	4
Meiosis	5	50	41	61	55.5	5
Genetics and inheritance	5	50	41	61	55.5	5
Human endocrine system	5	50	40	59	54.5	6
Biosphere, biomes and ecosystems	5	50	39	58	54.0	7
Population ecology	6	60	32	48	54.0	7
Biodiversity and classification of plants	4	40	45	67	53.5	8

Table 3.2 shows that four of the top raking ten concepts: chromosomes, DNA and gene structure, and function; the genetic code; meiosis; and genetics and inheritance, are related to the study of genetics. Consequently, genetics was selected as the topic for use in the study.

3.6.2 Selection of contexts for material development

After selecting the topic which provided the content, the contexts upon which the development of the context-based materials used in this study was based were selected by learners in a second survey. Two high schools that did not form part of the main study sample were randomly selected from Pretoria. Seventy two grade 12 learners (34 girls and 38 boys) from these two high schools, who had already completed the study of genetics, took part in the survey.

A questionnaire consisting of statements about various familiar situations and experiences was developed and exposed to learners so that they could select the contexts that they considered interesting, relevant, understandable and meaningful in the study of genetics.

3.6.2.1 Development and administration of questionnaire for selecting relevant contexts

Statements about situations and experiences that correlate strongly with learners' needs and daily life circumstances were adapted from previous questionnaires on learners' views about science, such as the Relevance of Science Education (ROSE) (Schreiner & Sjøberg, 2004), and Views on Science-Technology-Society (VOSTS) (Aikenhead & Ryan, 1992). These context statements were used to develop a three-point Likert scale questionnaire (appendix IV), which was administered to the Grade 12 learners. Respondents indicated, by marking a tick (√) in the appropriate space, whether the idea represented by a given context statement was important, unimportant or whether they were undecided about its potential to make the study of genetics interesting, relevant, understandable and meaningful to learners. Table 3.3 shows examples of context statements used in the questionnaire.

Table 3.3 Example of items from the questionnaire for selecting contexts

Item code	Context statement	Options		
		Important	Un-decided	Not Important
SOCIETAL ISSUES (SI)				
1	The use of genetics in crime fighting			
2	Cloning of animals			
3	The role of genetics in sex and reproduction			
4	Transmission of genetic diseases			

3.6.2.2 Scoring questionnaire items

To score the questionnaire items, an 'unimportant' response was allocated a score of 1; an 'undecided' response was allocated 2; and 'an 'important' response was allocated 3. A blank was regarded as an 'undecided' response and was therefore allotted a score of 2. Mean scores were calculated for each questionnaire item (table 3.4). Contexts statements with a mean score of more than 2 were considered important to learners. Statements with a mean score of 2 represented a neutral (undecided) response, while those with mean scores of less than 2 were considered unimportant to learners. The mean score for each context statement and the percentages of learners who selected a particular option were calculated (table 3.4). This method was used by Jenkins and Pell (2006) to measure learners' interest in a given science topic.

Table 3.4 Mean scores for each context statement and percentages of learners who selected each option, per context statement

Item code	Context statement	Mean Score	% of learner who selected the option		
			Important	Un-decided	Not Important
SCIENTIFIC AND TECHNOLOGICAL INNOVATIONS (ST)					
C5	Life outside earth	1.3	21.4	0.3	78.3
C6	Very recent inventions and discoveries in genetics and technology	2.9	95.0	0.0	5.0
C10	The role of genes in evolution	2.1	49.0	0.8	50.2
C12	The origin and evolution of life on earth	1.7	21.4	3.3	75.3
C16	Study of the human genome	2.9	97.0	0.3	2.7
C20	Cloning of animals	2.8	100	0.0	0.0
C28	Gene therapy (curing disease using genes)	2.7	99.6	0.3	0.1
Average		**2.3**	**69.1**	**0.7**	**30.2**

Table 3.4 cont. Mean scores for each context statement and percentages of learners who selected each option, per context statement

Item code	Context statement	Mean Score	% of learner who selected the option		
			Important	Un-decided	Not Important
ACADEMIC EXCELLENCE (AE)					
C2	Famous scientists and their lives	1.2	40.1	1.5	58.4
C7	How to develop or improve my knowledge and abilities in genetics	1.3	33.7	0.4	65.9
C9	Improve my grades in exams	1.5	48.0	0.0	52.0
C13	To further my education	1.0	18.1	0.9	81.0
C19	Achieve lifelong education	1.1	9.5	0.1	90.4
C24	The number of degrees I have	1.2	36.0	0.6	63.4
C38	Coming up with new ideas	1.3	51.0	0.0	49.0
Average		**1.2**	**33.8**	**0.5**	**65.7**
SOCIETAL ISSUES (SI)					
C14	The use of genetics in crime fighting	2.9	98.9	0.1	1.0
C17	Genetic decisions and ethics	2.3	86.3	5.2	8.5
C22	How genes are passed from one person to another	2.6	98.2	0.1	1.7
C27	Cloning of animals	2.8	97.4	1.0	1.6
C35	The role of genetics in sex and reproduction	2.5	91.2	0.7	8.1
C39	Transmission of genetic diseases	2.7	98.1	0.1	1.8
C42	Use of genetics to Improve food production	2.6	68.9	0.0	31.1
Average		**2.6**	**91.3**	**1.0**	**7.7**
CAREER PROSPECTS (CP)					
C1	Earn lots of money	1.5	31.2	5.2	63.6
C15	A satisfying career	1.1	33.1	0.1	66.8
C18	Becoming a famous scientist	1.2	47.0	0.2	52.8
C23	To secure a marketable career	1.1	29.3	2.8	67.9
C29	Well-paying jobs	1.3	51.2	0.9	47.9
C33	Genetics-related jobs	1.1	49.6	3.1	47.3
C40	Use of genetics to become rich	1.2	56.0	2.3	41.7
Average		**1.2**	**42.5**	**2.1**	**55.4**
PERSONAL BENEFITS (PB)					
C4	How genes help in the formation of my characteristics	3.0	99.9	0.0	0.1
C8	How genetics affects the structure and functions of the human body	2.9	94.0	0.0	6.0
C11	The role of genetics in my personal relationships	2.7	58.3	0.2	41.5
C21	What I need to eat to keep healthy and fit	3.0	96.9	0.0	3.1
C25	How genes can determine the sex of my child	2.8	99.6	0.4	0.0
C31	The cure of human diseases	2.8	97.9	0.7	1.4
C37	How genes help my body to grow and mature	2.9	96.7	0.2	3.1
Average		**2.9**	**91.9**	**0.2**	**7.9**
ENVIRONMENT ISSUES (EI)					
C3	Animals and plants in my area	1.4	47.8	3.2	49.0
C26	Poisonous plants in my area	1.8	43.0	0.0	57
C30	The extinction of species	2.4	76.9	0.4	22.7
C32	Formation of new species (organisms)	2.6	89.0	0.5	10.5
C34	How living organisms and the environment depend on each other	2.7	73.0	0.5	26.5
C36	The diversity of organisms	2.3	87.8	0.7	11.5
C41	The causes of disease in animals and plants	2.3	40.3	9.9	49.8
Average		**2.2**	**65.4**	**2.2**	**32.4**

The scored context statements were grouped into six context domains (categories), adapted from De Jong's (2008) four domains of the origin of context. The six domains are Science and Technology (ST); Academic Excellence (AE); Societal Issues (SI); Career Prospects (CP); Personal Benefits (PB); and Environmental Issues (EI). Each of the six context domains comprised seven context statements. The average mean scores and percentages of learners who chose a given option from each context domain were computed (table 3.4).

A challenge that arose when allocating context statements to context domains was that a given context statement could be suitable for assignment to more than one context domain, because of overlap of domains. For example, a context statement such as 'Cloning of animals' could be allotted to the context domains of 'societal issues' and 'scientific and technological innovations'. Consequently, the context domains are not mutually exclusive. De Jong (2008) also acknowledged the difficulty inherent in demarcating context domains.

3.6.2.3 Criterion for selecting contexts for use in the study

Context domains in which the average percentage of learners that chose the 'important' option was more than fifty per cent (> 50%) were considered popular with learners, regarding their potential to make the study of genetics interesting, relevant, understandable and meaningful. Conversely, context domains in which the average percentage of learners choosing the 'important option' was less than or equal to fifty per cent (≤ 50%) were considered less popular.

Based on the percentage of learners that chose the 'important' option, the results of the survey (table 3.4) show that the majority of the learners regarded context statements from the context domains of personal benefits (91.9%), societal issues (91.3%), scientific and technological innovations (69%) and environmental issues (65%) as being important for enhancing learners' interest, having greater relevance to learners and making the study of genetics more comprehensible. The results also show that less than 50% of the learners considered career prospects (42.5%) and academic excellence (33.8%) as important in enhancing interest, relevance and comprehensibility in the study of genetics (table 3.4).

Based on these results, the context domains of personal benefits, societal issues, scientific and technological innovations, and environmental issues were considered important to learners in the study of genetics. The context domains considered important by learners in this study are closely related to the 'profiles' chosen by Ghanaian learners (health and wellbeing, appreciation of nature, and usefulness in everyday life) as being motivating for learning school science (Anderson 2006). The profiles chosen in these studies are similar in the sense that in both cases, the chosen situations are related to personal, environmental, and community issues.

Ideas based on context statements from the selected context domains that had a mean score of more than 2 (see above) were used to formulate the context narratives used in the study (see sections 3.6, 3.7 and appendix VI). An example of a context statement with a mean score of more 2, from the context domain of 'societal issues', is 'the use of genetics in fighting crime' (table 3.4). A narrative based on this context statement in the developed materials and approach concerns the use of genetics to identify a murder suspect (appendix VI, example 5 - unit 9.8). Narratives used in the study also met the following criteria:

- They were based on learners' real-life experiences and situations that are familiar to them (not abstract circumstances).
- They had the potential to arouse learners' interest and empathy.
- They were contemporary issues and relevant to learners' daily lives.
- They required high-level reasoning skills (e.g problem-solving, decision-making, analysis).
- They were comprehensible to learners.
- They were based on themes and concepts from the South African life sciences (genetics) national curriculum.

3.6.3 Organisation of content and contexts into learning activities

To develop the context-based materials used in the study, the life sciences national curriculum statement (DoE, 2008) was examined to identify concepts, ideas and principles that were related to genetics. These were organised into the following eight genetics themes (appendix VI):

1. Variations in the characteristics of individuals
2. Inheritance of characteristics (including sex determination)
3. Determination of blood groups
4. Genetic diseases (protein deficiency diseases)
5. Genetically modified organisms
6. Cloning of organisms
7. Determination of offenders using genetics (fingerprinting and forensics)
8. Genetic counselling, decisions and ethics

For each of these themes, carefully selected narratives, based on the contexts chosen by the learners and which met the criteria explained in section 3.6.2.3, were interwoven into stories. Such narratives constituted the contexts that were used as the starting point of every lesson in the adopted context-based teaching approach. Relevant genetics content (concepts, principles, ideas) was selected carefully and used to elucidate and illustrate these contexts (appendix VI). The following is an example of a narrative, based on a social issue, which required an understanding of the genetics concepts of blood typing, alleles, antigens, antibodies, etc.

> Two baby girls were born in Baragwanath Hospital, to Mrs Mathe and Mrs More. Unfortunately, the nametags on the babies were lost, and the babies were mixed up. (All the other babies born that day were boys.) The hospital staff could not tell which baby belonged to which parent. Mrs Mathe and Mrs More both have blood type **A**. Mr Mathe's blood type is **AB**, whereas Mr More's blood type is **A**. The blood type of baby girl 1 is **O**, and that of the baby girl 2 is **B**. The parents want to know which baby is their real child.
>
> How can this situation be resolved?

The use of appropriate genetics content to elucidate such narratives facilitated the linkage of contexts and content. Further, practical activities were used to link genetics concepts and ideas to contexts, through simulation of real-life genetics processes. For instance, this excerpt from a practical activity on cloning of animals shows the application of genetics in contemporary life.

> Mr Van Wyk is a farmer who produces sheep for sale. Some of Mr Van Wyk's sheep have better fur quality than others, and such sheep sell at a higher price. Mr Van Wyk wants to have more of the sheep with quality fur so that he could make more money. He decides to ask you as a professional genetics scientist to help him produce more of the sheep with good fur.

In this experiment, learners were asked to simulate the cloning of animals using improvised materials (see appendix VI for the complete experiment). Practical activities were designed in such a way that learners had to use prior knowledge and apply genetics concepts, ideas and principles to the situations in order to make meaning of them. The activities were therefore envisaged as encouraging learner-centred, hands-on, and minds-on learning; challenging and stimulating learners' intellectual engagement with the learning materials; fostering learning skills, such as critical thinking skills, including decision-making and problem-solving, and science inquiry skills; and arousing learners' interest in the study of genetics. The activities were also expected to motivate both science specialists (learners who intended to pursue the study of life sciences) and non-specialists (learners who did not intend to study life sciences further) in the study of genetics.

Finally, assessment activities were developed to evaluate learners' understanding of the contexts and genetics content that they had studied. These assessment activities required learners to apply learned knowledge to situations that were new to them, but were similar to those studied. For example, in order to apply the concepts learned in the narrative of the 'mixed babies' (above) to a new situation, learners were required to solve problems such as the following:

> Susan, a mother with blood type **B**, has a child with blood type **O**. Susan claims that Graig, who has blood type **A**, is the father of her child. Graig says that he cannot possibly be the father of a child with blood group **O**. Susan sues Graig for child support. Further blood tests ordered by the judge reveal that Graig is homozygous **A**. The judge should rule that:
>
> A Susan is right, and Graig must pay for child support.
> B Graig is right, and must not pay for child support.
> C Susan cannot be the real mother of the child. Her real child could have been swapped with another in the hospital when the child was born.
> D It is impossible to reach a conclusion based on the limited information available.
>
> Explain your answer.

In summary, the development of the genetics materials used in this study involved selecting contexts regarded by learners as relevant, interesting and comprehensible in the study of genetics, weaving these contexts into narratives (contexts), choosing the genetics content needed to understand the contexts, designing learning activities that linked contexts and appropriate content, and constructing assessment tasks that required learners to apply the knowledge they had learned to new situations. Consequently, the three elements of the core component (content, context, and linkages) of the conceptual framework were addressed.

3.6.3.1 Validation of developed context-based materials

According to Babbie (2011: 131), 'validity' refers to "the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration". There are various types of validity, which include construct validity, content validity, criterion-related validity, and face validity (Gall & Borg, 2007). Of these, content validity, defined as "the degree to which a measure covers the range of meanings included with a concept" (Babbie, 2011: 131), was considered relevant to this study. To determine the content validity of the materials, three university life sciences lecturers reviewed them to assess whether:

- The materials incorporated the identified contexts as starting-points and foundations within which genetics concepts were introduced.
- Only the genetics concepts relevant to understanding, giving meaning to, or explaining the context were introduced.
- The materials enhanced the development of higher order thinking skills
- The materials were relevant to the South African life science national curriculum statement.
- The materials were suitable for use by high school learners.
- There were no factual errors.

The three lecturers who reviewed the materials consisted of one male and two females. The male lecturer holds a PhD in science education, and he specializes in teaching life sciences to trainee educators at university level. He is therefore well acquainted with the South African National Curriculum Statement (NCS) for life sciences. One of the female lecturers also holds a PhD in science education, while the other has a Master's degree in science education and is currently studying for her doctoral degree. The two female lecturers teach life sciences to foundation year (first year of a four-year degree at a university) students in the faculty of Natural and

Agricultural Sciences. Both lecturers were high school (secondary school) life sciences educators before joining the university. They therefore have experience with the life sciences NCS. The lecturers were selected on the basis of their expertise and experience in the NCS for life sciences, and science education in general.

All three assessors agreed that the materials met the stated requirements. However, some assessors commented on the length of certain narratives, and suggested the inclusion of certain genetics concepts, and removal of others. They also recommended the removal of certain phrases and terms considered difficult for learners. Comments from the assessors were used to revise the developed materials. The validated materials were used to teach the experimental group, using a learning cycle that involved five phases, as described below.

3.7 CONTEXT- BASED TEACHING APPROACH USED IN THE STUDY

The five phases of the learning cycle used in the study were presented in this order:

1. Introduction of context
2. Interrogation of the context
3. Concept introduction
4. Linkage of concepts and context
5. Assessment of learning

Phase 1: Introduction of context

During this phase, learners were provided with relevant authentic situations (contexts) related to the genetics concepts to be studied. The criteria for selecting the contexts for narratives were that they had to belong to at least one of the four context categories chosen by learners in the initial survey (learners' personal lives, societal issues, environmental issues, and scientific and technological innovations), and that they had to meet the features for the selection of appropriate contexts (as discussed in section 3.5.2.3). These contexts were presented in the form of narratives, stories, genetic dilemmas, and familiar social incidents (Gilbert, 2006). Here is an example of a narrative.

> Mr and Mrs Sizwe have been married for twenty years, and have four daughters, but no sons. This situation worries Mr. Sizwe because, according to his custom, not having a son means that there will be nobody to take over as his heir when he dies. Mr Sizwe decided to consult his elders about his situation, and they advised him to marry a second wife who could bear him a son. To his dismay, the second wife gave birth to a girl (appendix VI).

The Introduction of real-life situations to learners was meant to capture their attention (Brown & Abell, 2007) and to keep them focused on a specific context upon which the learning of subsequent scientific concepts would be based. The phase was therefore envisaged to provide a rationale for teaching new scientific concepts (Gilbert, 2006) and to provide a setting of real-life experiences in order to relate the learning of science to learners' daily lives, as a way of enhancing the relevance of learning science.

Phase 2: Interrogation of context

The second phase involved an exploration of the introduced situations (contexts) by learners through question-and-answer sessions, discussions, brainstorming, debates and problem-solving activities. For the example provided above (phase 1), learners worked in small groups to answer questions about the situation, such as:

1 Who is responsible for determining the sex of a child (the husband or wife)?
2 How is the sex of a child determined?
3. Why do some couples have only girls or only boys? Etc. (See appendix VI.)

This phase allowed learners to think about the situation and draw on their preconceptions in order to participate in the exploration activity. The educators' role at this juncture was to facilitate and keep the discussions on track. At the same time, educators were able to identify and note learners' alternative conceptions for remediation during the subsequent phase (3).

The second phase was intended to serve the purpose of motivating learners to study new scientific concepts by arousing their curiosity about the scientific principles related to the contexts introduced (Gilbert, 2006). The cerebral engagement of learners during this phase was envisaged as helping learners to reveal their preconceptions (Bybee, et al, 2006), stimulating their thinking and curiosity about the contexts, and maintaining focus. The phase was designed to encourage inquiry learning and critical thinking as learners raised questions and attempted to answer them through self-reflections and reasoning around the context (Hung, 2006), which addressed the process component of the conceptual framework of the study.

Phase 3: Introduction of content

The third phase involved the presentation of genetics content by the educator. The content was introduced to learners using a variety of teaching approaches such as guided discussions, knowledge exposition, role play, practical activity, investigations, and simulations. Regardless of the method used, only content that was necessary to explain, clarify, solve or comprehend the introduced context was taught. For instance, for the context example given above (phase 1), only concepts related to sex determination, such as human karyogram, X and Y chromosomes, segregation during meiosis, gametogenesis, and fertilization were taught. The teaching of the concepts and ideas were actively linked to the contexts under consideration at opportune times.

To supplement the theoretical introduction of concepts, ideas and principles, the phase also involved investigations, simulations and practical activities involving genetics processes and applications. The narrative given in section 3.5.3, about the sheep farmer, Mr Van Wyk, is an example of a practical activity used to illustrate a genetics principle.

> ”Mr Van Wyk is a farmer who produces sheep for sale. Some of Mr Van Wyk’s sheep have better fur quality than others, and such sheep sell at a higher price. Mr Van Wyk wants to have more of the sheep with quality fur so that he could make more money. He decides to ask you as a professional genetics scientist to help him produce more of the sheep with good fur.”

Learners were asked to simulate the cloning of animals using specified genotypes (genetic composition of an organism) and phenotypes (characteristics), to simulate the steps involved in animal cloning (appendix VI). Practical activities therefore further exposed learners to the knowledge and skills necessary for understanding the context (real-life genetics applications and processes). Some of the concepts addressed were essential to understanding different contexts in the unit. As a result, the genetics concepts, principles and facts were revisited in different themes and activities, as required to promote the understanding of the contexts.

The introduction of content that was specifically related to the contexts under consideration and the use of the same concepts and principles in various themes (Bennett & Lubben, 2006) were envisaged as promoting coherence within, and between concepts and contexts. The coherence would in turn enhance learners' conceptual understanding as suggested in Piaget's mental function model (Abraham & Renner, 1986). Finally, the phase was meant to provide educators with an opportunity to address learners' alternative conceptions, which were identified during the context interrogation phase (2). The introduction of content and the practical activity in this phase focused on the content and research elements of the conceptual framework.

Phase 4: Linkage of content and context

The activities of this phase were designed to encourage learners to use the studied content to explain and resolve the issues under consideration. In this phase, learners were required to work in small groups and revisit the issues and questions addressed in the second phase of the cycle, in order to make the necessary links between the content and the context. For instance, in the example on sex determination, learners discussed these questions:

> Having learned the principles that govern sex determination, consider the issues discussed in phase 2 (context interrogation phase), and attempt to explain them again. Do you still maintain the explanations and answers you gave earlier (appendix VI)?
>
> 1. If your answer is yes, explain why you think your original explanations and answers are correct.
> 2. If your answer is no, why have you decided to change your original explanations and answers?
> 3. Do you have any questions that cannot be answered using the information provided?

The fourth phase was therefore aimed at providing learners with an opportunity to evaluate and perhaps re-evaluate their initial thinking and decisions, as they attempt to explain, resolve, understand and clarify the issues raised in the interrogation phase in the light of new knowledge (the introduced content). This phase was meant to enable learners to directly relate scientific concepts to their' daily lives in order to further enhance the relevance of science and to promote coherence between content and contexts. The phase was also meant to improve learners' higher-order thinking skills such as problem-solving and decision-making, since it required them to make decisions, explain, or solve problems using the content learnt during the third phase. The phase therefore emphasized the reasoning and reflection elements of the process component of the conceptual framework of the study.

As learners engaged in the activities in this phase, it was hoped that they would develop a specific way of talking (scientific language) in relation to the content and contexts under consideration (Gilbert, 2006). The phase was further intended to provide educators with feedback on the effectiveness of the learning cycle in enhancing conceptual understanding and in making explicit the connections between the content and real-life situations.

Phase 5: Assessment of learning

In the final phase, learners were given tasks that required them to apply the concepts they had learned to new situations. Class exercises, quizzes, problem-solving tasks and tests were used to assess learners' conceptual knowledge and skills, as well as their ability to transfer learned concepts to new situations which were not previously used in class. The tasks involved applying content in order to understand or resolve socio-scientific issues:

1. Explain why some twins have the same sex, while others have different sexes.
2. Your friend tells you that it is possible for a couple to decide whether to have a girl or a boy. What would you tell him or her (appendix VI)?

This phase was expected to provide learners with the opportunity to practice the transfer of learned materials to situations that were not previously addressed in class, as well as to reinforce the relevance of learning scientific concepts. In addition, the phase served to illustrate and show the applications of scientific concepts. Further, it was meant to provide educators with an opportunity to assess learners' competence in the principles and ideas under study (Bybee, et al, 2006), and to evaluate the effectiveness of the teaching materials in achieving their objectives.

In summary, the five-phase learning cycle developed in this study was envisaged as:

- Capturing learners' attention and focusing their thinking on a specific context
- Providing a social setting and rationale for teaching scientific concepts
- Eliciting learners' prior conceptions about the contexts under consideration
- Providing educators with an opportunity to identify and address learners' alternative conceptions
- Enabling learners to engage in inquiry learning and improving their thinking skills
- Providing learners with the opportunity to make linkages between contexts and content, thus highlighting the coherence between science and real life contexts
- Enhancing the relevance of studying science so as to motivate learners to learn
- Encouraging learners to evaluate their preconceptions (self-reflections), in order to reason and construct their own understanding of study materials
- Illustrating and show the applications of scientific concepts
- Promoting learners' ability to transfer learnt materials to novel situations
- Providing educators with an opportunity to assess learners' competence in the topic under study

3.7.1 Comparison of the developed approach and the BSCS 5E learning cycle

From the above description of the learning cycle used in the current study and the purposes of the different phases, it is clear that there are some similarities between the described learning cycle and the BSCS 5E learning cycle. However, the two learning cycles are quite distinct in their design and implementation. For instance, during the first phase of the 5E model (the engagement phase), learners are exposed to short activities that assess their prior knowledge and helps them become engaged in a new concept. The first phase of the learning cycle used in the study (context introduction phase) simply involves the introduction of a familiar authentic situation to learners by the educator, without engaging learners in any activities.

The exploration phase (2) of the 5E models allows learners to gain experience with the contexts through practical investigations using their prior knowledge. The corresponding phase (2) in the developed approach is similar in the sense that it also allows learners to gain experience with the context by interrogating the contexts through discussions and debates, based on their prior knowledge. However, learners are not required to carry out investigations (at this stage) before they are exposed to relevant content.

The explanation phase (3) of the 5E model allows learners to gain content knowledge from the educator and their own inferences from previous investigations (done during phase 2). Phase 3 of the developed approach likewise allows learners to gain relevant content knowledge through various learning activities, including practical activity, mainly organized by the educator. Nonetheless, the content introduced in this phase is meant to empower learners with the necessary knowledge to decipher, and rationally solve the issues encountered in phase 2.

The elaboration phase (4) of the 5E model allows learners to apply their understandings to new situations or contexts, while phase (4) of the developed approach focuses on allowing make meaning of the context using the scientific knowledge gained in phase 3. The phase is meant to enhance learners' self-reflections and reasoning through linkages of learned concepts, previously introduced context and prior conceptions.

Finally, the evaluation phase (5) of the 5E model provides an opportunity for educators to assess learners' progress and for learners to reflect on their new understandings. Phase 5 of the developed approach also enables educator and learners to assess knowledge acquisition, but it also emphasizes the application of learnt concepts to new situations or contexts, which is addressed during phase 4 of the 5E model.

3.8 DATA COLLECTION INSTRUMENTS

Seven instruments were used to collect data in this study, as indicated in table 3.5. (The abbreviations in brackets are the codes used to represent the instruments). The development and validation of the instruments are discussed in the subsequent sections.

Table 3.5 Instruments used to collect data

	Instrument	Variable measured
i	Genetics Content Knowledge Test (GCKT)	Genetics content knowledge
ii	Test of Science Inquiry Skills (TOSIS)	Science inquiry skills
iii	Decision-Making Ability Test (DMAT)	Decision-making skills
iv	Problem-Solving Ability Test (PSAT)	Problem-solving skills
v	Life Sciences Achievement Questionnaire (LSAQ)	Learners' attitude towards the study of life sciences
vi	Cognitive preferences test (CPT)	Cognitive preferences
vii	Interview schedules	Opinions of educators and learners on the intervention

3.8.1 Genetics Content Knowledge Test

The Genetics Content Knowledge Test (GCKT) was developed to determine learners' conceptual understanding of genetics. Initially, twenty questions adopted from the South African school-leaving National Senior Certificate (NSC) past examination papers in life sciences were selected for the test. Questions from past examination papers were used in order to assess learners on competencies and standards required in the actual life science national examinations. Examination papers are usually validated by subject specialists. Therefore, past examination questions are likely to enhance the validity of the GCKT instrument.

To test the content validity of the GCKT instrument, the questions were reviewed by three life sciences university lecturers, who were asked to identify the learning objectives assessed by each question. The highest level of learning objective (based on Bloom's taxonomy of cognitive learning objectives) assigned to each question was considered to be the main learning objective measured by the question (table 3.6). The lecturers were also asked to check the clarity of the questions and factual and grammatical errors.

Suggestions and comments from the reviewers were used to re-assess the questions. This appraisal reduced the items in the GCKT to seven questions; comprising one question, consisting of five multiple-choice sub-questions, and six structured questions with sub-sections.

The questions in the GCKT assessed learners' ability on the cognitive learning objectives of knowledge, comprehension, application and analysis. The test was scored out of a total of 55 marks (appendix VII). Table 3.6 shows the item specification of the GCKT instrument.

Table 3.6 Item specification for the Genetics Content Knowledge Test (GCKT)

	Learning objective	Items	Scores
1	Knowledge	1.1, 2.1, 2.2, 2.3, 2.4, 7.2, 7.4	7
2	comprehension	3.1, 3.4, 4.2, 4.3, 5.1, 5.2, 5.3, 5.4, 6.1, 6.2, 6.4, 7.1, 7.3	27
3	Application	1.2, 1.3, 1.4, 3.2, 4.1, 5.5, 5.3	15
4	Analysis	1.5, 3.3, 5.6, 5.7	6
Total score			55

An example of a question from the GCKT is given below.

> The body of a young woman was found on an open plot. She had allegedly been assaulted and murdered. DNA specimens were taken at the scene.
>
> 1. What is the purpose of taking DNA specimens at the crime scene?
> 2. What purpose (other than those mentioned in the question above) can DNA fingerprinting be used for?

A marking key for the test, developed by the researcher, was compared with memoranda for the examination papers from which the items were selected to ascertain its accuracy. The marking key was also given to the University lecturers to verify the answers, and they all agreed with the researcher on their accuracy. The reliability of the instrument was determined using a test-test reliability test (see section, 3.8 for explanation) and it was found to be 0.88 at 0.01, level of significance. The duration of the test was determined to be one hour (section, 3.8).

3.8.2 Test of Science Inquiry Skills

The Test Of Science Inquiry Skills (TOSIS) is a paper and pencil test, consisting of multiple-choice and structured questions. The test is meant to assess the integrated science inquiry skills of formulating hypotheses, identifying variables, designing experiments, graphing and interpreting results (drawing conclusions from results). To develop the test, several items were compiled. These were adapted from questions in the Tests of Integrated Science Process Skills (TIPS) developed by Dillashaw and

Okey (1979), by the researcher in an earlier study (Kazeni, 2005). The selected items were referenced to a set of objectives associated with the planning of investigations and analysis of results from investigations (Dillashaw & Okey, 1980; Onwu & Mozube, 1992). Table 3.7 shows the objectives to which the test items were referenced.

The items in TOSIS were given to the life science lecturers to comment on their clarity, their capacity to assess the stated inquiry skills, and on factual and grammatical errors. The reviewers were also asked to provide answers to the questions in order to verify the accuracy and objectivity of the marking key developed by the researcher. Comments from the reviewers about the length and clarity of the items were used to review them. During the review, certain items were re-worded or excluded from the test. At the end of the review process, seven items were selected for the test. They comprised multiple-choice and structured questions. Further review of the items resulted in the reviewers agreeing on their suitability for inclusion in the test. These items were administered to learners in pilot study.

Table 3.7 Objectives on which items for the test of inquiry skills were based

Inquiry skill	Objective
Formulating hypotheses	Given a problem with dependent variables and a list of possible independent variables, identify a testable hypothesis
	Given a problem with a specified dependent variable, identify a testable hypothesis
Identifying variables	Given a description of an investigation, identify the dependent, independent and controlled variables
	Given a problem with a specified dependent variable, identify the variables which may affect it
Designing investigations	Given a problem with dependent variables and possible independent variables, describe a suitable experiment to investigate the problem
	Given a problem with a dependable variable, select a suitable design for an investigation to test it
Graphing skills	Given a table of data from an investigation, draw an appropriate figure to show the relationship between the variables
Interpreting data	Given the results of an investigation, select the statement which describes the relationship between the variables
	Given the results of an investigation, select an appropriate conclusion of the investigation

These objectives were adapted from the Test of Integrated Science Process Skills for Secondary Schools developed by F.G. Dillashaw and J. R. Okey (1980).

An analysis of learners' pilot study responses revealed that two of the items were not clearly understood by learners, and were therefore removed from the instrument. The remaining five items (with sub-sections), carrying 20 marks, constituted the test instrument (appendix VIII). The reliability of the TOSIS was found to be 0.83 at 0.01, level of significance, while the duration was approximately 30 minutes. Here is an example of a question from TOSIS.

A learner wants to investigate the effect of acid rain on fish. She takes two jars and fills them with the same amount of fresh water. She adds fifty drops of vinegar (weak acid) to one jar, and adds nothing to the other. She selects four similar live fish, and puts two in each jar. Both pairs of fish are provided with the same amount of all their requirements (e.g. oxygen, food.). After observing the fish for one week, she draws her conclusion.

*Which of the following would you suggest to do in this experiment, in order to improve it?

1. Prepare more jars with different amounts of vinegar (weak acid).
2. Add more fish to the two jars already in use.
3. Add more jars with different types of fish.
4. Add more vinegar (weak acid) to the two jars already in use.

*Select a suitable explanation for your answer to the above question from the following explanations.

1. When more fish are added to the two jars, the effects of the acid will no longer be felt.
2. More jars with different types of fish will show you a variety of effects of the acid on the fish.
3. Preparing more jars with different amounts of vinegar will show the effect of different concentrations of acid.
4. Adding more vinegar to the two jars will produce a greater effect on the fish and make the acid effect clearer (appendix VIII).

The item specification for the TOSIS is shown in table 3.8 below.

Table 3.8 Item specification for the test of science inquiry skills (TOSIS)

	Inquiry skills	**Items**	**Scores**
1	Formulation of hypotheses	1.1, 2.1, 4.1	3
2	Identification of variables	1.2, 1.3, 3.2	3
3	Experimental design	2.2, 5.1, 5.2	5
4	Graphing skills	3.1	6
5	Interpreting results	3.3, 4.2	3
	Total score		20

3.8.3 Decision-Making Ability Test

The Decision-Making Ability Test (DMAT) required learners to make a choice from various possibilities. Learner competence in decision-making was assessed using the following set of criteria.

- Ability to identify a problem from a given situation
- Ability to consider alternative options
- Ability to evaluate alternative options
- Ability to select a viable option based on available information (facts)
- Consideration of stakeholders in making a decision

These criteria were adapted from the decision-making process coding scheme used by Hong and Chang (2004). Other researchers (Kuhn, Shaw & Felton 1997; Maloney, 2007; Ratcliffe, 1997) used similar coding systems to determine learners' decision-making ability.

The DMAT used in this study consisted of two questions, adapted from previous instruments on decision-making ability (Maloney, 2007; Salters-Nuffield Advanced Biology (SNAB), 2005). In both questions, a short description of a situation was provided to learners, which was followed by a list of facts about it. Learners were required to answer questions about the situation. The questions were designed to assess learners' ability to use the above stated decision-making criteria in their responses (appendix IX). The example below is one of the questions from DMAT.

*You are given the responsibility of managing a school library. The roof of the library has a lot of bats, which scare some learners who want to use the library.

(*Some facts about bats are provided after this statement*).

*For question *[1], choose the correct option by marking a cross [☒] on the letter representing the correct answer.

*[1] What problem does the existence of the bats in the library roof present?

A. Bats are considered to be an endangered species.
B. The bats make the library to look dirty.
C. Some learners are scared to use the library.
D. There is a R2 000.00 fine for killing bats.

*[2] How could one deal with the bats?

*[3] Being the person responsible for managing the library, what would you do about the bats? Explain.
*[4] Your assistant comes up with a suggestion which differs from yours. How would you react to the suggestion? Explain.
*[5] The nature conservation board is responsible for taking care of wildlife. Would you consult them before implementing your final decision? Explain (appendix IX).

The DMAT instrument was reviewed by the life science lecturers to comment on its ability to assess the competencies stated in the criteria, to establish the clarity of the statements, and to check factual and grammatical errors. Suggestions from the reviewers about the clarity of statements were used to revise the test items. The reliability and duration of DMAT were determined as described in section 3.8, and were found to be 0.95 at 0.01 level of significance, and approximately 20 minutes respectively. The final DMAT instrument was scored as shown in table 3.9 below.

Table 3.9 Item specification for the Decision-Making Ability Test (DMAT)

Criterion	Criterion statement	Items	Score
1	Ability to identify/state the problem in a given situation	1.1; 2.1	2
2	Ability to consider/identify alternative options	1.2; 2.2	2
3	Use of facts to evaluate/eliminate options and select a viable option	1.3; 1.4; 2.3; 2.4	4
4	Consideration of stakeholders in making a decision.	1.5; 2.5	2
Total score			10

Percentages of learner scores were calculated and used as determinants of their decision-making ability.

3.8.4 Problem-Solving Ability Test

Problem-solving ability in the context of this study refers to the process by which a learner understands, develops and carries out a plan to resolve a question or a situation that requires, but lacks an immediate answer or solution (Sorenson et al., 1996). The problem-solving principles used in this study were based on a problem-solving criteria suggested by Polya (1946), and used by other researchers (OEDC, 2004; Mourtos et al., Rhee, 2004; Sorenson et al., 1996). They include the ability to:

- Understand/define/state/ describe the problem
- Explore/analyse/forecast/ the problem

- Devise a strategy and plan to resolve the problem (reasoning through the problem)
- Execute the plan
- Evaluate the results

To develop the Problem-Solving Ability Test (PSAT), several problem situations with applicable questions were compiled. A review of the PSAT instrument by the life science lecturers resulted in the removal of some questions, in which the instructions to learners were not clear. The final PSAT instrument comprised two questions, each adapted from Reeff, et al. (2006) and the Organization for Economic Co-operation and Development (OECD, 2004). Each of these questions consisted of a statement introducing the problem, which was followed by the information needed to solve the problem, and several variables and constraints (appendix X).

For instance, in one of the questions, learners were informed that a youth club was organizing a five-day camp. Information about the number of children going on the camp and several other variables, requirements and constraints for camping were provided. The information included these statements:

- Forty-six children (26 girls and 20 boys) registered for the camp.
- Eight educators (4 men and 4 women) volunteered to attend and organise the camp.
- Seven dormitories with different numbers of beds are available at the camp site (the number of beds per dormitory was provided).
- All the people involved need to be accommodated at the camp, and the rules of the camp must be observed.
- Males and females are **not** allowed to sleep in the same dormitory.
- At least one educator **must** sleep in each dormitory (appendix X).

Learners were required to state the problem to be solved in this situation, and to allocate people to the dormitories, while observing all the variables and constraints of the camp. Correct allocation of people to the dormitories required learners to apply the problem-solving criteria stated above.

To assess learners' problem-solving ability, responses to the questions were scored as shown in table 3.10 below, determined according to the estimated mental demand of each question.

Table 3.10 Item specification for the Problem-solving Ability Test (PSAT)

Criterion	Criterion statement	Items	Score
1	Understand/define/state/ describe the problem	1.1; 2.1	2
2	Explore/analyse/forecast/ the problem	1.2; 2.2	3
3	Devise a strategy and plan to resolve the problem (reasoning through the problem)	1.3; 1.4; 2.2	3
4	Evaluate the results	1.5; 2.2	2
Total score			10

Percentages of learner scores were computed and used as determinants of the level of competence in problem-solving. The reliability (0.82 at 0.01, level of significance) and duration (30 minutes) of the instrument were determined in the pilot study (section 3.8).

3.8.5 Life Science Attitude Questionnaire

Items comprising the Life Sciences Attitude Questionnaire (LSAQ) were mostly adapted from existing questionnaires on learner attitudes towards science (Ferreira, 2004; Jenkins & Nelson, 2005; Prokop et al., 2007; Sjøberg & Schreiner, 2005). The compilation of the LSAQ initially involved the selection of 50 items, which were classified under five attitude categories of: Application of life sciences/genetics to everyday life (Att 1); Learners' perceptions of life science lessons/classes (Att 2); Learners' perceptions of life science career prospects (Att 3); Learners' opinions of genetics as a topic (Att 4); Learners' opinions of life sciences as a subject (Att 5).

Each category comprised ten positively and negatively phrased items. The questionnaire was reviewed by life science lecturers, who commented on the clarity and suitability of each item for determining learners' attitudes towards the study of genetics and life sciences as a subject. Items that did not meet the approval of the reviewers were re-worded or omitted. The validation process reduced the items to 42, which were reconsidered by the reviewers. The second appraisal resulted in the reviewers agreeing with the researcher on the clarity and suitability of all the items. The 42 item questionnaire was administered to a group of 36 Grade 11 learners in the pilot study for further review, and to determine the reliability of the instrument, which was found to be 0.931 at the 0.01 level of significance. A time limit was not set for completion of the questionnaire.

Further review of the items led to the removal of items that were not attempted by learners, or for which a large number of learners chose the 'undecided' option, as they were regarded to possibly be unclear to learners. This exercise resulted in a 30-item LSAQ questionnaire, which was based on a five-point Likert scale (appendix XI). The options for each item were Strongly Disagree (SD), Disagree (D), Undecided (U), Agree (A), and Strongly Agree (SA). Learners were required to choose the option that best represented their thoughts by marking an (X) against it. Here are examples of items from the LSAQ.

- Genetics is an interesting topic to study
- Without the study of life sciences, it would be difficult to understand life.
- What is taught in genetics cannot be used in everyday life.

The item specifications of the final LSAQ are presented in table 3.11 below.

Table 3.11 Item specification for the life science attitude questionnaire (LSAQ)

Attitude category	Items per category
Application of life sciences / genetics to everyday life (Att 1)	A2, A6, A8, A17, A24, A27
Learners' perceptions of life science lessons / classes (Att 2)	A3, A11, A12, A14, A18, A20, A22
Learners' perceptions of life science career prospects (Att 3)	A10, A13, A21, A25
Learners' opinions of genetics as a topic (Att 4)	A1, A7, A9, A23, A30
Learners' opinions of life sciences as a subject (Att 5)	A4, A5, A15, A16, A19, A26, A28, A29

The LSAQ instrument was scored by assigning numbers to the options: SD=1, D=2, U=3, A=4 and SA=5 for positively phrased items, whereas a reverse scoring order was used for the negatively phrased items. Consequently, a score of 5 always represented a Strongly Agree' (SA) response, whereas a score of 1 represented a Strongly Disagree (SD)' response.

3.8.6 Science Cognitive Preference Inventory

The items used to determine learners' cognitive preferences were adopted from the Science Cognitive Preference Inventory (SCPI) developed and validated by Van den Berg (1978). Five of the original SCPI items based on biology (life sciences) were selected for use in this study. The purpose of using SCPI in this study was to categorize learners according to their cognitive preferences in order to determine the interactive influence of cognitive preferences and treatment, if any, on the attainment of the learning outcomes assessed in the study.

Items in the SCPI consisted of a stem (initial) statement based on biological principles. The statement was followed by four correct options (statements) related to the stem statement. Each of the four optional statements corresponds closely to Heath's (1964) cognitive preference modes of application, recall, questioning and principle (appendix XII).

The SCPI was given to six life sciences university lecturers, who were asked to assign the optional statements for each item to the appropriate cognitive preference mode (Application, Recall, Questioning or Principle). Five of the lecturers agreed with the researcher on the allocation of each optional statement to a particular cognitive preference mode. One of the reviewers differed from the researcher on allocations of two items. These discrepancies were discussed with the concerned reviewer until consensus was reached. The reliability of the SCPI was determined to be (exact p = + <0.001), while the duration of the test was approximately 10 minutes. Here is an example of a question in the SCPI:

*** A function of a stem of a plant is to bear leaves, flowers and later fruits**.

A. Fibres used in cloth are made of stems of certain plants.
B. The maximum height of a plant depends on the shape and the amount of wood in the stem.
C. Some stems are soft, others are woody.
D. How do old trees with hollow trunks remain alive? (Appendix XII)

An ipsative procedure was used to determine learners' cognitive preferences (Tamir & Lunetta, 1977). In this procedure, learners were informed, before administering the instrument, that all the optional statements for each item are correct, and that they are required to rank the optional statements according to the way they like them, by assigning them the numbers 4 to 1 as follows:

4 For the statement that you like most (the most interesting to you)
3 For the statement that you like second best
2 For the statement that you like third best
1 For the statement that you like least (the least interesting to you)

Learners' cognitive preferences were determined by computing the sum of the scores for each cognitive preference mode for all five items. The cognitive preference mode with the highest score was considered the predominant one for that particular learner (Tamir & Lunetta, 1977).

3.8.7 Interview schedules

Two types of interview schedules, namely; one-to-one semi-structured interviews and focus group interviews, were used to collect qualitative data from educators and learners respectively. The interview schedules consisted of several questions formulated to obtain participants' opinions and views on specific themes.

Educator interview themes were: learners' performance in the study of genetics, educators' ability to identify learners' preconceptions, the appropriateness and effectiveness of the approach used to teach genetics in enhancing learner performance in life sciences, the relevance of studying genetics to learners' lives, and learners' interest in the study of genetics (appendix XIII). Focus group interviews were used to establish learners' views on their performance in genetics, the way genetics was taught, the relevance of the study of genetics to their lives, and their interest in the study of genetics and life sciences (appendix XIV).

Both interview schedules were developed by the researcher, and were given to three life sciences lecturers involved in instrument validation to comment on the suitability of the questions to elicit appropriate responses, and to check for errors. Comments from these educators were used to revise the schedules.

The procedure for conducting the focus group interviews involved the introduction of the interview topic by the researcher. This was followed by a series of prompting questions related to themes, at opportune times (Kitzinger, 1995). Learners discussed and debated the questions with minimum involvement and interference from the researcher. A research assistant video-recorded the interview sessions, and assisted with the categorisation and verification of some aspects of the interview protocols.

3.9 PILOT STUDY

Thirty-six Grade 11 learners (16 boys and 20 girls) participated in a pilot study. They were from a high school in Pretoria that had been randomly selected from schools that were not chosen for involvement in the main study. The purposes of the pilot study were:

- To collect data for further review and improvement of the instruments
- To determine the approximate effective duration for each instrument
- To collect data for determining the reliability of the instruments
- To check for logistic problems and errors before conducting the main study

Learners were informed of the purpose of the pilot study, their role in it, the anonymity and confidentiality of measures and the results, and their right to decline to participate if they wished.

The instruments developed in this study (LSAQ, GCKT, TOSIS, DMAT, PSAT, SCPI and interview schedules) were administered to the participants of the pilot twice. The time gap between the two administrations of the instruments was one month. The duration of one month was considered short enough for learners not to have gained considerable amounts of new knowledge at the second administration of the instruments, and sufficiently long for them not to remember their previous responses (in the first administration of the instruments) (Trochim, 2006).

The results from the first administration of the instruments were used to review the items of the instruments in order to improve them, and to determine the approximate duration of each instrument. The duration of each instrument was determined by estimating the time taken by the first learner, by half the number of learners, and by the last learner to finish writing the test or complete the instrument. The average of these durations constituted the duration of the instrument.

Results from the second administration of the instruments were used to further review the items and the durations of the instruments. Data from the first and second administrations of the instruments (LSAQ, GCKT, TOSIS, DMAT, PSAT and SCPI) were used to determine their reliabilities. According to Babbie (2011:129), “reliability is a measure of whether a particular technique or instrument applied repeatedly to the same object yields the same result each time". The test-retest method of testing reliability, which involves measuring the same object or phenomenon more than once, using the same technique or instrument (Field, 2009), was therefore used to test the reliabilities of the instruments used in this study.

The Pearson correlation coefficient was used to determine the relationship between the results of the two measurements (Field, 2009). Researchers (Gall & Borg, 2007; Nunnally, 1978) recommend a Pearson correlation coefficient of 0.7 or more for statistically reliable instruments. The results of the pilot study for the performance instruments yielded the following reliability coefficients (Pearson correlation coefficients) and durations: GCKT, p = 0.88, duration = 1 hour; TOSIS p = O.0.83, duration = 30 minutes; DMAT, p = 0.95, duration = 20 minutes; PSAT, p = 0.82, duration = 30 minutes; LSAQ, p = 0.93, duration = 15 minutes (appendix XV). All the performance instruments developed in this study were therefore considered reliable enough to be used in the main study.

A Fisher exact test (Stokes, Davis & Kock, 2000) was used to determine the association between the first and second administrations of the SCPI instrument, and a strong association (exact p = + <0.001) was found. A Fisher exact test was used because cognitive preferences are not presented in terms of numerical values, therefore the Pearson correlation coefficient could not be used to determine reliability. The duration of the SCPI was found to be approximately 10 minutes.

Finally, the two administrations of the instruments were used to check for possible logistical problems and shortcomings before the main study was conducted. The aspects observed included tools that could be required for each instrument (such as calculators, rulers, and pencils), special learner needs and others.

3.10 MAIN STUDY

The study commenced with the training of educators who taught the experimental group, followed by the pre-testing of learners. Thereafter, learners were taught genetics during the intervention. Post-testing and post-intervention interviews of participants concluded the main study. The researcher was present at all testing sessions (pre- and post-testing) in all participating schools. She attended the sessions as a passive observer to minimize her influence on the performance of the participants. The phases of the main study are described below.

3.10.1 Training of educators

The educators who taught the experimental group were trained on how to implement the developed context-based teaching materials, especially in relation to context-handling, regulation of learning and exertion of appropriate emphasis on knowledge development and the development of problem-solving, decision-making and science inquiry skills (see section 2.2.3 for explanation of these competences). The training also involved familiarization of the educators with the teaching materials.

Eight of the eleven volunteer educators from schools that had met the selection criteria (section 3.4) of the study took part in a two-day workshop facilitated by the researcher. Each educator was given a manual containing the context-based teaching materials and practical activities (see appendix VI for examples of teaching materials). The manual comprised notes to educators, an introduction to the teaching approach, the aims of the approach, a description of the five-phase learning cycle, the study themes, educators‘ and learners’ responsibilities during the implementation of the context-based materials, and instructions and procedures for conducting practical activities in the unit.

During the training workshop, the researcher explained the five phases of the learning cycle, demonstrated the implementation of the phases, and held trial runs with the educators on how to implement the phases. The use of a variety of teaching strategies during the content introduction phase was emphasized. At the end of the workshop, educators were given a week to study the teaching materials, and to prepare and present a context-based lesson of their choice to judges (university science education lecturers) and their peers. During presentations, the judges and peers were required to behave as though they were Grade 11 learners, and were asked to follow instructions from the presenter, and posit questions that Grade 11 learners would ask.

Presenters were judged according to criteria based on recommended educator competencies for context-based teaching (de Putter-Smits et al., 2009 - see section 2.2.2.6), which include the following:

- Level of confidence and competence in implementing the approach
    - ✓ Understanding of the context
    - ✓ Clear explanation of the context to learners
    - ✓ Ability to use contexts to guide learners to make meaning of the content
    - ✓ Guiding learners to transfer concepts to other contexts
- Ability to guide learners through the phases of the approach
    - ✓ Allowing learners enough time and freedom to construct their own understanding of concepts
    - ✓ Encouraging interactions among learners
    - ✓ Asking probing question
- Ability to identify and address learners' preconceptions
- Knowledge of genetics content

At the end of the presentations, three educators were selected, based on ratings from judges (90% consensus), to implement the context-based teaching approach in their respective schools as the experimental group. The educators who taught the control group were neither given a teaching manual nor trained to teach the genetics topic. This is because they were required to use the teaching materials and methods that they would normally employ in their day-to-day teaching of the topic. However, they (control group educators) were each given a list of the study themes and concepts which were contained in the context-based manual, so that learners from the experimental and control groups could be exposed to the same genetics content.

3.10.2 Pre-testing

Pre-testing involved administration of the six instruments developed in the study to the experimental and control groups. Before administering the instruments, the consent protocol used in the pilot study was followed. The instruments were administered to learners in this order: life science attitude questionnaire, science cognitive preference test, decision-making ability test, problem-solving ability test, test of science inquiry skills and genetics content knowledge test.

The attitude questionnaire was administered before the performance tests (DMAT, PSAT, TOSIS and GCKT) to minimize the influence of these tests, if any, on learners' responses to the attitude questionnaire.

The pre-test results for the science cognitive preference inventory were used to categorize learners according to their learning styles (section 3.7.6), whereas the results from other (performance) instruments were used to determine learner competence. This was necessary for comparison of the performances of the experimental and control groups before the intervention.

3.10.3 Administration of the study - intervention

After pre-testing, the control and experimental groups were taught the same genetics concepts, ideas and principles for seven weeks. Genetics lessons included most of the concepts, rules, principles and theories that appear in the South African life sciences curriculum statement (DoE, 2008). The experimental group were taught genetics using the developed context-based teaching materials and approach (section 3.7). The control group were taught using the materials and methods usually employed by educators when teaching genetics (traditional approaches).

3.10.4 Field visits

During the intervention period, lessons were conducted outside normal teaching and learning times, in accordance with the policy of the national department of education on educational research. The researcher made random visitations to both groups to observe the teaching, to video-record some lessons, and to discuss the progression of the programme. Follow-up meetings were held with participating educators from both groups, where necessary, to address logistical issues concerning the running of the programme. The experimental and control groups received approximately the same number of visits.

3.10.5 Post-testing and interviews

At the end of the seven-week intervention period, the same instruments administered in pre-testing were given again to the experimental and control groups in the same order. After the administration of the post-tests, post-intervention interviews were conducted with the six educators who taught the groups and volunteer learners from both groups. All interview sessions were video-recorded. The testing and interviewing of learners took place outside learning hours.

3.10.6 Potential threats to the validity of the study

Logically, experimental research requires the participants in the experimental and control groups to be relatively similar otherwise some participants may possess characteristics that could predispose them to success or failure during the experiment (Babbie, 2011). This requirement is usually addressed by random assignment of participants to treatment groups (Babbie, 2011). However, this is not practical in a school setting. The selection bias threat, posed by the non-random assignment of learners to the experimental and control groups, was addressed by using school selection criterion (section 3.4) that approximately equalized the characteristics of all the participating schools, thus minimizing discrepancies between the two groups.

The potential threat of experimental mortality, which entails participants dropping out during the experiment, was addressed by motivating participants to commit to the experiment. This was done by thoroughly explaining the importance and benefits of the study to the participants, and by issuing certificates of participation at the end of the programme. Ultimately, there was insignificant experimental mortality.

The design and nature of the study had built-in measures that addressed other threats to validity, such as the threats of testing, history, maturation, regression, and diffusion of treatment. These measures included long distances among participating schools, exposure of both groups to the same tests, pre-testing of the experimental and control groups, and the implementation of the study over a relatively short period.

3.11 PROCEDURES FOR ANALYSING DATA

The data obtained in this study were analysed as described in the ensuing sections.

3.11.1 Analysis of quantitative data

One of the challenges faced by the researcher during data processing was the enormous number of test scripts to be marked and collated into eligible data for analysis. Research assistants were therefore trained and deployed to mark the scripts and to capture the data. The use of research assistants posed the threat of inconsistency in the marking of the test scripts. To address this problem, marking rubrics were thoroughly explained to the research assistants. Trial marking runs on allocated questions were done by the research assistants. The marked scripts were re-assessed by the researcher together with the markers, before they were allowed to embark on a full-scale marking. Each assistant was given a marking rubric and was required to mark all the study scripts (from both the experimental and control groups) for the specific questions allocated to them. The researcher carried out random checks on all the marked scripts to assure uniformity in marking.

All learners who participated in the study were given codes, against which their quantitative results from the pre- and post-tests were recorded. Initially, descriptive statistics of mean scores ($\bar{x}$) and standard deviations (SD) were computed for scores from all the performance tests. These descriptive statistics were examined and tested to ensure that the required assumptions of normality (inspection of histograms), homogeneity (equality) of variance (Levene's test at 5% level of significance), homogeneity of regression slopes (customized analysis of covariance (ANCOVA) model on SPSS), and independence of covariates and treatment effects (t-test), for use with parametric statistical analyses had been met (Field, 2009). Where a variable failed a particular test, a proper data transformation was used to meet the required assumptions before performing parametric statistical analyses.

Once the assumptions for parametric tests had been met, the SAS® 9.2 (SAS Institute, 2008) was used to determine the statistical significance of differences in the mean scores of the experimental and control groups, using the inferential statistics of analysis of variance (ANOVA) and analysis of covariance (ANCOVA).

An ANOVA of the pre-test mean scores was computed to compare the competence of the experimental and control groups on all the learning outcomes – genetics content knowledge, test of science inquiry skills, decision-making ability test, problem-solving ability test, and life sciences attitude questionnaire. The ANOVA testing was necessary to assess the significance of differences, if any, between the abilities of the control and experimental groups prior to the intervention. Non-significant ANOVA results were considered to suggest congruence in the competence of the two groups in the learning outcomes before the intervention. The ANOVA of the pre-test scores for the two groups also addressed the ANCOVA assumption of the independence of covariate and treatment effect (Field, 2009).

Second, using pre-test scores as covariates, an ANCOVA of post-test mean scores was used as the main inferential statistic to compare the performances of the experimental and control groups after the intervention. ANCOVA was also used to determine the interactive influence of gender and learners' cognitive preferences on learner performance on the learning outcomes.

ANCOVA was used to compare post-test scores because in quasi-experimental non-equivalent pre-test–post-test control group design, the post-test scores may have a significant linear relationship with pre-test scores (Field, 2009; McDonald, 2009). For instance, the scores of learners in a pre-test may influence their post-test scores. Moreover, the use of non-equivalent treatment groups (experiment and control groups) in quasi-experimental designs may result in extraneous variables that could affect the post-test results (Field, 2009). Trochim (2006) contends that of all possible extraneous variables, the pre-test covariates are usually the most highly correlated with post-test scores. Hence removal of their influence from post-test scores eradicates more extraneous variability. It was against this background that it was considered necessary to assess the significance of treatment effects after covariance adjustment in ANCOVA. In all statistical testing of hypotheses in this study, a *p*-value equal to or less than 0.05 ($\alpha \leq 0.05$) was considered statistically significant at 5% significance level.

The analyses of learners' mean scores for the TOSIS, LSAQ and the assessment of the interactive effects of gender and cognitive preferences required further computations, which are discussed below.

3.11.1.1 Science inquiry skills

The TOSIS was designed to assess various science inquiry skills, as stated in section 3.7.2. As a result, it was deemed necessary to compare learners' performance on both the overall science inquiry skills and the specific science inquiry skills components (ability to formulate hypotheses, ability to identify variables, ability to design experiments, graphing skills competence, and ability to draw conclusions from (interpret) results. Descriptive ($\bar{x}$& SD) and inferential (ANOVA & ANCOVA) statistics were therefore conducted on the overall science inquiry skills and on the specific inquiry skills components.

3.11.1.2 Attitude towards the study of life sciences

To analyse learners' attitudes towards the study of life sciences, the options in the LSAQ were assigned scores of 1, 2, 3, 4 and 5 for Strongly disagree, Disagree, Undecided, Agree, and Strongly agree, respectively (see section 3.7.5). Therefore, for the items constituting the LSAQ, the lowest possible total score was 30 (30 items x 1 – the most negative attitude), while the highest possible total score was 150 (30 items x 5 - the most positive attitude). The median score of 75 (150/2) was considered to represent neutral attitude towards the study of life sciences. Based on these criteria, total scores of more than 75 were regarded as representing a positive attitude, with the strength of the positivity increasing as the score approached 150. Conversely, total scores of less than 75 were considered to represent a negative attitude, with the strength of the negativity increasing as the score approached 30.

Analysis of the difference in attitudes towards life sciences between the experimental and control groups was done on two levels. The first level involved the comparison of learners' attitudes on the overall LSAQ, which was done in three steps. First, the total score of each learner for the thirty items in the instrument was computed. Second, the average of the total scores of learners was calculated for the experimental and control groups (i.e. sum of the total learner scores, divided by the total number of learners in the group). Third, the mean scores of the control and experimental groups were compared using ANOVA and ANCOVA for the pre-test and post-test respectively, to determine whether there were significant differences in the overall attitudes of the two groups towards the study of life sciences.

The second level of analysis involved the comparison of learners' attitudes in the specific categories of life science attitude (application of life sciences / genetics to everyday life; learners' perceptions of life science lessons/classes; learners' perceptions of life science career prospects; learners' opinions of genetics as a topic; and learners' opinions of life sciences as a subject). To compare learner attitudes in these categories of the LSAQ, first, mean scores were calculated for each item (for example, the sum of learners' scores on item 1 divided by 30). Second, for each item in the LSAQ, the mean scores for the experimental and control groups were compared using ANOVA for the pre-test and ANCOVA for the post-tests. This comparison was meant to determine whether there were significant differences in the attitudes of the two groups towards each item statement.

Third, the LSAQ items were then grouped according to the life science attitude categories (see above). The significance of differences between the mean scores of the experimental and control groups in these categories were assessed by inspecting the mean scores and p-values of the individual items in each category.

3.11.1.3 Interactive influence of gender, cognitive preferences and treatment

The interactive influences of gender and cognitive preferences on the attainment of the learning outcomes were assessed using only the post-test results. This was because the researcher was more interested in understanding how these intervening variables interacted with the teaching approaches used in the study in attaining the learning outcomes. However, pre-test mean scores were used as covariates in the ANCOVA employed to assess these interactive influences.

An ANCOVA involving a 2 x 2 factorial design was used to assess the interactive influence of gender and treatment on the attainment of the learning outcomes, while an ANCOVA involving a 2 x 4 factorial design was used to assess the interactive influence of cognitive preferences. The compound interactive influence of gender and cognitive preferences and treatment on the attainment of the learning outcomes was measured using an ANCOVA involving a 2 x 2 x 4 factorial design. Factorial designs were used because of the need to assess treatment variations, and to examine interactive effects at the same time (Gall & Borg, 2007; Trochim, 2006).

3.11.2 Analysis of qualitative data

To analyse the qualitative data, video recordings taken during learner and educator interviews were transcribed from the videotapes into written texts. In order to identify the sources of the transcripts, participating learners displayed cards bearing their identification codes during the interviews. Each transcript was written against the identification code of the source (the participating learner). The transcribed and coded scripts were assigned to pre-determined interview themes. The themes were learner perceptions of performance in genetics; the way genetics was taught; relevance to their lives of studying genetics; and their interest in the study of genetics.

For educator interviews, responses were also coded and categorized into the themes of learners' performance in the study of genetics and life sciences; educators' ability to identify learner preconceptions; appropriateness and effectiveness of the approach used to teach genetics in enhancing performance in life sciences; the relevance of studying genetics to learners' lives; and learners' interest in the study of genetics and life sciences.

Each interview theme consisted of many transcribed texts, which were carefully examined to determine the overall (or general) views and opinions of the control or experimental groups. Recurring views or statements were regarded as representing the popular (overall) view of the group for the theme under consideration. Popular views and opinions for each theme were determined in collaboration with a research assistant who examined the responses independently and drew his own conclusions.

The recorded overall views of learners and educators from the experimental and control groups were compared, and assessed in relation to the quantitative data, for triangulation of information and for clarification of quantitative data. These overall views and comparisons formed the basis for discussing the findings of the study.

3.12 ETHICAL CONSIDERATIONS

In conducting this study, the ethical requirements of the Faculty of Education of the University of Pretoria, were adhered to. These are discussed in the sections below.

3.12.1 Ethical considerations before data collection

Permission to conduct the study in schools was sought beforehand from the Gauteng Provincial Department of Education (appendix XXIII) and the principals of the participating schools (appendix XXIV). After clearance was received from these authorities, written consent was obtained by the researcher from participating educators (appendix XXV) and the parents of all participating learners (appendix XXVI).

3.12.2 Ethical considerations during data collection

At the commencement of the study, its essence and potential benefits, including its objectives, the roles of learners and educators, and possible harm to the participants were thoroughly explained to participating learners and educators. Participants were informed of their right to withdraw from the research at any time during the course of the study (without repercussion), if they wished to do so.

Participating schools, educators and learners were assured of the anonymity and extent of confidentiality of the study results. To this end, schools and participants were given codes to use as identity numbers instead of their names. The need to use a video recorder was explained, and participants were informed that use of pictures of participants in the dissertation or its products, if necessary, would only be done with their approval and that of the relevant authorities. Participants were also informed of their right to refuse to be video-recorded. Further, participants were told that the data collected during the study would be stored in a safe place at the University of Pretoria, and would be destroyed after the number of years recommended by the Ethics Committee. Finally, to minimise the disruption of classes, study lesson sessions were held only after normal learning time.

3.12.3 Ethical considerations during data processing and analysis

The use of research assistants to mark test scripts and collate the data posed the risk of compromising confidentiality and anonymity. To address this problem, codes were used for recording data from all the participants and participating schools, so that they remained anonymous to the research assistants. The use of research assistants to mark and process data also lessened the possibility of researcher bias during these activities.

3.12.4 Ethical considerations during thesis writing and dissemination of research

To the best of the researcher's knowledge, the thesis does not contain falsified information, and all findings reported in it are a true reflection of the data obtained. As stipulated, a copy of the thesis will be presented to the University of Pretoria, which is the custodian of all research conducted under its jurisdiction. To maintain confidentiality and anonymity during the writing of the thesis and dissemination of the research, codes were used in all references to the participants or participating schools. Pictures of participants and participating schools were not included in the thesis. In addition, all data collected during the study will be stored in a safe place at the University of Pretoria, and will be disposed of at the recommended time.

3.13 CHAPTER SUMMARY

The study sought to assess the comparative effectiveness of context-based and traditional teaching approaches in enhancing the performance of Grade 11 learners in life sciences. To do so, a mixed research method (QUAN/Qual) was employed, in which the primary data were collected using a quasi-experimental non-equivalent pre-test–post-test control group design and surveys. Supplementary qualitative data were gathered from learner focus group interviews and educator one-to-one interviews in order to augment and triangulate certain aspects of the quantitative data, and to provide greater insight into the results.

A survey involving Grade 12 learners was used to determine contexts considered relevant, interesting and accessible for the study of genetics. The results of the survey were used in developing context-based teaching materials. Several instruments were designed to measure learners' competence in the learning outcomes considered in the study. Data from the use of these instruments were assed using ANOVA and ANCOVA, while qualitative data were transcribed, coded and analysed. The ethical measures taken in the study were discussed.

CHAPTER FOUR

STUDY RESULTS

4.1 INTRODUCTION

This chapter presents the quantitative and qualitative results of the study. The quantitative results are presented first, because the qualitative data were used to augment the initial (quantitative) results.

4.2 QUANTITATIVE RESULTS

The quantitative part of the study focused on the first two research questions (section 1.5). In an attempt to answer the research questions, four hypotheses were tested to determine the significance of performance differences between the experimental and control groups, and the interactive influences of gender and cognitive preferences, if any, on the attainment of the following learning outcomes:

1. Genetics content knowledge (GCKT)
2. Science inquiry skills (TOSIS)
3. Decision-making ability (DMAT)
4. Problem-solving ability (PSAT)
5. Attitude towards the study of life sciences (LSAQ)

(The abbreviations in brackets are the codes that were used to represent the tests used to assess learner performance).

4.2.1 Comparison of learner performance in genetics, science inquiry skills, decision-making, problem-solving abilities and attitude towards the study of life sciences

Research question 1

How would learners exposed to a context-based teaching approach differ from those exposed to traditional teaching approaches with respect to the attainment of genetics content knowledge, science inquiry skills, decision-making ability, problem-solving ability, and their attitude towards the study of life sciences?

Null hypothesis 1

Ho 1 There is no significant difference between learners exposed to a context-based teaching approach and those exposed to traditional teaching approaches in the attainment of genetics content knowledge, science inquiry skills, decision-making ability, and problem-solving ability and their attitude towards the study of life sciences.

The results for testing this hypothesis are organised by first presenting a summary of the pre-test and post-test statistics for all the learning outcomes (descriptive statistics: mean scores ($\bar{x}$) and standard deviations (SD), and inferential statistics: F values and *p*- values). Second, the results of the analysis of variance (ANOVA) of pre-test mean scores, which compare learner performances prior to the intervention, are given. This is followed by the results of an analysis of covariance (ANCOVA of post-test mean scores, which compare learner performances after the intervention.

Table 4.1 Summary of pre-test and post-test descriptive and inferential statistics for the assessed learning outcomes (LSAS, GCKT, TOSIS, DMAT, PSAT)

Test	Treatment	Pre-test					Post-test				
		N	Mean ($\bar{x}$)	SD	F - value	*p*-value	N	Mean ($\bar{x}$)	SD	F value	*p*-value
GCKT	E	87	10.21	5.15			85	26.68	11.14		
	C	101	10.35	5.31			93	15.46	7.6		
	Difference		-0.14		0.03	**0.861**		11.22	3.54	63.00	**<0.0001***
TOSIS	E	86	23.95	11.61			80	28.92	10.74		
	C	99	23.38	10.75			86	25.41	13.61		**0.0654**
	Difference		0.57		0.12	**0.7296**		3.51	-2.87	3.44	
DMAT	E	87	58.32	23.62			85	68.3	18.85		
	C	94	52.23	22.25			86	54.7	24.79		
	Difference		6.09		3.19	**0.0759**		13.6	-5.94	17.22	**<0.0001***
PSAT	E	88	29.69	21.31			86	48	25.8		
	C	96	30.63	20.51			88	34.06	19.53		
	Difference		-0.94		0.09	**0.7629**		13.94	6.27	16.57	**<0.0001***
LSAQ	E	86	121.66	10.78			77	127.96	9.98		
	C	99	122.37	10.49			82	117.16	17.73		
	Difference		-0.71		0.21	**0.6504**		10.8	-7.75	25.04	**<0.0001***

KEY: * Indicates a significant treatment effect at α = 5% significance level.

GCKT:	Genetics Content Knowledge Test	E:	Experimental group
TOSIS:	Test of Science Inquiry Skills	C:	Control group
DMAT:	Decision-Making Ability Test	SD:	Standard deviation
PSAT:	Problem-Solving Ability Test		
LSAQ:	Life Sciences Attitude Questionnaire		

Table 4.1 shows that there were no significant differences between the mean scores and standard deviations (SD) of the experimental and control groups in all the learning outcomes prior to the intervention. However, after the intervention, there were significant differences between the mean scores and standard deviations of the experimental and control groups in all the learning outcomes, except in the attainment of overall science inquiry skills. Detailed pre-test and post-test results for each learning outcome are presented below.

4.2.1.1 Attainment of genetics content knowledge

Ho 1.1 *There is no significant difference in their attainment of genetics content knowledge between learners exposed to the context-based teaching approach and those exposed to traditional teaching approaches.*

The results of testing this hypothesis showed that the pre-test mean score for the control group was 10.35 ± 5.31, and for the experimental group was 10.21 ± 5.15 (table 4.2(a)). ANOVA results (table 4.2(a)) showed no significant difference between the pre-test mean scores of the control and experimental groups (F [1,186] = 0.03 and a p = 0.8610) at 5% significant level. Learners from the control and experimental groups could therefore be assumed to have had approximately the same genetics content knowledge prior to the intervention.

Table 4.2(a) Pre-test mean scores ($\bar{x}$), standard deviations (SD) and ANOVA results for genetics content knowledge (GCKT)

Treatment	Pre-test				
	N	Mean ($\bar{x}$)	SD	F -value	*p*-value
E	87	10.21	5.15	0.03	**0.861**
C	101	10.35	5.31		
Difference		-0.14			

The post-test mean scores of the control and experimental groups were 15.46 ± 7.6 and 26.68 ± 11.14 respectively (table 4.2(b)). The results of an ANCOVA to compare the post-test mean scores for the experimental and control groups are shown in table 4.2(b).

Table 4.2(b) Post-test mean scores ($\bar{x}$), standard deviations and ANCOVA results for genetics content knowledge (GCKT)

Treatment	Post-test		
	N	Mean ($\bar{x}$)	SD
Experiment	85	26.68	11.14
Control	93	15.46	7.6
Difference		11.22	3.54

Source of variation	F	Sum of Squares	Mean Square	F Value	*p*-value
TREATMENT	1	5579.741514	5579.741514	63.00	<.0001
GCKT_RG	1	234.142064	234.142064	2.64	0.1058
Error	175	15498.182700	88.561040		
Corrected Total	177	21258.818140			

These ANCOVA results show a significant difference at 5% significant level between the post-test mean scores of the control and experimental groups (F [1,175] = 63.00, *p* = <.0001; table 4.2(b)) in favour of the experimental group. According to these results, the experimental group performed significantly better than the control group in attaining genetics content knowledge. Therefore, the null hypothesis that there is no significant difference between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches in their attainment of genetics content knowledge was rejected.

4.2.1.2 Attainment of science inquiry skills

Ho 1.2 There is no significant difference between learners exposed to context-based teaching approach and those exposed to traditional teaching approaches, in their attainment of science inquiry skills.

The analysis of learner performance on science inquiry skills was divided into two parts: overall attainment of science inquiry skills; and attainment of specific components of science inquiry skills (discussed below).

(i) Attainment of overall science inquiry skills

Table 4.3(a) shows the pre-test mean scores ($\bar{x}$), standard deviations (SD) and the inferential statistics for learners' attainment of overall science inquiry skills.

Table 4.3(a) Pre-test mean scores ($\bar{x}$), standard deviations (SD) and ANOVA results for science inquiry skills (TOSIS)

Treatment	Pre-test				
	N	Mean ($\bar{x}$)	SD	F - value	*p*-value
Experiment	86	23.95	11.61	0.12	**0.7296**
Control	99	23.38	10.75		
Difference		0.57			

According to the results in table 4.3(a) above, the ANOVA showed no significant difference between the competence of the control and experimental groups in overall science inquiry skills prior to the intervention (F [1,183] = 0.12 and p = 0.7296; table 4.3(a)). The overall science inquiry skills competence of the two groups was therefore assumed to be approximately the same before the intervention.

The post-test mean scores and standard deviations were 25.41 $\pm$ 13.61 for the control group, and 28.92 $\pm$ 10.74 for the experimental group, with a mean difference of 3.51 (table 4.3(b)). ANCOVA results for these mean scores showed no significant difference at 5% significance level (F= 3.44, p = 0.0654; table 4.3(b)). This result means that the competence of the control and experimental groups in overall science inquiry skills was approximately the same after the intervention.

Table 4.3(b) Post-test mean scores ($\bar{x}$), standard deviations and ANCOVA results for overall science inquiry skills (TOSIS)

Treatment	Post-test		
	N	Mean ($\bar{x}$)	SD
Experiment	80	28.92	10.74
Control	86	25.41	13.61
Difference		3.51	-2.87

Source of variation	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	***p* - value**
TREATMENT	1	511.1988710	511.1988710	3.44	0.0654
RTOT	1	627.1296884	627.1296884	4.22	0.0415
Error	163	24221.3927000	148.5975000		
Corrected Total	165	25397.2590400			

Based on this result, the hypothesis that there is no significant difference in their attainment of science inquiry skills between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches was not rejected.

(ii) Attainment of specific components of science inquiry skills (OT1–OT5)

A summary of the pre-test and post-test mean scores, standard deviations and inferential statistics for specific components of TOSIS is shown in table 4.4 below.

Table 4.4 Summary of pre-test and post-test statistics for the components of the Test of Science Inquiry Skills (TOSIS; T1 to T5)

Category of inquiry skills	Treatment	PRE-TEST SCORES					POST-TEST SCORES				
		N	mean($\bar{x}$)	SD	F-value	*p*-value	N	Adjusted mean ($\bar{x}$)	SD	F-value	*p*-value
OT1	E	86	3.6046	4.5930	2.80	0.0962	80	5.8971	2.3639	33.21	<.0001*
	C	98	4.2857	2.7806			85	3.9085	2.0549		
OT2	E	86	3.61492	3.6149	0.13	0.7222	80	4.1317	3.7123	0.00	0.9866
	C	98	4.79591	4.0562			86	4.1216	3.9994		
OT3	E	86	5.6395	4.5242	1.94	0.1657	80	7.7157	6.8410	0.05	0.8273
	C	98	6.5816	4.6305			86	7.4736	7.3063		
OT4	E	86	7.3255	6.0729	4.29	0.0398*	80	5.8380	4.1643	0.54	0.4642
	C	98	5.3061	7.0277			86	6.5459	7.5401		
OT5	E	86	2.7906	3.8043	0.06	0.8034	86	5.3860	4.7212	7.70	0.0062*
	C	98	2.6530	3.6752			79	3.4244	4.4233		

KEY: * Indicates a significant treatment effect at α = 5% significance level.

OT1: Ability to formulate hypotheses
OT2: Ability to identify variables
OT3: Ability to design experiments
OT4: Graphing skills
OT5: Ability to draw conclusions from results

SD: Standard deviation
E: Experimental group
C: Control group

The results in table 4.4 show that an ANOVA of pre-test scores for the components of TOSIS showed no significant difference between the performances of the control and experimental groups (OT1- F [1,182] = 2.80, *p*=0.096; OT2 - F [1,182] = 0.13, *p*=0.722; OT3 - F [1,182] = 1.94, *p*=0.166; and OT5 - F [1,182] = 0.06, *p*=0.803), except for graphing skills, where a significant difference was observed between the performances of the experimental and control group (OT4 - F [1,182] = 4.29, *p*=0.040; table 4.4) in favour of the experimental group.

The post-test ANCOVA results showed a significant difference in the ability to formulate hypotheses (OT1 - F [1,162] = 33.21, *p*=<0.0001; table 4.4) and to draw conclusions from results (OT5 - F[1.162] = 7.70, *p*=0.006; table 4.4) at 5% significant level, in favour of the experimental group. No significant differences were observed between the performances of the two groups for the science inquiry skills of identification of variables, experimental design, and graphing skills (OT2 - F [1,163] = 0.00, *p*=0.9866; OT3 - F [1,163] = 0.05, *p*=0.827; and OT4 - F [1,163] = 0.54, *p*=0.464; table 4.4).

4.2.1.3 Attainment of decision-making ability

Ho 1.3 There is no significant difference in their attainment of decision-making ability between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches.

Comparison of the pre-test mean scores of the control and experimental groups using an ANOVA showed no significant differences between the performances of the two groups on decision-making ability (F [1,179] = 3.19, *p*=0.0759; table 4.5(a)).

Table 4.5(a) Pre-test mean scores ($\bar{x}$), standard deviations (SD) and ANOVA results for decision-making ability (DMAT)

Treatment	**Pre-test**				
	N	**Mean ($\bar{x}$)**	**SD**	**F - value**	***p*-value**
Experiment	87	58.32	23.62	3.19	**0.0759**
Control	94	52.23	22.25		
Difference		6.09			

The ANCOVA results on learner performance in the decision-making ability test (DMAT) showed a significant difference between the performances of the control and experimental groups (F [1,168] = 17.22, *p* = <0.0001; table 4.5(b)) in favour of the experimental group. This result suggests that learners from the experimental group showed a higher decision-making ability than those from the control group after the intervention.

Table 4.5(b) Post-test mean scores ($\bar{x}$), standard deviations and ANCOVA results for decision-making ability (DMAT)

Treatment	Post-test		
	N	Mean ($\bar{x}$)	SD
Experiment	85	68.3	18.85
Control	86	54.7	24.79
Difference		13.6	-5.94

Source of variation	DF	Sum of Squares	Mean Square	F Value	*p* – value
TREATMENT	1	7748.441415	7748.441415	17.22	<.0001
DMAT_RD	1	6488.142102	6488.142102	14.42	0.0002
Error	168	75587.931770	449.92817		
Corrected Total	170	92134.502920			

Therefore, the null hypothesis that there is no significant difference in their attainment of decision-making ability between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches was rejected.

4.2.1.4 Attainment of problem-solving-ability

Ho 1.4 There is no significant difference between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches, in their attainment of problem-solving ability.

Comparison of the pre-test mean scores of the experimental and control groups, using an ANOVA, revealed a non-significant difference between the performances of the two groups before the intervention (F [1,182] = 0.09, *p* = 0.7629; table 4.6(a)).

Table 4.6(a) Pre-test mean scores ($\bar{x}$), standard deviations (SD) and ANOVA results for problem-solving ability (PSAT)

Treatment	Pre-test				
	N	Mean ($\bar{x}$)	SD	F - value	*P*- value
Experiment	88	29.69	21.31	0.09	**0.7629**
Control	96	30.63	20.51		
Difference		-0.94			

An ANCOVA of the experimental and control post-test mean scores showed that learner performance on the problem-solving ability test (PSAT) differed significantly at 5% significant level in favour of the experimental group (F [1,171] = 16.57, *p*=<0.0001; table 4.6(b)).

Table 4.6(b) Post-test mean scores ($\bar{x}$), standard deviations and ANCOVA results for problem-solving ability (PSAT)

Treatment	Post-test		
	N	Mean ($\bar{x}$)	SD
Experiment	86	48	25.8
Control	88	34.06	19.53
Difference		13.94	6.27

Source of variation	DF	Sum of Squares	Mean Square	F Value	*p* - value
TREATMENT	1	8452.76672	8452.766720	16.57	<.0001
PSAT_RP	1	2537.65115	2537.651151	4.98	0.0270
Error	171	87219.20006	510.05380		
Corrected Total	173	98268.53448			

According to these results, learners from the experimental group showed higher problem-solving ability than those from the control group after the intervention. The null hypothesis that there is no significant difference in their attainment of problem-solving ability between learners exposed to context-based teaching approaches and those exposed to traditional teaching approaches was therefore rejected.

4.2.1.5 Learners' attitude towards the study of life sciences

Ho 1.5 There is no significant difference in their attitude towards the study of life sciences between learners exposed to context-based teaching approach and those exposed to traditional teaching approaches.

(i) Overall learner attitude towards the study of life sciences

The maximum possible score (most positive attitude) for LSAQ was 150. A score of 75 (150/2) represented a neutral attitude, and the minimum possible score (most negative attitude) was 30. Thus a score of more than 75 represented a positive attitude, while a score of less than 75 represented a negative attitude (see section 3.10.1.2).

The pre-test mean scores and standard deviations ($\bar{x}\pm$ SD) of the control and experimental groups were 122.37 $\pm$ 10.49 and 121.66 $\pm$ 10.78 respectively, (table

4.7(a)). The mean scores of both groups were above the 75 score, which implies that both groups had a relatively positive attitude towards the study of life sciences before the intervention. An ANOVA of pre-test LSAQ mean scores showed no significant difference between the pre-test mean scores of the control and experimental groups (F[1,183] = 0.21 *p*=0.6504; table. 4.7a), at the 5% significance level.

Table 4.7(a) Pre-test mean scores ($\bar{x}$), standard deviations (SD) and ANOVA results for attitude towards life sciences (LSAQ)

Treatment	Pre-test				
	N	Mean ($\bar{x}$)	SD	F - value	*P*- value
Experiment	86	121.66	10.78		
Control	99	122.37	10.49		
Difference		-0.71		0.21	**0.6504**

The post-test mean scores and standard deviations of the control and experimental groups were (117.16 $\pm$ 17.73) and (127.96 $\pm$ 9.98) respectively (table 4.7(b)). ANCOVA results revealed a significant difference between attitudes of the two groups towards the study of life sciences (F [1,156] = 25.04, *p*=<0.0001), at 5% significant level (table 4.7(b)). The experimental group had a more positive overall attitude towards the study of life sciences than the control group.

Table 4.7(b) Post-test mean scores ($\bar{x}$), standard deviations and ANCOVA results for attitude towards life sciences (LSAQ)

Treatment	Post-test		
	N	Mean ($\bar{x}$)	SD
Experiment	77	127.96	9.98
Control	82	117.16	17.73
Difference		10.8	-7.75

Source of variation	DF	Sum of squares	Mean square	F Value	*p*-value
TREATMENT	1	4609.062600	4609.062600	25.04	<.0001
RATOT	1	4316.766395	4316.766395	23.45	<.0001
Error	156	28719.442030	184.098990		
Corrected Total	158	37145.823900			

Therefore the null hypothesis that there is no significant difference in their overall attitude towards the study of life sciences between learners exposed to the context-based teaching approach and those exposed to traditional teaching approaches was rejected.

(ii) Learner attitude according to categories of the study of life sciences

To further explore the significance of the treatment effect on learners' attitude towards the study of life sciences, individual LSAQ items were grouped according to these attitude categories: the application of life sciences to everyday life (ATT1); life science lessons/classes (ATT2); life science-related career prospects (ATT3); genetics as a topic (ATT4), and life sciences as a school subject (ATT5).

ANOVA of the LSAQ pre-test mean scores showed no significant differences between the attitudes of the control and experimental groups for all LSAQ items, except item RA5 (I admire people who are knowledgeable in life sciences), in which the control group showed a more positive attitude than the experimental group (p= 0.037; appendix XVI).

Statistical comparisons (ANCOVA) of post-test mean scores on specific attitude statements showed significant differences between the experimental and control groups on a number of items in favour of the experimental group (table 4.8).

Table 4.8 Comparison of post-test control and experimental mean scores ($\bar{x}$) for LSAQ items according to LSAQ categories

Item Code	Item statement	N	Control MEAN ($\bar{x}$) ± SD	N	Experiment MEAN ($\bar{x}$) ± SD	p-value
CATEGORY (ATT 1): APPLICATION OF LIFE SCIENCES / GENETICS TO EVERY DAY LIFE						
OA2	Without the study of life sciences, it would be difficult to understand life.	81	3.936 ± 1.065	77	3.951 ± 0.857	0.9225
OA6	I like studying life sciences because of its importance in understanding the environment.	80	4.046 ± 1.168	77	4.289 ± 1.049	0.1740
OA8	What is taught in genetics cannot be used in everyday life.	81	4.285 ± 0.746	77	4.441 ± 0.639	0.1623
OA17	Ideas in genetics are not related to human needs.	82	4.284 ± 0.933	76	4.312 ± 0.867	0.8486
OA24	What is learnt in life sciences can be applied to our daily lives.	80	4.350 ± 0.969	77	4.584 ± 0.767	0.0983
OA27	Discoveries in life sciences and genetics have improved human life.	80	3.899 ± 1.023	77	4.391 ± 0.566	0.0003*
CATEGORY (ATT 2): LEARNERS' PERCEPTION OF LIFE SCIENCE/GENETICS LESSONS / CLASSES						
OA3	Performing practical activities in genetics helps me to understand genetics concepts and ideas better.	80	4.388 ± 0.665	77	4.545 ± 0.597	0.1228
OA11	There are too many concepts (ideas) to learn in genetics, as a result, I have lost interest in the topic.	81	3.518 ± 1.352	76	3.881 ± 1.222	0.0809
OA12	I do not bother about what we learn in genetics because I do not understand them.	81	4.356 ± 0.899	77	4.587 ± 0.784	0.0857
OA14	I usually feel like running out of the class during life science lessons.	81	4.151 ± 1.188	77	4.512± 0.883	0.0304*
OA18	I do not understand genetics lessons.	82	3.865 ± 1.124	77	4.391 ± 0.712	0.0004*
OA20	I feel quite happy when it is time for genetics lessons.	81	3.727 ± 1.109	77	4.040 ± 0.857	0.0456*
OA22	I really enjoy the life science lessons which deal with my daily life experiences.	80	4.310 ± 1.003	77	4.496 ± 0.883	0.2152

Table 4.8 Cont. Comparison of post-test control and experimental mean scores ($\bar{x}$) for LSAQ items according to LSAQ categories

Item Code	Item statement	N	Control MEAN ($\bar{x}$) $\pm$ SD	N	Experiment MEAN ($\bar{x}$) $\pm$ SD	p-value
CATEGORY (ATT 3): LEARNERS' PERCEPTION OF LIFE SCIENCE CAREER PROSPECTS						
OA10	My future career/profession has nothing to do with genetics, so I don't study it a lot.	80	4.004 $\pm$ 1.169	77	4.217 $\pm$ 0.995	0.2237
OA13	Genetics will be very useful in my future career/ profession. I therefore want to study it very well.	81	3.879 $\pm$ 1.187	77	4.100 $\pm$ 1.021	0.2087
OA21	I hope to study genetics and life sciences further, because I want to take up a career in medicine.	82	3.511 $\pm$ 1.219	77	3.780 $\pm$ 1.096	0.1472
OA25	I will have fewer job opportunities if I study genetics and life sciences.	81	4.133 $\pm$ 1.081	77	4.211 $\pm$ 0.864	0.6213
CATEGORY (ATT 4): LEARNERS' OPINION OF GENETICS AS A TOPIC						
OA1	Genetics is an interesting topic to study.	81	4.301 $\pm$ 1.008	77	4.683 $\pm$ 0.471	0.0026*
OA7	Genetics is a difficult topic.	81	3.409 $\pm$ 1.034	77	3.713 $\pm$ 0.092	0.0530
OA9	I enjoy studying genetics.	78	4.196 $\pm$ 1.106	77	4.359 $\pm$ 0.826	0.3041
OA23	I don't like studying genetics.	81	4.202 $\pm$ 0.993	77	4.437 $\pm$ 0.805	0.0950
OA30	I like setting difficult tasks for myself when studying genetics.	82	3.652 $\pm$ 1.280	77	3.968 $\pm$ 1.224	0.1180
CATEGORY (ATT 5): LEARNERS' OPINION OF LIFE SCIENCE AS A SUBJECT						
OA4	Life sciences is more difficult than other science subjects.	81	3.779 $\pm$ 1.084	77	4.194 $\pm$ 0.904	0.0102*
OA5	I admire people who are knowledgeable about life sciences.	80	4.120 $\pm$ 0.882	77	3.979 $\pm$ 0.938	0.3388
OA15	I enjoy studying life sciences.	82	4.160 $\pm$ 0.975	77	4.453 $\pm$ 0.787	0.0373*
OA16	Studying life sciences is a waste of time.	81	4.311 $\pm$ 1.169	77	4.803 $\pm$ 0.539	0.0010*
OA19	I do not agree with many ideas (concepts) in life sciences.	81	3.734 $\pm$ 1.049	77	4.111 $\pm$ 0.932	0.0171*
OA26	Life sciences is an easy subject.	82	3.248 $\pm$ 1.277	77	3.827 $\pm$ 0.812	0.0008*
OA28	Life sciences is not my favourite subject.	79	3.913 $\pm$ 1.194	77	4.258 $\pm$0.772	0.0335*
OA29	I sometimes avoid studying life sciences.	82	3.555 $\pm$1.187	76	4.099 $\pm$0.982	0.0020*

* Indicates a significant treatment effect at α = 5% significance level.

The items in which the experimental group showed a more positive attitude than the control group included these statements:

- OA1: Genetics is an interesting topic to study
- OA4: Life sciences is more difficult than other science subjects
- OA14: I usually feel like running out of the class during life science lessons;
- OA15: I enjoy studying life sciences
- OA16: Studying life sciences is a waste of time
- OA18: I do not understand genetics lessons
- OA19: I do not agree with many ideas (concepts) in life sciences
- OA20: I feel quite happy when it is time for genetics lessons
- OA26: Life sciences is an easy subject
- OA27: Discoveries in life sciences and genetics have improved human life
- OA28: Life sciences is not my favourite subject
- OA29: I sometimes avoid studying life sciences (table 4.8).

Of these 12 items, eight (OA1, OA4, OA15, OA16, OA19, OA26, OA28 & OA29, table 4.8) are about learner attitudes towards the study of genetics as a topic and life sciences as a subject. This result suggests that after the intervention, learners from the experimental group appreciated the study of genetics and life sciences more than those from the control group. Three of the twelve items (OA14, OA18& OA20) are about learner perceptions of life science lessons/classes. It appears that after the intervention, learners from the experimental group appreciated and enjoyed life science lessons more than their counterparts from the control group, and had a better understanding of genetics lessons.

The ANCOVA results showed non-significant treatment effects for items that associated the study of life sciences with career prospects. Similarly, there was no significant treatment effect on items linking the study of life sciences and genetics with everyday life (table 4.8). Item OA5 (I admire people who are knowledgeable about life sciences), in which the control group had a more positive attitude than the experimental group in the pre-test (appendix XVI), showed a non-significant difference between the mean scores of the two groups in the post-test (table 4.8).

In summary, before the intervention the attitudes of the experimental and control groups towards the study of life sciences were positive and approximately the same. However, after the intervention, learners from the experimental group showed a more positive attitude towards the study of life sciences than those from the control group.

Research question 2

Would there be any interactive influences of gender and cognitive preferences, on learner attainment of the learning outcomes?

In an attempt to answer this research question, three hypotheses were tested in relation to the interactive influences of gender, cognitive preferences, and the collective interactive influence gender and cognitive preferences on the acquisition of the learning outcomes.

4.2.2 Interactive influence of gender and treatment

NULL HYPOTHESIS 2

Ho.2 *There is no significant interactive influence of gender on learners' attainment of genetics content knowledge, science inquiry, problem-solving, decision-making abilities, and their attitude towards the study of life sciences.*

The results of a 2 x 2 factorial ANCOVA showed no significant interactive influence of gender on learner performance on all the learning outcomes assessed: ([GCKT: F (1,173) = 0.360,*p*=0.5497], [TOSIS: F(1,161) =2.64, *p*=0.1059], [DMAT: F(1,166) = 0.38, *p*=0.5372], [PSAT: F(1.169) = 0.61, *p*=0.4353], and [LSAQ: F(1, 154) = 0.16,*p*=0.6859], table 4.9).

Table 4.9 Summary of post-test statistics for the interactive influence of gender on the learning outcomes (GCKT, TOSIS, DMAT, PSAT, LSAQ)

Dependant Variable	Treatment	Gender	N	Mean ± SD	F- value	*p*-value
GCKT	C	F	49	16.499 ± 8.639	**0.36**	**0.5497**
		M	44	14.370 ± 6.154		
	E	F	55	26.736 ± 10.749		
		M	30	26.485 ± 12.001		
TOSIS	C	F	45	28.444 ± 14.453	**2.64**	**0.1059**
		M	41	21.951 ± 11.878		
	E	F	50	28.980 ± 10.389		
		M	30	29.000 ± 11.477		
DMAT	C	F	45	56.444 ± 26.038	**0.38**	**0.5372**
		M	41	50.976 ± 23.324		
	E	F	54	69.444 ± 19.074		
		M	31	68.710 ± 18.751		
PSAT	C	F	47	32.660 ± 20.848	**0.61**	**0.4353**
		M	41	35.610 ± 18.034		
	E	F	55	49.273 ± 26.095		
		M	31	45.806 ± 25.531		
LSAQ	C	F	42	116.833 ± 20.376	**0.16**	**0.6859**
		M	40	118.125 ± 14.678		
	E	F	46	127.261 ± 9.715		
		M	31	128.194 ± 10.512		

KEY:				
	GCKT:	Genetics Content Knowledge Test	E:	Experimental group
	TOSIS:	Test of Science Inquiry Skills	C:	Control group
	DMAT:	Decision-Making Ability Test	M:	Male learners
	PSAT:	Problem-Solving Ability Test	F:	Female learner
	LSAQ:	Life Sciences Attitude Questionnaire	SD:	Standard deviation

Analysis of the interactive influence of gender on the acquisition of the specific components of science inquiry skills showed no significant effect on learner ability to formulate hypotheses (F= 0.00; *p*=0.9989), identify variables (F= 2.59; *p*=0.0552), design experiments (F= 0.90; *p*=0.3440), draw and interpret graphs (F= 1.22; *p*=0.2703), and draw conclusions from results (F= 0.03; p=0.8595) (appendix XVII).

Based on these results the hypothesis that there is no significant interactive influence of gender on learners' attainment of genetics content knowledge, science inquiry, problem-solving, decision-making abilities, and their attitude towards the study of life sciences was accepted.

4.2.3 Interactive influence of cognitive preferences and treatment

Null hypothesis 3

Ho 3 *There is no significant interactive influence of learners' cognitive preferences on their attainment of genetics content knowledge, science inquiry skills, decision-making ability, problem-solving ability, and their attitude towards the study of life sciences*

A 2 x 4 factorial ANCOVA showed no significant interactive influence of cognitive preferences on learner performance on all the learning outcomes at 5% level of significance: ([GCKT: F(3,148) =1.57, *p*=0.2001], [TOSIS: F(3,137) = 0.36, *p*=0.7831], [DMAT: F(3, 142) = 0.03, *p*=0.9922], [PSAT: F(3,144) = 0.43, *p*=0.7291] and [LSAQ: F(3,130) = 0.90, *p*=0.4419], table 4.10). Analysis of the interactive influence of learner cognitive preferences on the acquisition of the various components of science inquiry skills showed no significant influence either. Therefore, learners' cognitive preferences did not significantly interact with the materials used to teach the experimental and the control groups in the attainment of the assessed learning outcomes.

Table 4.10 Summary of post-test ANCOVA statistics for the interactive influence of cognitive preferences on the learning outcomes

Dependant variable	Cognitive preference	CONTROL			EXPERIMENTAL			F Value	*p*-value
		N	Mean	SD	N	Mean	SD		
GCKT	**A**	15	15.7575758	6.7565759	16	28.0681818	9.2463976	1.57	0.2001
	P	26	15.3146853	7.6307005	27	29.3602694	9.7221894		
	Q	15	18.1515152	10.0478000	19	28.9952153	13.2292589		
	R	28	14.1331169	6.1629481	11	19.6694215	9.2287077		
TOSIS	**A**	14	28.9285714	18.3112588	15	28.3333333	9.7590007	0.36	0.7831
	P	25	27.6000000	12.0000000	26	31.1538462	10.7058575		
	Q	15	24.0000000	11.9821296	18	29.1666667	10.0366974		
	R	23	21.3043478	13.9167485	10	27.0000000	13.9841180		
DMAT	**A**	15	55.3333333	23.5634907	16	73.1250000	21.2033802	0.03	0.9922
	P	26	51.5384615	23.9486630	27	68.8888889	19.0814717		
	Q	14	56.4285714	28.1772256	20	73.5000000	16.3111199		
	R	22	51.8181818	26.1199365	11	68.1818182	16.6241883		
PSAT	**A**	15	34.6666667	20.9988662	16	42.5000000	24.3584345	0.43	0.7291
	P	26	38.0769231	19.2912894	27	52.2222222	25.0128172		
	Q	15	32.3333333	21.2860339	20	48.0000000	26.6754372		
	R	23	29.5652174	18.8241288	11	51.8181818	30.2714987		
LSAQ	**A**	13	117.692308	21.6347892	16	130.187500	10.3808718	0.90	0.4419
	P	22	123.409091	16.2822108	24	128.500000	8.6727960		
	Q	15	112.333333	16.2905173	16	128.125000	6.7515430		
	R	24	114.208333	19.0308198	9	125.222222	14.7120510		

KEY:
GCKT: Genetics Content Knowledge Test — A: Application mode
TOSIS: Test of Science Inquiry Skills — P: Principle mode
DMAT: Decision-Making Ability Test — Q: Questioning mode
PSAT: Problem-Solving Ability Test — R: Recall mode
LSAQ: Life Sciences Attitude Questionnaire — SD: Standard deviation

Based on these results, the hypothesis that there is no significant interactive influence of learner cognitive preferences on their attitude towards the study of life sciences, and their attainment of genetics content knowledge, science inquiry skills, decision-making ability, and problem-solving ability was not rejected.

4.2.4 Interactive influence of gender, cognitive preferences and treatment

Null hypothesis 4

Ho 4 There is no significant interactive influence of gender and cognitive preference on learners' attainment of genetics content knowledge, science inquiry skills, decision-making ability, problem-solving ability, and attitude towards the study of life sciences.

A 2 x 2 x 4 factorial ANCOVA showed no significant interactive influence of gender and learners' cognitive preferences on the performance of learners on all the assessed learning outcomes ([GCKT: $F(3,140) = 1.98$, p=0.1199], [TOSIS: F (3,129)=0.74, *p*=0.5278], [DMAT: F (3,134)=0.96, *p*=0.4122], [PSAT: F(3,122) = 0.49, *p*=0.6905] and [LSAQ: F (1,154) = 0.38, *p*=0.7659) (appendix XIX). The implication of these results is that learners' gender and cognitive preference did not have a significant combined interactive influence on the attainment of the learning outcomes when using the context-based approach or the traditional teaching approaches.

4.2.5 Comparison of pre-test and post-test cognitive preferences of the experimental group

Some researchers (Tamir, 1975) have suggested a possible influence of instructional approaches on learners' cognitive preferences. It therefore became necessary to find out whether the context-based materials and approach affected learners' cognitive preferences. A Fisher exact test (Stokes, et al., 2000) was used to determine the significance of the relationship, if any, between pre-and post-intervention cognitive preferences of the experimental group. The test results showed a strong correlation between the pre-test and post-test cognitive preferences of the learners (*p*=0.0003), at 5% level of significance (appendix XX). It was therefore assumed that learners' cognitive preferences were not significantly altered by the use of the context-based teaching approach.

4.3 QUALITATIVE RESULTS

Research question 3

What are learners' and educators' views that could account for differences in learner performance, if any?

This research question was explored by collecting qualitative data from participating learners and educators using focus group and one-to-one interviews respectively. The texts below present some of the data obtained from the interviews. (Detailed interview protocols are presented in appendix XXI).

4.3.1 Learners' opinions of the study of genetics

Codes were used to associate the interview transcripts with the respondents. The codes consist of the letters ES (for experimental group learners) and CS (for control group learners) and the identity numbers of the individual learners.

4.3.1.1 Learners' views on performance in genetics

Focus group interview protocols showed that the experimental group perceived the study of genetics to be more accessible and fun, and they thought that they had performed well in the post-test (ref. table 4.11(a)).

Table 4.11(a) Experimental group's perception of performance in genetics

ES9	The stories made the study of genetics easy, because we managed to understand what was happening, and we were able to explain the situations.
ES68	It was fun to learn genetics by using our own experiences. It just makes genetics so easy. I am sure I have passed the test.
ES3	When I wrote the first test (pre-test), it was difficult, but after studying genetics, I felt more excited, and it became easy. I think I passed the second test (post-test).

In contrast, most of the learners from the control group found the study of genetics inaccessible, challenging and confusing, even though it was interesting, as shown below (table 4.11(b)).

Table 4.11(b) Control group's perception of performance in genetics

CS181	Some educators start teaching genetics without us knowing where it comes from, where it is situated and how it affects us.
CS112	Genetics is challenging because some of us do not understand what it is based on.
CS97	I found the study of genetics to be difficult, because some of the terms, I cannot put them in my mind, especially the definitions. They are very confusing.
CS120	Genetics was interesting, but when it comes to tests and examinations, we get scared or panic and fail, or we don't pass the way we expect to pass.

4.3.1.2 Learners' views on the approaches used to teach genetics

The experimental group appeared to appreciate the teaching methods used, citing the use of hands-on activities, linkage of content with daily life experiences, small group class discussions, frequent interactions among themselves and the educators, and the use of stories, as the reasons for their appreciation (table 4.12 (a)).

Table 4.12(a) Experimental group's opinions of the way in which they experienced the teaching of genetics and how they would like to be taught genetics

ES64	The method used to teach genetics in this project was more practical, but other educators teach us theory only, which we don't understand.
ES15	The way our educator taught us made it easy. We talked about things that happen to us, so it was easy to understand. I especially enjoyed the part on diseases and the inheritance of features from our parents.
ES65	It was easy to understand the terms and ideas because we worked in groups and we learned from each other. If you are wrong, your friends explained the reasons to you.
ES82	In other classes, there is no interaction between us and the educators, but in this programme we are allowed to say what we think, even to argue with others or disagree with the educator.
ES28	The stories made the study of genetics easy because we managed to understand what was happening, and we were able to explain the situations.

The control group seemed to suggest that the way genetics was taught was not facilitative, and resulted in learners' memorization of concepts. They indicated that they preferred more hands-on activities, field trips, greater interaction with their educators, and the use of real-life issues in the study of genetics. These perceptions are indicated in these quotations from learner interview protocols (table 4.12(b)).

Table 4.12(b) Control group's opinions of the way in which they experienced the teaching of genetics and how they would like to be taught genetics

CS123	The way our educators teach us makes us to fail, because we find it boring. They just read from textbooks, then they give us many exercises, so we just 'cram' *(memorize)* the work because we don't understand.
CS112	The problem is that we do not do any practical activities in genetics. We would like to do practical activities so that we may understand genetics.
CS115	Our educators should organize trips to places where we can see what we learn in class.
CS116	Educators must be able to communicate with learners, not just get angry when we ask questions.
CS168	Educators should always relate what we learn to real-life issues, and give more examples of how the things we learn can be applied in life.

4.3.1.3 Learners' views on the relevance of studying genetics

The interview protocols revealed that learners from both groups perceived the study of genetics as relevant to their lives (tables 4.13 (a) & (b)). However, the two groups seemed to view the relevance of studying genetics from difference perspectives. The experimental group viewed relevance of the study of genetics mostly in terms of applications to everyday issues as well as their wellbeing, while the control group's appreciation of its relevance seemed to be confined to its importance in understanding their own body functions, as is evident in these comments (tables 4.13 (a) & (b)).

Table 4.13(a) Experimental group's perception of the relevance of the study of genetics

ES51	The study of genetics is good for us because we know how it (*genetics*) affects us, and we understand some of the issues we hear on TV.
ES70	The study of genetics helps us improve our daily lives and deal with the challenges that we have in our lives.
ES39	After studying genetics, I understand most of the things that happen in our societies, like why we have albinos.

Table 4.13(b) Control group's perception of the relevance of the study of genetics

CS132	In genetics we study what happens in our bodies, so I think it is relevant.
CS105	The study of genetics and life sciences helps us to know how to take care of ourselves.
CS97	Genetics makes us to be aware of how gene mutations can cause disabilities and disorders in our bodies.

4.3.1.4 Learners' views on interest in the study of genetics

The findings showed that learners from both groups expressed interest in the study of genetics (tables 4.14(a) & (b)). This observation is evident in these quotations.

Table 4.14(a) Experimental group's opinions of their interest in the study of genetics

ES42	Genetics was very interesting and fun. I used to look forward to the lessons.
ES65	I enjoyed the practical activities because they were about things that we see and that we hear from people.
ES42	The fact that we were dealing with things that happen in our lives made the study of genetics very interesting.

Table 4.14(b) Control group's opinions of their interest in the study of genetics

CS132	Genetics was interesting because it deals with things that affect our lives.
CS106	Genetics is interesting because we learn about ourselves, how we are made, and how certain characteristics come about.
CS145	I found it (*genetics*) interesting because of the way the educator framed the question about genetics.

In sum, the comments from learners show that learners taught with the developed materials and approach enjoyed the study of genetics and they found it to be relevant to their lives. They were confident about their performance in genetics and they were pleased with the way genetics was taught because they were able to interrogate their preconceptions and review them in light of new knowledge (tables 4.11(a), 4.12(a), 4.13(a) & 4.14(a). Learners from the control group showed interest in, and were of the view that genetics is relevant to their lives because the study of genetics deals with their own characteristics. However, they were of the view that the methods used to teach genetics were not facilitative enough for them to perform well in the post-tests (tables 4.11(b), 4.12(b), 4.13(b) & 4.14(b).

4.3.2 Educators' opinions on their learners' performance and the teaching approach

The subsequent passages show representative comments from educators' interview protocols. (Detailed interview protocols are contained in appendix XXI). The codes used to identify the educators are ET (experimental group educator) and CT (control group educator), followed by the identity number of the educator.

4.3.2.1 Educators' views on learner performance in genetics

Comments from the educators who taught the experimental group indicated that they were optimistic about their learners' performance in the post-tests. They attributed learners' enhanced performance to the use of authentic situations during lessons, ability of learners to relate with the teaching materials, and the linkage of content to contexts (table 4.15(a)).

Table 4.15(a) Opinions of educators from the experimental group concerning their learners' performance in genetics

ET2	The learners who were exposed to the new teaching approach performed much better when compared with my previous learners' performance.
ET3	The use of real-life situations in the lessons helped learners to quickly remember things learned, because they can relate the concepts to situations which they are familiar with.
ET2	Once you tell them [learners] what happens in real life, and then teach them the relevant genetics concepts, it becomes easier for them to understand.

Educators from the control group expressed dissatisfaction with their learners' achievement in genetics. They were of the opinion that learners were unable to comprehend the processes and applications of genetics, partly because they are lazy to study the topic. Some educators felt that genetics is often taught as abstract concepts which is not facilitative, and that some learners believe that genetics is a difficult topic, and therefore do not put effort in studying it (table 4.15(b)).

Table 4.15(b) Opinions of educators from the control group concerning their learners' performance in genetics

CT6	What I notice with my classes is that they seem to understand the lessons when we start the study of genetics, but as we get deeper into the processes and applications of genetics, they get lost, and become bored.
CT4	Probably learners are just lazy to study.
CT5	At times what makes learners get lost during the study of genetics is the way educators present the lessons as abstract concepts.
CT4	I would say they fail because they believe that genetics is very complex, so they just shut down.

4.3.2.2 Educators' views on their ability to identify learner preconceptions

Educators from the experimental group indicated that they were able to note learners' preconceptions easily, and could address them at a later stage, as indicated in table 4.16(a)).

Table 4.16(a) Educators from experimental group's opinions of their ability to identify and address learners' preconceptions

ET1	When you listen to their arguments, you could easily pick out the wrong explanations and the correct ones, and during the content introduction, most learners corrected themselves, and I also emphasized the ideas which they misunderstood during the next stage of the lesson.
ET3	If you start a lesson by saying to the learners, tell me something, then they feel free to tell you what they know, and then you can pick up misconceptions and correct them.

Those from the control group commented that it was difficult to get the learners to express their views. As a result, it was not easy for them to know their learners' preconceptions. These opinions are expressed in the quotations below (table 4.16(b)).

Table 4.16(b) Educators from the control group's opinions of their ability to identify and address learners' preconceptions

CT4	Because they (learners) are usually quiet, it is difficult to know what they think, or what they know or don't know.
CT5	At times when you ask them a question, they just stare at you without saying anything, so it is difficult to know what they are thinking.

4.3.2.3 Educators' views of the methods used to teach genetics

Educators from the experimental group were of the view that the context-based approach to the teaching of genetics was facilitative, highlighting the use of authentic narratives, the interactive nature of the approach, ability to identify and address preconceptions, and the linkage of content and contexts as some of the features of the approach that could enhance learner performance. The educators recommended the approach for teaching other topics in life sciences (table, 4.17(a)).

Table 4.17(a) Educators from the experimental group's views about appropriate and effective ways of teaching genetics

ET2	To me, as an educator, the context based method, when followed correctly, will always achieve the expected objectives. All life sciences learning outcomes can be addressed, when you use the new teaching method.
ET1	If you link real-life issues with the syllabus, they become more meaningful and clearer to the learners.
ET3	The exploration of contexts stage allows for interaction and discussion, and it paves the way for the information (concept) stage where the content relating to that scenario, is presented by the educator.
ET1	When you listen to their arguments, you could easily pick out the wrong explanations and the correct ones, and during the content introduction, most learners corrected themselves, and I also emphasized the ideas which they misunderstood.
ET1	What made them understand genetics was the teaching method of starting the lesson with real-life issues (*narratives*), and then relating the concepts to those issues. Then the lessons made sense to them.
ET2	I had the opportunity to use this technique to teach genetic topics and personally feel it can work very well in teaching other life science topics, especially controversial topics, like evolution, organ donation.
ET3	It was time consuming. Adequate time is required to get information from learners and to correct their misconceptions.
ET2	The educator needs to be well prepared and collect sufficient information for content, because there will be lots of questions to answer.
ET1	The only problem with this method is that we cannot use it in our classes because we do not have enough resources for practical activities.

Some of the educators from the experimental group surmised that the approach might present challenges in schools, with regard to time constraints, excessive work for educators, and lack of resources (table 4.17(a)).

There was lack of consensus among educators from the control group regarding their views on appropriate and effective ways of teaching genetics, and they seemed to be unsure of the causes of learners' poor performance in the topic. However, some of the educators identified learners' academic inability, incompetence of some educators, use of ineffective instructional approaches, and lack of resources as possible determinants of poor performance in genetics (table 4.17(b)).

Table 4.17(b) Educators from the control group's views on appropriate and effective ways of teaching genetics

CT6	I believe that the way I normally teach is the best way of teaching genetics, because I always strive to do the best in whatever I do.
CT4	I think the way we teach genetics is limited to the sense of hearing. Our learners are not good at exploring issues on their own. They are very much reliant on the educator.
CT5	At times what makes learners get lost during the study of genetics is the way educators present the lessons as abstract concepts.
CT4	I can't pick up exactly where the problem lies; it's probably the way we teach genetics, or the type of resources that we use, because we normally use the chalk board, posters, textbooks, old models, and they don't seem to be effective in enhancing learners' achievement in genetics.
CT5	Even some educators are not comfortable with some parts of genetics, so how can they arouse learners' interest and improve performance in those parts?
CT6	I think practical activities can help to clarify the theory, but the problem is that, there are very few practical activities in genetics, and the materials are expensive, so we end up teaching theory only.
CT6	Probably they are not just good at mastering the genetics concepts. I really don't know why they can't grasp the concepts.

4.3.2.4 Educators' views on the relevance to learners of studying genetics

Educators from the experimental and control groups seemed to be in accord regarding the relevance to learners of the study of genetics. They appeared to believe that the study of genetics was meaningful in learners' lives and that the learners themselves viewed the study of genetics as important to their lives. These opinions are relayed in the quotations below (tables 4.18 (a) and (b)).

Table 4.18(a) Opinions of educators from the experimental group on the relevance of the study of genetics to learners' lives

ET2	Genetics is the basis of life itself. Without genes, there is no life, so the study of genetics is very relevant to the learners.
ET1	And I know that the learners who were involved in this programme saw how genetics impacts on our lives. What they learned will be useful throughout their lives.
ET3	The advantage of the way genetics was taught in this programme is that learners know that what is taught in class is actually happening in their own communities.

Table 4.18(b) Opinions of educators from the control group on the relevance of the study of genetics to learners' lives

CT4	I believe that genetics is relevant and important to learners' lives, because it teaches them about the inheritance of diseases and certain abnormalities.
CT5	Of course, genetics is very relevant to learners, but they need to understand it for them to appreciate it.
CT6	Yes I think that learners realise the importance of genetics to their lives, although there are some topics which they think are not important to their lives, such as the study of plants.

4.3.2.5 Educators' opinions on learners' interest in the study of genetics

Comments from interviews showed that educators from both the experimental and control groups believed that their learners enjoyed the study of genetics. However, educators who taught the experimental group indicated that their learners were eager to take part in class discussions and express their views, while those from the control group expressed discontent with learner participation during lessons. These views are stated in the comments below (tables 4.19(a) & (b)).

Table 4.19(a) Opinions of educators from the experimental group concerning their learners' interest and participation in genetics lessons

ET2	Learners were very enthusiastic and motivated to learn more.
ET1	The learners were very interested in the lessons, they all wanted to say something and convince the others about their views.
ET3	For the first time, I did not have to force my learners to talk. In fact I had to control them at times. Everyone wanted to say something.

Table 4.19(b) Opinions of educators from the control group concerning their learners' interest and participation in genetics lessons

CT4	Learners like genetics because it is an interesting topic.
CT5	I would say learners generally like the study of genetics, but not all the different concepts of genetics.
CT4	Our learners are scared or shy to express themselves and reveal what they think. I think they are also scared that their friends will laugh at them if they speak broken English, because as you know, English is not their mother tongue, and they are not good at it.

Overall, the educators who taught the experimental group seemed to believe that their learners were interested in the study of genetics and that they performed well in the topic because of the teaching approach used. They also indicated that they were able to identify learners' alternative conceptions, which they addressed at a later stage. On the other hand, educators who taught the control group appeared to be discontent with their learners' performance in genetics, although they felt that their learners were interested in the study of the topic. The educators indicated that they could not easily identify learners' preconceptions because their learners were unwilling to participate in lessons.

4.4 CHAPTER SUMMARY

In summary, the results of this study showed that the use of the context-based teaching approach was more effective in improving learners' overall performance than traditional teaching approaches. The study results showed no significant interactive influences of gender and learners' cognitive preferences, and treatment on learner's attainment of all the learning outcomes. The qualitative data seems to corroborate the quantitative findings about the relative effectiveness of the two approaches in enhancing learner performance.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 INTRODUCTION

This chapter presents a discussion of the results of the study. The first section involves a discussion of the relative effectiveness of context-based and traditional teaching approaches in enhancing learner performance. The second section looks at the interactive influences of gender and cognitive preferences on the attainment of the learning outcomes. Finally, the context-based teaching approach that was developed in the study is evaluated.

5.2 EFFECT OF CONTEXT-BASED AND TRADITIONAL TEACHING APPROACHES ON LEARNER PERFORMANCE

The first research question sought to assess the relative effectiveness of context-based and traditional teaching approaches in enhancing learner performance. The results from analysis of covariance (ANCOVA) of post-test mean scores of the experimental and control groups showed that the experimental group performed significantly better than the control group in genetics content knowledge, problem-solving ability and decision-making ability, and had a more positive attitude towards the study of life sciences. No significant difference was observed between the experimental and control groups in the acquisition of overall integrated science inquiry skills. However, when specific science inquiry skills were analyzed separately, results showed that the experimental group performed significantly better than the control group in the ability to formulate hypotheses and to draw conclusions from results. These results are discussed in detail in subsequent sections.

5.2.1 Learners' content knowledge of genetics

Previous studies on the effect of context-based approaches to the teaching of science (Barber, 2001; Barker & Millar, 1996; Bennett & Holmann, 2002; Ramsden, 1998, 1997, 1992; Taasoobshirazi & Carr, 2008) have reported inconclusive results or non-significant differences between the conceptual knowledge of learners exposed to context-based teaching approaches and those exposed to traditional approaches, even though a few other studies (Bloom & Harpin, 2003; Gut-Wise, 2001; Yager & Weld, 1999) showed improvements in the conceptual understanding of learners exposed to context-based approaches.

In this study, learners who experienced the context-based approach showed a significantly better content knowledge of genetics than those who were taught according to the usual traditional teaching methods (Experimental F=63.00; p= <0.001, table 4.1). The question arises as to what could account for the significant difference in learner performance in this particular study, especially since the competence of the two groups in genetics content knowledge was approximately the same before the intervention (table 4.1).

Comments from participating learners and educators suggest that differences in the performance of the two groups, after the intervention is likely to have derived from the methods used to teach genetics. Participants from the experimental group contend that the use of familiar contexts, to which learners could relate, and the use of minds-on and hands-on learning activities, as well as the linkage of content and contexts, were possible determinants of the enhanced performance of the experimental group as discussed below.

The contexts used to develop the context-based materials were determined by the learners themselves. Hence the materials were probably more familiar and relatable to learners than those used in previous context-based materials. The relevance of the selected contexts to the daily lives of the learners from the experimental group is likely to have motivated them to study genetics, as is evident from learners' views in these quotations.

> ES68 It was fun to learn genetics using our own experiences. It just makes genetics so easy. I am sure I have passed the test.

> ES51 The study of genetics was easy because we were able to link it to what happens in our homes.

The use of contexts selected by learners could have negated some of the difficulties usually experienced by learners in contextualized learning (DeJong, 2008; Pilot & Bulte, 2006). The educational benefits of involving learners in decisions about the development of curriculum materials, for familiarity and relevance of the materials, have been acknowledged by researchers (Cox et al, 2009; Osborne & Collins, 2001).

The control group that was taught using traditional approaches did not seem to be familiar and be able to relate with the learning materials, as evident from the following comments from the group.

CS181 Some educators start teaching genetics without us knowing where it comes from, where it is situated and how it affects us.

CS132 What makes it difficult is that we can't really see the things which we learn about.

CS130 It (*genetics*) can be relevant if we talk about things which we can see, not just things we imagine in our minds.

Learners' inability to relate with the learning materials was probably a result of the fact that educators mainly used materials that were mostly predetermined by national curriculum developers and those found in textbooks. None of the educators who taught the control group indicated any involvement of learners in decisions concerning the teaching and learning materials. Neither was such a practice observed by the researcher during the study. Similarly, most of the existing contexts-based materials are developed from contexts selected solely by curriculum developers without involving the learners (Bennett & Holmann, 2002), as pointed out in sections 2.2.2.4 and 2.2.2.6. The exclusion of learners' views during material development could make the materials inaccessible to them.

The other element of the developed materials and approach that could have enhanced learner performance was the use of narratives based on real-life (authentic) situations, at the beginning of each lesson, which is consistent with Herbart's model for effective educational instruction, and constructivism. These teaching and learning models promote the commencement of lessons with what learners have experienced and they already know. The use of real-life narratives could have made the significance of studying genetics more explicit to the learners and thereby enabling them to construct knowledge. It could also have improved learners' attitudes towards the study of genetics, and made them want to learn more, and hence perform well in the topic. Learners' appreciation of the materials is implied in these quotations from the experimental group interview protocols:

ES74 The nice thing about the lessons was that we were talking about things that happen in our homes. I now understand why my brother looks so different from all of us.

ES60 If the things we learn are put to us as stories, it becomes easier to understand, rather than just giving us past questions, which we do not know how they relate to our lives.

Educators who taught the experimental group expressed similar sentiments about the use of real-life narratives in teaching genetics:

ET1 Learners who were taught using the new method really understood the lessons, because they were able to relate everything they did in class to what happens in real life.

ET3 Once you tell them what happens in real life, and then teach them the relevant genetics concepts, it becomes easier for them to understand.

ET2 The teaching approach used in this programme turned out to be an exciting and interesting experience to learners. This is because situations and problems which relate to their everyday lives were used.

Comments from the control group on the other hand show that learners found some aspects of genetics difficult to understand. They cited the abstractness of concepts, the profusion of genetics terms, insufficient study time and educator-centred memory-oriented teaching approaches as possible reasons. These quotations from the control group interview protocols attest to these observations:

CS102 Genetics is challenging because some of us do not understand what it is based on.

CS199 Genetics is difficult because it is just rules and terms, which are difficult to understand.

CS131 What makes it difficult is that we can't really see the things which we learn about.

Several researchers (Dogru-Atay & Tekkaya, 2008; Ibanez-Orcajo & Martnez-Aznar, 2005; Lewis & Kattman, 2004) have identified issues similar to those cited by learners from the control group: misconceptions in genetics; domain specific vocabulary and terminology in genetics; and perceived irrelevance to learners' daily lives, as possible reasons for poor learner performance in genetics.

Educators from the control and experimental groups admitted that in traditional approaches to the teaching of genetics, scientific concepts are rarely clearly explained and/or linked to real-life situations. These assertions are derived from educators' comments, such as those stated in the quotations below.

ET1 Most educators do not usually link their lessons to issues happening outside the classroom. They rush to finish the syllabus by just presenting theory. In the end, the learners do not understand anything. That's why we have high failure rates.

CT5 At times what makes learners get lost during the study of genetics is the way educators present the lessons as abstract concepts.

The five-phase learning cycle used to implement the context-based materials involved interrogating the contexts before exposing learners to relevant content, linking content and contexts, and applying learned content to novel situations, as suggested in Herbart' model for effective instruction. These elements created opportunities for learners to discuss, explain, and argue about real-life issues. The mental engagement allowed learners to examine the adequacy of their prior knowledge and beliefs (or preconceptions), and forced them to test these preconceptions against the content they had learned. According to educational theorists such as Dewey, Piaget, and von Glasersfeld, this intellectual engagement is likely to enhance the construction of knowledge (Abraham & Renner, 1986; Bybee, et al., 2006; von Glasersfeld, 1989). The role played by these cerebral activities in enhancing conceptual understanding was acknowledged by learners, as is evident in the experimental group's interview protocols:

ES57 When we learned genetics, our educator allowed us to give our views, but with the other classes, we are not given an opportunity to say what we think.

ES82 In other [usual] classes, there is no interaction between us and the educators, but here we are allowed to say what we think, even to argue with others or disagree with the educator.

ES16 The way our educator taught us made the study of genetics easy. We talked about things that happen to us, so it was easy to understand. I especially enjoyed the part on diseases and the inheritance of features from our parents.

Educators who taught the experimental group echoed their learners' views in the following statements from their interviews:

ET2 One outstanding aspect of the new approach is that the learners become very active during lessons, and therefore the learners understood the lessons better.

ET3 For the first time, I did not have to force my learners to talk. In fact I had to control them at times. Everyone wanted to say something.

ET3 The involvement of learners in the lessons made them feel appreciated, because they felt that the little they knew from home was integrated in the lessons.

Learners' active participation in lessons could have helped educators and learners to identify learners' alternative frameworks of pre-conceptions, which would then have been addressed in the content introduction phase. Contemporary research in cognitive science has shown that eliciting learners' prior knowledge and experiences is a necessary component of the learning process (Eisenkraft, 2003). Comments from the experimental group learners' and educators' interviews reveal the importance of giving learners an opportunity to express their views before introducing content (scientific concepts):

ES42 The discussions made me realize the myths which I had. By studying genetics, I managed to know the truth.

ET3 What is good is that during the information phase, you have the opportunity to explain, and emphasize those issues where you noted the misconceptions.

ET1 What I liked is that, during the content introduction phase, when you 'touch' on issues where learners had alternative conceptions, they would ask for clarification.

Stakeholders in traditional science education seem to assume that curriculum statements and textbooks contain sufficient information to develop learners intellectually and socially. Because of this assumption, educators and learners are expected to go over these materials and adopt them without question. Unfortunately, in an attempt to internalize curriculum and textbook information, the majority of learners end up memorizing concepts in order to pass examinations, without understanding them in depth (Taasoobshirazi & Carr, 2008). This transmitter and passive recipient view of science education seems to have been the case in the control group, as suggested by comments from learners and educators from the group:

CS131 We want to be involved in the lessons. Our educators talk and talk and talk, and we get bored, and at times feel sleepy.

CS126 Genetics is difficult because we do not understand it, and the educators don't allow us to ask too many questions.

An educator who taught the control group acknowledged the possibility of instructional shortcomings about the traditional ways of teaching genetics in these statements:

CS4 I think the way we teach genetics is limited to the sense of hearing. Our learners are not good at exploring issues on their own. They [learners] are very much reliant on the educator.

CS4 I can't pick up exactly where the problem lies. It's probably the way we teach genetics or the types of resources that we use, because we normally use the chalkboard, posters, textbooks, and old models, and they don't seem to be effective in enhancing learners' achievement in genetics.

There seems to be a problem of educator-centred teaching in the traditional genetics classes. Comments from the control group appear to suggest that learners and educators blame each other for the lack of learner involvement in the lessons.

Further, the five-phase learning cycle used in the study emphasized practical activity, such as experiments and simulations, during the concept introduction phase. These activities are also common in the BSCS 5E learning cycle model (Bybee, et al., 2006), which has been effective in improving conceptual understanding in Biological sciences. The hands-on activities could have enhanced learners' enjoyment of genetics lessons, and in turn motivated them to study and try to comprehend genetics concepts, as indicated in these comments from learners who participated in the experimental group:

> ES65 I enjoyed the practical activities because they were about things that we see and that we hear from people.
>
> ES82 I think the practical activities helped me to understand the concepts better.
>
> ES64 The method used to teach genetics in this project was more practical, but other educators teach us theory only, which we don't understand.

Over the years, researchers (Hodson, 1993; Hofstein & Lunetta, 2004; Tobin, 1990) have noted that practical work enhances conceptual understanding in science. However, learners taught using traditional teaching methods are rarely involved in practical activity, especially in poor rural schools (Barmby et al., 2008; EC, 2007; Lyons, 2006; OECD, 2006; Onwu & Stoffels, 2005). When practical activity is used, learners often follow a 'cookbook' approach to experimentation (EC, 2007; Kang & Wallace, 2005; Lyons, 2006; OECD, 2006). It seems that practical activities were uncommon in the traditional approaches used to teach the control group in this study, as implied in these quotations from the group:

> CS112 The problem is that we do not do any practical activities in genetics. We would like to do practical activities so that we may understand genetics.
>
> CS141 We should be using microscopes to see what really happens in the cells.

Lack of practical activity in the traditional approaches to teaching genetics seems to derive from educators' lack of knowledge of relevant experiments that could be conducted in genetics, and non-availability of materials for practical activities, as confessed by some of the participating educators during their interviews.

ET2 Learners (from the experimental group) enjoyed the practical activities a lot. They could easily see the processes that are explained in theory. Frankly, I did not know that there were such interesting practical activities in genetics.

CT6 I think practical activities can help to clarify the theory, but the problem is that, there are very few practical activities in genetics, and the materials are expensive, so we end up teaching the theory.

ET3 I did not know that one could conduct interesting experiments in genetics. (*Previously)* It was very difficult to come up with genetics experiments which learners could be interested in, and which made sense. This method of teaching is really good.

Finally, the five-phase learning cycle introduced genetics content to learners in small manageable amounts (drip feed). Content delivered in small amounts could have reduced the load on learners' working memory. In addition, genetics concepts were revisited again and again in the various themes of the developed materials, which could have familiarized the learners with those concepts and increased the depth of mental processing. The drip feed manner of introducing content and the subsequent re-visiting of the content in different contexts is characteristic of many large-scale context-based materials, such as developed in Salters Projects (Bennett & Lubben, 2006), Chemie in Kontext (Parchmann, et al, 2006), and ChemCom (ACS, 2002) (See section 2.2.2.4). Some researchers (Bennett, 2003; Hung, 2006) affirm that introducing content in small quantities and revisiting it can enhance learners' conceptual understanding.

In sum, the findings of this study suggest that the use of contexts that are familiar and relatable to learners and the use of a five-phase learning cycle significantly enhanced learners' understanding of genetics concepts and the development of higher-order thinking skills. The efficacy of the five-phase learning cycle in enhancing learner performance is in consonance with findings from previous studies (Barman, Barman & Miller, 1996; Musheno & Lawson, 1999; Purser & Renner, 1983; Saunders & Shepardson, 1987), which showed that the use of a learning cycle enhances conceptual understanding. On the other hand, traditional ways of teaching genetics, which usually constitute the transmission of abstract information and which seldom incorporate minds-on and hands-on activities could account for the control group's overall poor performance in genetics.

5.2.2 Skills development

The higher-order thinking skills assessed in this study include integrated science inquiry skills, decision-making and problem-solving ability. The performance of learners in these skills is discussed in the succeeding sections.

5.2.2.1 Integrated science inquiry skills

Learners' competence in the integrated science inquiry skills of hypotheses formulation, identification of variables, experimental design, graphing, and data interpretation (ability to draw conclusions from results) was assessed. The results showed no significant differences between the control and experimental groups in their competence in overall science inquiry skills. However, a comparison of learners' performance in specific inquiry skills showed that the experimental group were significantly more competent than the control group in hypotheses formulation and the ability to draw conclusions from results.

The enhanced competence of the experimental group in formulating hypotheses and drawing conclusions from data probably resulted from learners' involvement in lesson activities that required them to engage in practical work and in discussions involving making predictions and providing explanations for science-related phenomena. For example, in a lesson about genetic counselling, decisions and ethics (appendix VI, unit 9.5), learners were required to make predictions and provide explanations, based on the information provided, as shown in the following example:

> Claassen and Susan got married recently, and both have brothers who have cystic fibrosis (CF). Susan is now pregnant. Genetic tests show that Claassen and Susan are both carriers of the CF trait, and that the embryo is homozygous for the CF trait.
>
> (a) Given the knowledge of the embryo's genotype, what would you advise Susan to do about the pregnancy?
> (b) If your friends disagree with your advice to Susan, how may you defend your views?
> (c) What moral problems should they consider in making decisions about the embryo?

Questions such as those in the example (above) engaged learners in mental activity that required them to reason in terms of 'if …, then ...' statements, which characterize hypothesis formulation. Learners were also required to provide explanations for their suggestions and assumptions in light of learned information. These activities are meant to allow learners to have a deeper understanding of the phenomenon being studied (Bybee, et al. 2006; Eisenkfraft, 2003). Such activity could have provided practice in drawing conclusions from results. These comments from the educators who taught the experimental groups attest to the involvement of learners in the described activity:

> ET2. The lessons highlighted situations and problems, and then provided explanations and possible solutions as they unfold in the various stages.
>
> ET3. Probing learners to give you what they understand about the topic makes them to think broadly. It therefore increases their thinking capacity, and makes them want to know more.

The ability of context-based teaching approaches to enhance certain science inquiry skills was shown by other researchers (Wierstra, 1984; Yager & Weld, 1999), who found considerably more inquiry learning and creativity in context-based than in control (traditional) classes.

In this study, the control group did not seem to have sufficient practice in activities that required them to make predictive statements and to provide explanations for socio-scientific issues. Learners tended to participate in lessons as passive recipients of knowledge, as indicated in the quotations below from learners who participated in the control group:

> CS167 They [educators] should use practical activities and examples which should include things like diseases that are caused by genetics. It will be easier to understand, because we would be able to apply what they teach us to our life.
>
> CS131 We want to be involved in the lessons. Our educators talk and talk and talk, and we get bored, and at times feel sleepy.
>
> CS167 Some learners learn by cramming [memorization] without interest, and without thinking about what they have crammed. They just want to pass the examination. They don't think about why these things happen.

The lack of significant differences between the performances of the experimental and control groups in the inquiry skills of identification of variables, experimental design and graphing could mean that these skills are acquired from the usual practical activities that are used to teach science in traditional classes, and that the context-based approach used in this study did not emphasize the development of these skills. Hence the context-based materials and approach did not have an advantage over traditional approaches in the attainment of the stated skills.

5.2.2.2 Decision-making ability

One of the hypotheses that were tested in this study was whether there would be any significant differences in the decision-making ability of learners in the control and the experimental groups. The experimental group showed significantly higher decision-making ability than the control group. The difference in decision-making ability of the two groups might have resulted from the fact that the activities in the context-based materials and approaches often required learners to make decisions about real-life situations, during context interrogation and when linking content to contexts.

There seems to be a supposition in science educational systems that exposing learners to curriculum materials automatically enhances the development of higher-order thinking skills which are crucial to contemporary life, such as decision-making ability. According to Aikenhead (1980), decision-making techniques and wisdom do not develop sufficiently in learners unless they constitute an explicit content of science curricula and examinations. However, the majority of science curricula do not contain materials that clearly teach decision-making skills. The South African life sciences curriculum for instance does not make explicit provisions for teaching decision-making techniques (DoE, 2008). It is therefore understandable that educators do not necessarily see the need to teach and emphasize such skills.

Science lessons tend to place more emphasis on acquiring conceptual knowledge, with little room for developing decision-making skills, because this is what is usually examined. Descriptions of typical genetics lessons by educators from the control group suggest that there were no explicit attempts to involve learners in activities that would allow them to practise decision-making techniques during lessons.

> CT4 I normally teach genetics lessons by giving an introduction, involving some background to the lesson, and then I speak more about the lesson and give them content from the textbook, and then some exercises to do.

> CT6 I usually start with a mind capture, like something that happened somewhere, to capture their (*learners*) attention. Then I teach them the concepts, and give them an assessment to see if they have followed the lesson.

In the experimental group, the context-based materials and approach frequently engaged learners in tasks that required them to explore problems, evaluate options, and make valid judgments on issues. Involvement in these mental activities demonstrated to learners how knowledge of science content guides decision-making in contemporary life, and provided practice in decision-making.

5.2.2.3 Problem-solving ability

Another learning outcome assessed in the study was competence in problem solving. A comparison of learner competence in problem solving showed that the experimental group were significantly better than the control group. The enhanced competence in the experimental group could once again be related to the nature of the tasks in the materials, which required learners to solve real-life problems.

The context-based materials developed in this study involved tasks that challenged learners' intellect and motivated them to assess problems, reason around them, and use available information to seek solutions (see appendix VI). The extensive use of problem-solving activities in the experimental group probably contributed to the enhanced performance of this group in the PSAT, as suggested by one of the educators from the experimental group:

> ET2 What I really like about this new approach is that it encourages teamwork, develops problem-solving skills, communication skills, tolerance and understanding of diverse cultures.

> ET2 The lessons highlighted situations and problems, and then provided explanations and possible solutions as they unfolded in the various stages.

In summary, it appears that the teaching materials developed in this study improved learners' decision-making and problem-solving abilities, and enhanced the development of some science inquiry skills. The emphasis on learner- and activity-centred teaching, as well as discussions involving real-life issues, seems to have contributed significantly to improved higher-order thinking skills in the experimental group. The control group seemed to lack exposure to these activities and hence performed poorly in inquiry, decision-making and problem-solving assessments.

5.2.3 Attitude towards the study of life sciences

The study sought to determine learners' attitudes towards the study of life sciences. Comparisons of learners' overall attitudes showed that the experimental and the control groups had positive attitudes towards the study of life sciences before and after the intervention. However, after the intervention, the post-test mean score of the experimental group was significantly higher than that of the control group. The results imply that while the overall attitudes of the experimental group towards the study of life sciences improved after the intervention, those of the control group were shown to be less positive (table 4.7 (b)). The enhanced attitudes of learners exposed to the materials developed in this study corroborate earlier findings (Ramsden, 1998, 1992; Reid & Skryabina, 2002; Yager & Weld, 1999) that context-based teaching approaches have a motivational effect on learners.

While it is acknowledged that attitude towards any school subject can be affected by a number of factors – such as ability, disposition, the quality of teaching, and learning environment – the control group's poor performance and their discontentment with the teaching approaches, even though they found the study of genetics interesting, could have influenced their attitude towards the study of genetics and life sciences as a subject. This supposition is drawn from these comments from the control group's interview protocols:

> CS97 Some of our educators just read from the textbook or give us questions from past examination papers, so we don't understand what is going on.

> CS188 The educators are the ones that make the study of genetics difficult, because most of them pretend to know genetics, but just follow what is written in textbooks, and they do not help us understand what is going on.

Conversely, the significant improvement in the attitudes of the experimental group could be attributed to their appreciation of the teaching approach, and their anticipated improved performance in the post-tests, as indicated in these comments:

> ES 34 Because of the way we were taught genetics, I am now interested in genetics, because it helped me to understand many things in life, such as how we happen to look alike with our brothers and sisters.

> ES 3 When I wrote the first test (pre-test), it was difficult, but after studying genetics, I felt more excited, and it became easy. I think I passed the second test (post-test).

> ES77 Everything about the topic was perfect; the practical activities and the stories made the topic fun.

Interestingly, inspection of post-intervention mean scores on items under various attitude categories (see table 4.8) revealed that the experimental group scored significantly higher than the control group on items from the following attitude categories: interest in the study of genetics as a topic (OA1); life sciences as a subject (OA4, OA15, OA16, OA19, OA26, OA28, and OA29); and learners' perception of life sciences/genetics lessons (OA14, OA18, and OA20). This observation provides some support that learners from the experimental group found genetics lessons fun and comprehensible.

The lack of significant differences in the attitudes of learners from the experimental and control groups in the attitude categories of 'the application of life sciences to everyday life and 'the importance of studying life sciences for the enhancement of career prospects' suggests that learners from both groups were equally aware of, and valued the applications of life sciences to everyday life and the importance of studying life sciences in related professions.

Further, both the experimental and control groups claim to have interest in the study of life sciences (section 4.3.1.4) in spite of the discrepancies in their achievement in the genetics content test. It appears that interest and attitude alone might not have been necessarily determinants of achievement, although they could have motivated learners in the study of life sciences. Other workers (Belt, Leisvik, Hyde, & Overton, 2005; Campbell et al., 2000; Ramsden, 1992) have found that learners' interest and enjoyment (interest) of the study of science in context did not always translate into increased achievement. What is perhaps clear is that the teaching approaches used to instruct the experimental and control groups might explain the differences in the achievement of the two groups.

In concluding, the use of contexts selected by learners to develop context-based materials and the implementation of the materials using the five-phase learning cycle seem to have played significant roles in enhancing learner performance as evident in the following comments by learners from the experimental group.

> ES48 The method we used to learn genetics should be used in other topics in life sciences and other science subjects, not just in genetics, so that we may understand what we learn.

> ES44 The genetics programme that we did should be compulsory so that everyone can benefit from it, because those who missed the programme are disadvantaged.

It appears that the developed approach was also beneficial to the educators who implemented it, which in consequence improved their learners' performance, as stated in the comments below, from educator interviews.

ET3 I would like to mention that the context-based approach is also helpful to the educator. It is a fact that most educators do not understand what they teach. This approach forces educators to understand what they teach because they know that the learners are likely to ask questions which they might not know how to answer.

ET2 Genetics topics usually pose a lot of teaching challenges for educators and comprehension difficulties for learners, but the teaching method used in this programme made it easier for learners to understand.

It is acknowledged that the traditional ways of teaching science could be effective in enhancing learner performance. However, the results of this study show that lack of active learner involvement in hands-on and minds-on learning and of exposure to problem-solving and decision-making opportunities had a negative impact on the performance of the control group. These features of traditional teaching were also identified by Mji and Makgatho (2006) as some of the factors associated with South African high school learners' poor performance in science and mathematics.

5.3 INTERACTIVE INFLUENCES OF GENDER AND COGNITIVE PREFERENCES AND TREATMENT ON LEARNER PERFORMANCE

The second research question of the study sought to assess the interactive influences of gender and cognitive preferences, and the instructional approaches on learner performance. The reason for the inclusion of this aspect was to establish whether the developed materials had any significant bias against a particular group of learners in terms of gender and cognitive preferences.

5.3.1 Interactive influence of gender and treatment

The results of this study showed no significant interactive influence of gender and treatment on the attainment of all the assessed learning outcomes, for either the experimental or the control group (table 4.9). The lack of significant gender differences in the achievement of learners exposed to traditional teaching approaches seems to contradict earlier findings, which showed gender discrepancies in science attainment (Arnott et al., 1997; Howie & Hughes, 1998; Osborne, et al., 2003). However, the results corroborate earlier findings (Wierstra, 1984; Yager & Wield, 1999) that context-based approaches tend to narrow the science achievement gap between girls and boys.

In developing the context-based materials for this study, an attempt was made to make the materials gender sensitive. For example, the situation discussed in unit 9.2.1 (appendix VI), which involves the birth of an albino in a family, is an issue that is equally relatable to both boys and girls. The use of materials that are applicable to boys and girls in the same way is likely to arouse their interest and encourage participation in discussions to the same degree, and consequently achieve similar results. Research evidence (Cohen, 1983; Murphy, 1991) seems to support the assumption that when deliberate efforts are made to make teaching materials relatable to boys and girls in the same way, especially in activity-centred teaching approaches, the performance of the girls may be the same as that of the boys. This study has provided some empirical support to this assertion.

5.3.2 Interactive influence of cognitive preferences and treatment

Previous studies (Okebukola & Jegede, 1989; Tamir, 1988) have shown that achievement in science could be influenced by learners' cognitive preferences. In this study, the results showed no significant effects of cognitive preferences on learners' attainment of the learning outcomes in the experimental and control groups (table 3.10). This could be an indication that the teaching materials were accessible to all learners, regardless of their cognitive preferences. Most importantly, however, the findings suggest that the developed materials had no adverse effect on learners with different cognitive preferences in the achievement of learning outcomes.

The results did not show any significant differences between the pre- and post-intervention cognitive preferences of learners, either. This is not surprising, since cognitive preferences are fairly stable over time (MacKay, 1975). A seven-week intervention was therefore unlikely to significantly alter learners' cognitive preferences.

5.3.3 Interactive influence of gender and cognitive preferences, and treatment

An assessment of the combined influences of gender and cognitive preferences on the attainment of the learning outcomes showed no significant interactive effect with the teaching approaches used. The explanations given earlier for gender sensitivity and accessibility of the materials by learners with varying cognitive preferences (sections 5.3.1 and 5.3.2) could also account for this lack of influence in this instance.

To sum up, it appears that gender and learners' cognitive preferences did not independently or collectively significantly influence the attainment of the learning outcomes assessed in the study for either the experimental or the control group. The materials and approach used in this study could therefore be considered to have no significant bias towards particular groups of learners in relation to gender and cognitive preferences.

5.4 EVALUATION OF THE CONTEXT-BASED APPROACH DEVELOPED IN THE STUDY

The driving force for developing the materials and approach used in this study was the need to enhance learner performance in life sciences, specifically in genetics. From the findings of the study, it is clear that the context-based materials and approach were more effective than traditional teaching approaches in enhancing learners' achievement in genetics, problem solving and decision making.

The main features of the developed materials and the approach that could account for their efficacy in improving learner achievement appear to be the use of contexts that are familiar and relatable to learners in developing the teaching materials, and the use of a five-phase learning cycle to expose the materials to learners. A detailed evaluation of these features is provided below.

A review of the literature (Pilot & Bulte, 2006; Taasoobshirazi & Carr, 2008) suggests that the apparent inefficiency of existing context-based approaches in improving achievement could stem from shortcomings in design and developmental processes, and from difficulties in implementing context-based materials. Researchers (De Jong, 2008; Shiu-sing, 2005) have suggested that the contexts used to develop materials should not detract learners from the intended concepts, should not be so complicated and abstract that they confuse learners, and should not be irrelevant to the extent that they fail to motivate learners. Other researchers (Pilot & Bulte, 2006) have pointed out that the relevance of contexts, in contextualized teaching, is influenced by time and regional priorities.

Previously, the contexts used to develop teaching materials were usually determined solely by adults without involving the learners (Bennett & Holmann, 2002). Teaching materials developed and used in this manner might not be suitable, relatable, facilitative or even appreciated by certain populations of learners. In addition, in both existing contextualized and traditional teaching approaches, materials developed by curriculum developers and educators for specific learners in different regions at various times are usually recycled over and over for different audiences. Hence the effectiveness of such materials in improving learner performance could have been compromised by changing priorities and preferences by learners.

Teaching and learning theorists (Dewey, Herbart, Piaget, von Glaserfield and Vygotsky) as pointed out severally, recommend the use of materials that are familiar relatable and appreciated by learners, for effective learning. The development of the materials used in this study was based on contexts determined by the learners themselves. The materials therefore had the potential to meet the needs, perceptions, aspirations, time and regional priorities of the learners, as suggested in literature (De Jong, 2008; Pilot & Bulte, 2006; Shiu-sing, 2005). Learners exposed to the materials were likely to relate to, appreciate and engage more with them better than those determined by adults only.

Further, evidence from the literature (Gilbert, 2006: 960-966), as stated in section 2.2.2, suggests that the principles that guide the development of context-based materials include the following:

1. Context-based materials should provide a setting (social setting) in which learners may engage in mental encounters with events on which attention is focused.
2. The environment in which the mental encounters take place must be of genuine inquiry, which reflects the conditions under which scientists operate.

3 The way of talking within the environment should be developed by the learners.

4 Preconceptions of learners must be used, and their explanatory adequacy explored.

Some of the context-based models and materials that are used to teach science do not take all of these principles into account. For example, models based on 'contexts as the direct applications of concepts' do not usually provide social settings, they evoke little background knowledge, do not provide high quality learning tasks, and they do not provide opportunities for learners to develop a specific scientific language' (Gilbert, 2006: 967). Omission of some of the suggested principles for developing context-based materials could impede the effectiveness of the materials in enhancing learner achievement.

The five-phase learning cycle that was used to implement the context-based materials provided learners with opportunities to explore real-life societal, environmental and personal issues and to relate them to concepts and ideas taught in science classes, which are essential for effective learning as suggested by educational theorists, such as Dewey, Herbart, Piaget, von Glaserfield (Abraham & Renner, 1986; Bybee, et al., 2006; von Glasersfeld, 1989). By basing lessons on authentic societal and environmental sceneries, the developed materials provided social settings within which to engage learners in cerebral activity during the study of genetics concepts, as required in contextualized teaching (Gilbert, 2006).

Further, the learning activities in the developed materials were mostly inquiry based, requiring learners to raise and explore questions about familiar situations, use relevant information to seek solutions, and to make decisions on socio-scientific issues. This manner of learning is consistent with Dewey's model of reflective experience, which is required for effective learning. Furthermore, the learning activities were mainly learner-centred, involving discussions, debates and brainstorming sessions directed by the learners themselves, based on their preconceptions and comprehension of the issues, hence developing a specific scientific language, as suggested by Gilbert (2006). The learning activities were also significant in eliciting learners' prior knowledge, which according to researchers (Eisenkraft, 2003) is a critical part of effective learning.

The approach used in this study therefore embraced all the principles for developing effective context-based materials (Gilbert, 2006), which could have significantly enhanced its efficacy in improving learner achievement. In addition, eliciting learners' prior knowledge enabled educators to identify learners' alternative conceptions in order to take appropriate remedial measures during the content introduction phase. Moreover, learners were given an opportunity to reflect on the perceptions they had held before acquiring new scientific knowledge, hence they were able to rectify some of their alternative conceptions. Learner self-reflection, according to researchers (Abraham & Renner, 1986; Bybee, et al., 2006; von Glasersfeld, 1989) is a crucial element in learning. Finally, learners were required to apply learned scientific concepts to novel situations outside the classroom, as recommended in Herbart's model for effective instruction. As a result, learners were able to see the transferability of scientific concepts to varying contexts. These activities are likely not only to have enhanced learners' conceptual understanding, but also to have developed higher order thinking skills.

A notable challenge with context-based teaching has been educators' reluctance or inability to implement the approaches effectively. In most cases, educators are loath to learn and adopt new instructional approaches such as context-based teaching (Eilks, Parchmann, Gräsel, & Ralle, 2004). It is not unusual for educators to want to adhere to instructional approaches with which they are familiar, and which they perceive to have been successful. One of the contributing factors to educators' unwillingness to adopt new teaching approaches could be the use of national examinations with assessment requirements that, in most countries, differ from those of context-based approaches (Pilot & Bulte, 2006). Educators are often under strong pressure from learners, parents and examining boards to maintain conventional teaching approaches and familiar subject matter, which they regard as enhancing learner success in these examinations.

Lack of competence and cooperation from educators, in implementing context-based approaches, could limit the effectiveness of these approaches in increasing achievement in science. Pilot and Bulte (2006) contend that the attitudes of educators are a key factor in the success or failure of most educational innovations, such as contextualized teaching. This is because educators are the ones charged with the responsibility of implementing the new educational innovations.

To ensure that the materials developed in this study were implemented effectively, the educators who taught them were thoroughly trained in context-based teaching competencies such as; context-handling, regulation of learning, and placing sufficient emphasis on the development of scientific knowledge and higher-order thinking skills (Stolk, et al., 2009; Gilbert, 2006). Further, the implementation process was closely monitored and supervised by the researcher to ensure that the principles of the approach were adhered to. It is possible that educators' competence and diligence in implementing the approach effectively could have contributed to the enhanced efficacy of the approach in improving learner achievement.

The described features of the developed materials and approach used in this study have not been explicitly exploited in a systematic manner in either the traditional or existing context-based approaches to the teaching of science. The explained features could therefore account for the significantly enhanced performance of the experimental group in this study.

Although the educators who taught the experimental group expressed positive views about the context-based materials and approach, and recommended them for teaching life sciences in schools, they indicated that its wider use might be hindered by time constraints and the heavy cerebral demand on educators.

Some educators who taught the experimental group pointed out that implementing the new approach in schools might have time constraints because in South African schools the duration for a lesson is about 40 minutes, whereas the time required to complete all five phases of the new teaching approach could be take longer. One of the educators, however, admitted that this possible time constraint could be insignificant if the teaching method is well planned and correctly applied. Moreover, the ultimate educational benefits to learners, of enhanced conceptual understanding and the development of higher order thinking skills are likely to offset the time spent in planning and applying the method.

Educators who implemented the approach also posited that it might present challenges to educators who have not been trained in this approach because it requires clear understanding of the concepts to be taught and careful planning by the educator. According to these educators, careful prior planning is necessary so that educators can raise appropriate questions to stimulate interest, respond adequately to questions raised by learners, be alert to learners' preconceptions and address them at an opportune time, as well as provide appropriate content for the situations being studied. These activities require substantial intellectual commitment by educators.

While the intellectual demand on educators may be a reality when using the approach, careful lesson planning and understanding of concepts have always been a requirement for effective teaching, and therefore should not be viewed as a new or negative attribute in this approach. Moreover, adequate training of educators would equip them with the necessary skills and practice to implement the approach effectively. In fact, one of the interviewed educators pointed out that the approach could be beneficial to educators because it forces them to ensure that they understand what they teach, so that they could be in a position to answer the questions which their learners may ask them.

Lastly, an educator from the experimental group inferred that the use of the approach in large classes might be difficult owing to lack of resources for practical activity. Nonetheless, the materials used in the approach can be devised cheaply from household items, such as beads, thin wires from cables, cotton wool and paper. In other words, effective use of the approach in large under-resourced classes could be easily accomplished through improvisation. Moreover, the context-based approach required learners to work in small groups, which lessens the difficulty of managing large classes, and the need for large amounts of teaching resources.

5.5 CHAPTER SUMMARY

In conclusion, the discussions in this chapter showed that the use of contexts determined by learners to develop the materials, and the five-phase learning cycle were identified as possible determinants of the efficacy of the approach in improving learner performance.

Contexts decided by learners themselves made the teaching materials more familiar relatable and interesting to them. The features of the learning cycle that were construed to account for enhanced learner performance include the interrogation of contexts by learners before scientific concepts are introduced; the introduction of relevant content in small manageable quantities; revisiting concepts and ideas again and again in various themes; linking content and contexts; learner self-reflections and applying learned content to new situations.

Both learners and educators from the experimental group appreciated the context-based approach that was used to teach genetics. Nonetheless, some educators indicated that use of the approach in schools might be hampered by time constraints, heavy intellectual demands on educators, and lack of resources (especially in large classes). These concerns could be addressed through careful planning and training of educators, as well as improvisation of materials for practical activity.

Comments from participants indicated that the traditional ways of teaching genetics were characterised by educator-centred teaching, lack of practical activity, and teaching of abstract concepts that could not be comprehended by learners. Consequently, both learners and educators from the control group were apprehensive about the performance of learners in genetics. Learners from the control group were discontented with the approaches used to teach genetics and blamed their educators for the difficulty experienced in the study of genetics. Their educators on the other hand were of the opinion that learners' reluctance to participate during lessons and to study genetics, and the abstract nature of genetics could account for poor learners' performance in genetics.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 INTRODUCTION

In this chapter, the summary, conclusions and recommendations of the study are presented. The contribution of the study to the field of education is discussed, as well as suggestions for further research.

6.2 SUMMARY OF THE STUDY

This study set out to determine the relative effectiveness of context-based and traditional approaches to teaching life science in enhancing learner performance. The assessed learning outcomes included attainment of genetics content knowledge, science inquiry skills, problem-solving ability, decision-making capability, and improvement of learners' attitudes towards the study of genetics and life sciences. In addition, the significance of the interactive influences of gender and learners' cognitive preferences, and treatment on the achievement of the learning outcomes, if any, was assessed. Finally, the views of participating learners and educators on learner performance in genetics, and the efficacy of the approaches to teaching and learning genetics were explored.

The context-based approach involved the use of contexts (science and technology, society, personal benefits, and the environment) selected by the learners themselves as relevant, interesting and accessible to develop materials for teaching genetics. The materials were exposed to learners using a five-phase learning cycle, consisting of introduction of contexts (narratives depicting real-life situations), interrogation of contexts by learners, introduction of content, linkage of content and context, and assessment of learning. The traditional approach involved the use of materials and methods usually employed by the educators themselves to teach genetics (educators used textbooks and their own teaching and learning materials).

Quantitative data were collected from 190 learners, using six instruments, namely genetics content knowledge test, test of science inquiry skills, problem-solving ability test, decision-making ability test, life sciences attitude questionnaire and a science cognitive preference inventory. The performances of the control and experimental groups in the achievement tests were compared to determine whether there were significant differences in learners' competence in the assessed learning outcomes. The science cognitive preference inventory was used to group learners according to their cognitive preferences in order to determine their influence on learners' attainment of the assessed learning outcomes.

The quantitative results showed that prior to the intervention, there were no significant differences between the performances of the experimental and control groups in the assessment tests. After the intervention, post-test mean scores showed significant differences between the performances of the two groups in almost all the learning outcomes assessed, in favour of the experimental group. No significant differences were observed between the performances of the groups in the inquiry skills of identification of variables, experimental design, and graphing.

The attitudes of learners towards the study of genetics and life sciences as a subject were found to be positive in both groups, although the attitudes of learners from the experimental group were found to be significantly more positive than those of the control group, after the intervention. Further, the quantitative results did not show significant interactive influences of gender and cognitive preferences, and treatment on the attainment of the learning outcomes, after the intervention.

Qualitative data derived from learner and educator interviews showed that the experimental group found the study of genetics fun, interesting and comprehensible. Learners and educators who were involved in the experimental group were appreciative of the context-based teaching approach, and recommended it for regular use in science classes.

Comments from the control group indicated that learners were interested in the study of genetics, but did not find the teaching methods used particularly helpful in making the learning of genetics accessible, relevant and comprehensible. Educators who taught the control group indicated that poor performance in genetics was a result of learners' unwillingness to participate in lessons and to study genetics.

6.3 CONCLUSIONS

In conclusion, the results of the study showed that:

- The context-based teaching approach was significantly more effective than the traditional approaches in improving learners' achievement in genetics content knowledge, problem-solving and decision-making capability, the ability to formulate hypotheses and to draw conclusions from results.
- There were no significant differences between the performances of the control and experimental groups in the inquiry skills of the ability to identify variables, design experiments, and to draw and interpret graphs.
- Learners from both the experimental and the control group indicated that the study of genetics was interesting.
- The quantitative data showed that learners from both groups had positive attitudes towards the study of genetics and life sciences, although the attitude of learners from the experimental group was significantly more positive than that of those from the control group.
- Neither the context-based nor the traditional approaches used in this study had significant interactive influences of gender and cognitive preferences, and treatment on the attainment of the genetics content knowledge, science inquiry skills, problem-solving, and decision-making ability.
- Learners and educators from the experimental group valued the context-based approach used to teach genetics, and they were of the opinion that it enhanced learner performance in the post-tests.
- The specific features of the context-based teaching approach that are likely to have contributed to the enhanced performance of the experimental group in the post-tests, as attested by participating educators and learners, include the following:
  - (i) The use of contexts (issues related to personal benefits, societal issues, environmental issues and scientific and technological innovations) selected by learners themselves to develop study materials.
  - (ii) The use of the five-phase learning cycle to implement the materials. The elements of the learning cycle that could have enhanced achievement comprise:

- ➢ Interrogation of situations and experiences before introducing relevant content, which focused learners' thinking, motivated them, and enabled preconceptions to be identified.
- ➢ Introduction of content in small quantities which reduced the load on learners' working memory.
- ➢ Revisiting content in different themes, increased familiarity with it.
- ➢ Linkage of content and contexts encouraged self-reflections on prior knowledge in light of new information. The reflective feedback facilitated reasoning, meaning making and motivation.
- ➢ Application of learned concepts to novel situations enhanced the transferability of learnt information to different contexts.

- Although learners from the control group indicated that they were interested in the study of genetics, they did not approve of the methods used to teach the topic.
- Learners and educators from the control group anticipated unsatisfactory performance in post-tests. According to the participants of the control group, the features of traditional teaching that could contribute to the anticipated poor performance of the group include:
  - ➢ Lack of active learner participation in lessons, such as class discussions, debates, which was not facilitative for minds-on experiences and which prevented educators from identifying learners' preconceptions.
  - ➢ Lack of hands-on activities to reinforce theory, especially with a topic like genetics that require application and reasoning skills.
  - ➢ Presentation of genetics as abstract concepts unrelated to the learners' real-life experiences, thus making the study of the topic seem irrelevant and difficult to them.

6.4 EVALUATION OF THE METHODOLOGY OF THE STUDY

Four aspects of the methodology used in this study need to be highlighted with respect to general problems and successes, as well as theoretical issues and possible limitations. These include the number of participants involved in the study, some data collection methods, the intervention, and data analysis procedures.

6.4.1. The number of participants

Although the number of learners who participated in the main study was fairly large (190), a larger number would have been preferred for generalization of the findings. Nevertheless, it was not practical to have a very large number of participants because of financial and logistic constraints. The study could accommodate only six schools (three schools each for the experimental and control groups) owing to the high costs of field work, training of educators, visiting schools, and acquiring teaching and assessment materials. The limitation of generalizing findings from a small sample should therefore be considered when applying the findings of the study to broader settings.

6.4.2 Data collection methods

The use of focus group interviews to determine learners' views and opinions on the study of genetics proved effective in obtaining the required information. Learners seemed relaxed and willing to share their views. As a result, useful insights into the effectiveness of approaches used to teach genetics were obtained. It is however possible that some lone voices could have been given less attention. Nonetheless, this concern might not have had a profound impact on the results because the researcher was mostly interested in the overall perceptions of the groups.

The use of 'one-to-one' interviews with educators was also useful, because most of the educators were quite comfortable to share their experiences of teaching genetics. The individual interactions of the researcher with the interviewees accorded her the chance to 'pick on' facial expressions and body language, which provided useful hints to participants' emotions. Educators from the experimental group seemed eager to voice their opinions and views on all aspects of the interview, whereas those from the control group seemed more inclined to give views on learners' behaviour and attitudes during the study of genetics, rather than their own contribution to the teaching and learning process.

6.4.3 The intervention

The educators who taught the experimental group were provided with teaching materials and trained on how to implement the materials, while those who taught the control group were only given a list of genetics concepts to be taught. The provision of materials and training of one group of educators could have the ethical implication of the experimental group having an advantage over the control group, in terms of pedagogical practice. However, the interest of the researcher was to compare the effectiveness of a particular approach (context-based) to the teaching of genetics and the usually ways of teaching the topic, in improving learner performance. It was therefore not appropriate to interfere with what is normally done in traditional genetics classes.

A major challenge in implementing the study was to motivate the learners and educators to remain committed to the study, given the high administrative and educational demands placed on them in South African schools. To counteract this challenge, the researcher instituted several measures, which included, first, giving thorough explanations of the necessity and importance of investigating possible ways of improving performance in genetics, and the likely benefits of the study to the participants and the education system as a whole. Second, a certificate of participation was issued to individuals who attended all the study sessions. These measures encouraged the participants to be committed to the project, with insignificant experimental mortality.

6.4.4 Data analysis procedures

The main inferential statistic used in the study was the analysis of covariance (ANCOVA). According to Field (2009), one of the assumptions of an ANCOVA that is commonly ignored or misunderstood by many researchers is the independence of covariate and treatment effect. Field suggests that this assumption could be checked using an analysis of variance (ANOVA), to find out whether the treatment groups differ on a given covariate before running an ANCOVA. If the ANOVA results show that the treatment groups do not differ significantly, then the covariate could be used in ANCOVA. This method of checking the independence of covariate and treatment was followed in this study (section 3.10.1).

Another factor that was of concern was the selection of representative responses from the interview protocols for discussing the results, which posed the threat of researcher bias in choosing the representative responses. Selecting responses was necessary because several hundreds of transcripts were transcribed from the interviews. Hence including every transcript in the discussion of results would probably have resulted in thousands of pages for the thesis. To counteract the threat of researcher bias, the transcripts were categorized into themes, from which the general views or opinions of the groups were determined. Researcher prejudice in determining the general views of groups for each theme was alleviated by using a research assistant to provide a 'second opinion' (section 3.10.2). Selecting representative responses, and using a judge to review these responses, was envisaged to provide the advantage of presenting the findings in a succinct and economical way, and still be reasonably inclusive of the interviewees' views, as well as reduce researcher bias.

On the whole, the methodology used in the study served the purpose for which it was intended, which was to systematically gather empirical data on the comparative efficacy of context-based and traditional teaching approaches in enhancing learner performance. However, it must be conceded that the use of a mixed method approach turned out to be time consuming and expensive in the long run.

6.5 Possible contribution of the study to academic knowledge

It is hoped that this study will make a number of contributions towards contemporary research in science education, especially in the development, implementation and the effect of context-based teaching approaches on learner performance.

First, in previous studies, contexts used to develop context-based materials were solely determined by curriculum developers and educators, without finding out from the learners themselves what they find interesting, important and accessible for studying a particular topic. In this study, the use of contexts whose relevance to learners is informed by empirical evidence has provided more insight into the extent to which the aspirations of using context-based approaches to the teaching of science are met. It is hoped that the use of contexts considered important by learners themselves will provide a useful approach to the development of context-based materials.

In addition, it is anticipated that this study will contribute towards the knowledge of contexts which are currently regarded by South African learners as appropriate and effective for the study of genetics (section 3.5.2.3).

Second, previous researchers (Bennett & Lubben, 2006; Hofstein & Kesner, 2006; Schwartz, 2006) have acknowledged the motivational effect of contextualized teaching. However, their effect on conceptual understanding and the development of higher-order thinking skills had not been unequivocally ascertained. The results from this study have shown that the amalgamation of contextualized teaching and the five-phase learning cycle can motivate learners, enhance their content knowledge in genetics and improve some inquiry-related skills, problem-solving and decision-making abilities. It might well be that the instructional approach developed in this study could prove to be not only an effective tool for teaching genetics, but also for teaching other science topics and subjects considered difficult for learners to learn.

Third, the findings of this study provide evidence in support of assertions by researchers (Lubben et al., 1996) that the use of real-life situations and increased interest in lessons alone might not be sufficient for conceptual understanding and the development of higher-order thinking skills, such as science inquiry skills, decision making and problem solving. The results of this study suggest that active minds-on and hands-on engagement of learners, in addition to the use of familiar authentic situations (as stated in sections 5.2.1 and 5.2.2) may be necessary for enhanced achievement in science.

Fourth, the study is likely to benefit life sciences educators by providing them with a prototype for developing context-based teaching materials. This is particularly significant because the current South African life sciences curriculum (NCS and CAPS) emphasizes the applications of life sciences and indigenous knowledge systems (DoBE, 2011; DoE, 2008), which invariably require educators to develop and use context-based teaching materials.

Lastly, the results of the study showed that the materials did not have significant interactive influences of gender and treatment on learners' attainment of the learning outcomes. This finding provides support to assertions that context-based teaching approaches could reduce gender discrepancies in learner performance in science (Wierstra, 1984; Yager & Weld, 1999).

In the same vein, the study showed that the materials did not have significant bias on the attainment of the assessed learning outcomes by learners of different cognitive preferences. Given the scarcity of literature on the interactive influences of cognitive preferences and contextualized teaching on learner performance, these findings might provide empirical evidence for the inclusivity of context-based teaching approaches with regard to learners' cognitive preferences.

6.6 RECOMMENDATIONS

Based on the findings of this study, the following recommendations for the development of instructional materials and classroom practice are made.

- The results of the study showed that the use of contexts that are familiar and relatable to learners, especially contexts determined by learners themselves, could enhance their performance in genetics and the development of higher-order thinking skills (Tables 4.15a; 4.18a; 4.19a; 4.23a). It is therefore recommended that curriculum developers and educators try to increase the socio-relevance of science and science education by involving learners in decisions about the context of curriculum materials, in order to increase their accessibility and motivational value to learners.

- The findings of the study also showed that providing learners with the opportunity to explore authentic situations related to the scientific concepts to be taught, particularly topics perceived difficult, before teaching the concepts, could improve conceptual understanding, expose learners' alternative conceptions and enhance higher-order thinking skills, such as problem-solving and decision-making ability. In addition, exploration of contexts at the beginning of lessons helps to arouse learners' interest, focus their' thinking and encourages them to participate in lessons, which seems to be lacking in traditional teaching approaches. It is thus recommended that educators provide learners with opportunities to explore applicable socio-scientific issues before teaching concepts considered difficult for them to learn.

- The results of the study further showed that attempts by learners to link learnt content and the context introduced earlier in the lesson, enabled them to evaluate their prior conceptions regarding a given scientific phenomenon. The self-reflections enhanced learners' reasoning skills, including inquiry skills, problem-solving and decision-making abilities. To this end, it is recommended that educators make deliberate efforts to encourage learners to make self-reflections through evaluation of previously held views regarding scientific ideas and principles, after learning the relevant content, for enhanced understanding and the development of higher-order thinking skills.

- Furthermore, the introduction of scientific concepts to learners in small manageable quantities helped learners to comprehend the content for improved performance, probably due to reduced memory load. It is consequently recommended that, when teaching abstract science topics, educators should introduce content in small quantities which could be easily grasped by learners.

- Finally, given the potential of the developed materials and approach to enhance both conceptual understanding and the development of higher-order thinking skills, and the critical role played by educators in implementing curriculum innovations, it is recommended that teacher training institutions incorporate, in their science education curricula, the development and implementation of the context-based teaching materials and approach developed in this study, for improved learner performance.

6.7 SUGGESTIONSFOR FURTHER RESEARCH

The findings of this study present some further research opportunities, which include the following:

- The context-based teaching approach developed in this study has proven to be effective in enhancing learner performance in genetics and in the development of science inquiry skills and ability in problem-solving and decision-making. It would be important to find out whether the approach could be effective in enhancing performance in abstract physical science topics, which may not have explicit socio-cultural applications.

- A longitudinal study to investigate the potential of the developed context-based approach in motivating young people to pursue science courses, and in particular life science-related courses, beyond the school level would be necessary, to determine the long term motivational effect of the approach.

- Research focusing on ways to increase the use of context-based materials and approaches, such as developed in this study, in schools for improved performance in science subjects is required.

- An investigation on how to empower educators in the development and implementation of context-based materials in schools.

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LIST OF APPENDICES

Appendix I: Summary of samples involved in the study

Purpose of sample	Number of schools	Number of learners				Number of educators
		Grade	Girls	Boys	Total	
Determination of study topic	10	12	30	37	67	10
Pilot study and validation of study instruments	1	11	20	16	36	
Determination of contexts for use in the study	2	12	34	38	72	-
Control group (C)	3	11	54	49	103	3
Experimental group (E)	3	11	55	32	87	3
Learner focus group interviews	6*	11	37*	21*	58*	-
Educator personal interviews	3*	-	-	-	-	6*
Total number of participants	19		193	172	365	16

* Not included in calculating the total number of participants because they form part of the samples of the experimental and control groups.

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Appendix II: Selection of difficult life sciences topics (concepts)

Please indicate whether you are a learner or an educator by ticking in the appropriate box.

Educator ☐ Learner ☐

Select the ten (10) most difficult life sciences topics according to your opinion, from the following list, by writing 1 in the box representing the most difficult topic, 2, in the box representing the next most difficult topic, until you reach the tenth most difficult topic.

Topic (Concept)	Rank
Molecules for life	
Cell structure and function	
Cell division - mitosis	
Plant and animal tissues	
Human diseases	
Indigenous knowledge systems	
Organs	
DNA structure	
Meiosis	
The genetic code	
Photosynthesis	
Nutrient cycles and energy flow	
Animal nutrition (Mammals)	
Homeostasis in humans	
Cellular respiration	
Gaseous exchange	
Support and transport in plants	
Support systems in animals	
Transport in mammals	
Excretion in humans	
Reproduction in vertebrates	
Reproduction in plants	
Human influence on the environment	
Human endocrine system	
The human nervous system	
Biosphere, biomes and ecosystems	
Population ecology	
Biodiversity and classification of animals	
Biodiversity and classification of plants	
Biodiversity and classification of micro-organisms	
Palaeontology (study of fossils)	
Geological time scales	
Life's history	
Mass extinctions	
Genetics and inheritance	
Evolution by natural selection	
Human evolution	

Appendix III: Ranking of life sciences topics according to perceived degree of difficulty

Life sciences topic (Concept)	Percentage of respondents					Rank
	Educators		Learners		Av.	
	No	%	No	%	%	
Chromosomes, DNA, and gene structure and function	7	70	46	69	69.5	**1**
The genetic code	6	60	49	73	66.5	**2**
Cellular respiration	6	60	46	69	64.5	**3**
The human nervous system	6	60	45	67	63.5	**4**
Meiosis	5	50	41	61	55.5	**5**
Genetics and inheritance	5	50	41	61	55.5	**5**
Human endocrine system	5	50	40	59	54.5	**6**
Biosphere, biomes and ecosystems	5	50	39	58	54.0	**7**
Population ecology	6	60	32	48	54.0	**7**
Biodiversity and classification of plants	4	40	45	67	53.5	**8**
Biodiversity and classification of animals	4	40	44	66	53.0	**9**
Evolution by natural selection	5	50	32	48	49.0	**10**
Photosynthesis	4	40	35	52	46.0	**11**
Palaeontology (study of fossils)	3	30	40	59	44.5	**12**
Geological time scales	3	30	29	43	36.5	**13**
Cell division - mitosis	2	20	34	50	35.0	**14**
Reproduction in plants	2	20	31	46	33.0	**15**
Nutrient cycles and energy flow	2	20	29	44	32.0	**16**
Human evolution	2	20	28	42	31.0	**17**
Biodiversity and classification of micro-organisms	4	40	12	18	29.0	**18**
Molecules for life	1	10	23	34	22.0	**19**
Animal nutrition (Mammals)	1	10	21	32	21.0	**20**
Reproduction in vertebrates	1	10	21	31	20.5	**21**
Support systems in animals	1	10	19	28	19.0	**22**
Life’s history	1	10	19	28	19.0	**22**
Gaseous exchange	1	10	17	26	18.0	**23**
Human diseases	2	20	10	15	17.5	**24**
Mass extinctions	1	10	15	23	16.5	**25**
Excretion in humans	1	10	13	19	14.5	**26**
Indigenous knowledge systems	1	10	12	18	14.0	**27**
Support and transport in plants	1	10	11	17	13.5	**28**
Cell structure and function	1	10	11	16	13.0	**29**
Plant and animal tissues	1	10	9	14	12.0	**30**
Homeostasis in humans	0	0	16	24	12.0	**30**
Human influence on the environment	0	0	10	15	7.5	**31**
Organs	0	0	9	13	6.5	**32**
Transport in mammals	0	0	9	13	6.5	**32**

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Appendix IV: Questionnaire for preferred learning contexts in genetics

Age ☐ **Gender** ☐

For each statement in the following table, indicate whether, in your opinion, it is important, not important or whether you are undecided concerning its potential (likelihood) to make the study of genetics interesting, relevant, understandable and meaningful. Indicate your opinion by marking a tick under the appropriate option.

Item number	**Item (context) statement**	**Options**		
		Not Important	Un-decided	Important
C1	Earn lots of money			
C2	Famous scientists and their lives			
C3	Animals and plants in my area			
C4	How genes help in the formation of my characteristics			
C5	How genetics can be used to control epidemics and diseases			
C6	Very recent inventions and discoveries in genetics and technology			
C7	How to develop or improve my knowledge and abilities in genetics			
C8	How genetics affects the build and functions of the human body			
C9	Improve my grades in exams			
C10	The role of genes in evolution			
C11	The role of genetics in my personal relationships			
C12	The origin and evolution of life on earth			
C13	To further my education			
C14	The use of genetics in crime fighting			
C15	A satisfying career			
C16	Study of the human genome			
C17	Genetic decisions and ethics			
C18	Becoming famous scientist			
C19	Achieve lifelong education			
C20	Cloning of animals			
C21	What I need to eat to keep healthy and fit			
C22	How genes are passed from one person to another			
C23	To secure a marketable career			
C24	The number of degrees I have			
C25	How genes can determine the sex of my child			
C26	Poisonous plants in my area			
C27	Cloning of humans			
C28	Gene therapy (curing disease using genes)			
C29	Well-paying jobs			
C30	The extinction of species			
C31	The cure of human diseases			
C32	Formation of new species (organisms)			
C33	Genetics-related jobs			
C34	How organisms and the environment depend on each other			
C35	The role of genetics in sex and reproduction			
C36	The diversity of organisms			
C37	How genes help my body to grow and mature			
C38	Coming up with new ideas			
C39	Transmission of genetic diseases			
C40	Use of genetics to become rich			
C41	The causes of disease in animals and plants			
C42	Use of genetics to Improve food production			

THANK YOU FOR YOUR PARTICIPATION IN THE STUDY

Appendix V: Mean scores and percentages of learners who selected each item (context) statement

Item	Item (context) statement	Context Theme	Mean Score	% of learners who selected the options		
				Important	Un-decided	Not Important
C1	Earn lots of money	CP	1.5	31.2	5.2	63.6
C2	Famous scientists and their lives	AE	1.2	40.1	1.5	58.4
C3	Animals and plants in my area	EI	1.4	47.8	3.2	49.0
C4	How genes help in the formation of my characteristics	PB	3.0	99.9	0.0	0.1
C5	Life outside earth	ST	1.3	21.4	0.3	78.3
C6	Very recent inventions and discoveries in genetics and technology	ST	2.9	95.0	0.0	5.0
C7	How to develop or improve my knowledge and abilities in genetics	AE	1.3	33.7	0.4	65.9
C8	How genetics affects the build and functions of the human body	PB	2.9	94.0	0.0	6.0
C9	Improve my grades in exams	AE	1.5	48.0	0.0	52.0
C10	The role of genes in evolution	ST	2.1	49.0	0.8	50.2
C11	The role of genetics in my personal relationships	PB	2.7	58.3	0.2	41.5
C12	The origin and evolution of life on earth	ST	1.7	21.4	3.3	75.3
C13	To further my education	AE	1.0	18.1	0.9	81.0
C14	The use of genetics in crime fighting	SI	2.9	98.9	0.1	1.0
C15	A satisfying career	CP	1.1	33.1	0.1	66.8
C16	Study of the human genome	ST	2.9	97.0	0.3	2.7
C17	Genetic decisions and ethics	SI	2.3	86.3	5.2	8.5
C18	Becoming famous scientist	CP	1.2	47.0	0.2	52.8
C19	Achieve lifelong education	AE	1.1	9.5	0.1	90.4
C20	Cloning of animals	ST	2.8	100	0.0	0.0
C21	What I need to eat to keep healthy and fit	PB	3.0	96.9	0.0	3.1
C22	How genes are passed from one person to another	SI	2.6	98.2	0.1	1.7
C23	To secure a marketable career	CP	1.1	29.3	2.8	67.9
C24	The number of degrees I have	AE	1.2	36.0	0.6	63.4
C25	How genes can determine the sex of my child	PB	2.8	99.6	0.4	0.0
C26	Poisonous plants in my area	EI	1.8	43.0	0.0	57
C27	Cloning of humans	SI	2.8	97.4	1.0	1.6
C28	Gene therapy (curing disease using genes)	ST	2.7	99.6	0.3	0.1
C29	Well paying jobs	CP	1.3	51.2	0.9	47.9
C30	The extinction of species	EI	2.4	76.9	0.4	22.7
C31	The cure of human diseases	PB	2.8	97.9	0.7	1.4
C32	Formation of new species (organisms)	EI	2.6	89.0	0.5	10.5
C33	Genetics-related jobs	CP	1.1	49.6	3.1	47.3
C34	How living organisms and the environment depend on each other	EI	2.7	73.0	0.5	26.5
C35	The role of genetics in sex and reproduction	SI	2.5	91.2	0.7	8.1
C36	The diversity of organisms	EI	2.3	87.8	0.7	11.5
C37	How genes help my body to grow and mature	PB	2.9	96.7	0.2	3.1
C38	Coming up with new ideas	AE	1.3	51.0	0.0	49.0
C39	Transmission of genetic diseases	SI	2.7	98.1	0.1	1.8
C40	Use of genetics to become rich	CP	1.2	56.0	2.3	41.7
C41	The causes of disease in animals and plants	EI	2.3	40.3	9.9	49.8
C42	Use of genetics to Improve food production	SI	2.6	68.9	0.0	31.1

APPENDIX VI: EXAMPLES OF GENETICS CONTEXT- BASED LESSONS

NOTE: THE COMPLETE CONTEXT- BASED TEACHING AND PRACTICAL MANUALS CAN BE PROVIDED ON REQUEST

UNIT STRUCTURE

Table 1: Unit themes and relevant genetics content

	Theme	Relevant genetics content
1	Variations in the characteristics of individuals	Environmental factors affecting characteristics, transcription, mRNA, Genetic code, codons and anticodons, Translation, Synthesis of proteins, Enzyme structure and function, chromosomal and genetic mutations, Effect of enzymes on chemical reactions in the body
2	Inheritance of characteristics (including sex determination)	Gamete formation – Meiosis; composition of the egg and sperm. Inheritance – Fertilization, homologous chromosomes, DNA replication and mitosis (growth), Mendel's experiments, Monohybrid inheritance, Dihybrid inheritance, Genotypes and phenotypes, Allelomorphic pairs (alleles), Mendel's laws, Dominant and recessive alleles, Complete, Incomplete dominance and Co-dominance, Crosses, test cross and the use of punnet squares, Patterns of inheritance – Proportions and predictions
3	Determination of blood groups	Alleles - Multiple alleles, ABO blood types, Antigen, A and B, Antibodies, Effects of blood transfusion, Universal donors and recipients, Rhesus factor (Rh+ and RH-)
4	Genetic diseases (Protein deficiency diseases)	Sex linked characteristics, Autosomal traits, Mutations definition, Chromosomal mutations (monosomy, trisomy, polyploidy), Abnormal sex chromosomal inheritance (XO, XXY, XXX, Changes in DNA structure (inversions, translocation, deletions, duplications, insertions, Causes of mutations, Consequences of mutations, Protein synthesis and structure and function, Enzymes, Pedigrees, Sex-linked characteristics, Common genetic diseases (Cystic fibrosis, Sickle cell anaemia, Colour blindness, haemophilia)
5	Genetically modified organisms	Monohybrid inheritance, Genetic probabilities, Autosomal disorders, Characteristics of Huntington disease (late onset, dominant trait), Genetic ethical issues
6	Cloning of organisms	Gene structure, Genetic engineering, Procedure for producing genetically modified organisms, Safety of genetically modified foods, Effect of genetically modified organisms on biodiversity, Ethical issues
7	Determination of offenders using genetics (Fingerprinting and forensics)	Genetic engineering, Procedure for 'reproductive cloning' of organisms, Procedure for 'therapeutic cloning' Genetic ethical issues
8	Genetic counselling, decisions and ethics	Chromosome structure, Protein synthesis, Blood typing, Finger-printing, DNA testing, Permanent and changeable characteristics.

Lesson example 1

9.2 TOPIC TWO: INHERITANCE OF CHARACTERISTICS

OBJECTIVES

At the end of this theme, learners should be able to:

1. State the stages of meiosis.
2. Explain how characteristics are inherited by offspring from their parents.
3. Distinguish between recessive and dominant genes.
4. Explain how a baby's sex is determined.
5. Describe mitosis and its link to the development (growth) of an embryo.
6. Differentiate between genotype and phenotype.
7. Briefly explain Mendel's monohybrid inheritance experiments.
8. Solve genetics problems.

9.2.1 INHERITANCE OF CHARACTERISTICS

Phase 1 Introduction of contexts

Mind capture

Ask learners to compare the characteristics (complexion, height, weight, eye colour and size, weight, and any other characteristics) of children with parents, grandparents and other family members (cousins, aunties and uncles) in table form. Ask learners to determine who resembles whom in the family, and for which characteristics.

Narrative

Nolwazi has been married to Jabulani for 30 years. They have four children named Betty, John, Beauty and James. Beauty and Betty look alike, and they share many features with their mother Nolwazi. John looks more like the father, Jabulani. However, James is an albino, just like his uncle Sipho, Jabulani's brother. Jabulani wonders how his son could have taken after the features of his brother, Sipho, when himself, and his wife Nolwazi are not albinos. He wonders whether his wife had a secret affair with his brother, Sipho.

Phase 2 Interrogation of contexts

Learners should discuss and attempt to provide answers to the following questions, and other questions which might arise. They should write down their answers for reference in phase 4.

1. Why do some members of the same family share common features, while others within the family may not have those features?
2. Why do some children have characteristics from both parents?
3. Do you think it is possible for James to be an albino, without Nolwazi his mother having an affair with her brother in-law, Sipho?
4. Why do some children look like their uncles, aunties or grandparents, but may not look like their own parents?
5. Why are people who are closely related usually not allowed to get married?

Phase 3 Introduction of content

Where do chromosomes in an individual come from?

- Gamete formation – meiosis; segregation, composition of the egg and sperm
- Inheritance – fertilization
- Homologous chromosomes
- DNA replication and mitosis (growth)

How are characteristics inherited from parents?

- Mendel's experiments
- Monohybrid inheritance
- Dihybrid inheritance
- Genotypes and phenotypes
- Allelomorphic pairs (alleles)
- Mendel's laws
- Dominant and recessive alleles
- Complete, incomplete dominance and co-dominance
- Crosses, test cross and the use of punnet squares
- Patterns of inheritance – Proportions (ratios) and predictions

Practical 2 Inheritance and variation of characteristics
(See the practical manual)

Phase 4 Linkage of content and context

Refer back to the questions in phase 2, and ask learners to review the questions in the light of the information provided. Learners should re-examine each question and decide on the following:

1. Do you consider your initial answers and views to be correct or wrong?
2. If you think they are wrong, what would be the appropriate answers and why?
3. Does the information provided link up with or clarify the situations presented earlier?

4. Are there any questions that you would like to ask which may not be answered using the information provided?

Phase 5 Assessment of learning

1. Draw a punnet square for a cross between a tall pea plant (Tt) and a short (tt) plant. What will the genotypes and phenotypes of the offspring be?

2. Dark hair (H) dominates fair hair (h) - which is recessive. A male with hybrid dark hair mates with a female with pure fair hair.
   (i) What are the genotypes of the male and female in this couple?
   (ii) What is the chance that their offspring will have dark hair?

3. Brown eyes (B), dominates blue eyes (b).
   (i) If one parent has pure brown eyes and the other has pure blue eyes, what are the possible genotypes of the offspring?
   (ii) If the children from these parents married, what would the genotypic and phenotypic ratios of their offspring be?
   (iii) If both parents have brown eyes and their children have blue eyes, what could the genotypes of the parents be?

4. If a snapdragon that produces white flowers is crossed with one that produces red flowers, all the offspring are pink.
   (i). What are the genotypes of the parents and the offspring?
   (ii). If two snapdragons with pink colours are crossed, what will the ratios of the genotypes and the phenotypes of their offspring be?

5. A certain species of bird has three colour types: yellow; blue and green. These colours are determined by a pair of genes: yellow (Y) and (B) blue.

   (i) What are the phenotypes of:

   (a) a yellow bird? (b) a blue bird? (c) and a green bird?

   (ii) If a yellow bird is mated with a green bird, what colours can their offspring be?

   (iii) If two green birds are mated,
   (a) What colours can their offspring be?
   (b) What percentage of the offspring would you expect to be green? Explain.
   (iv) If the birds produced four offspring, is it possible that all four could be green? Explain.

Lesson example 2

9.2.2 SEX CHROMOSOME AND DETERMINATION OF A CHILD'S SEX

Phase 1 Introduction of contexts

Mind capture

Ask learners to list the number of males and females in their families (nuclear or extended). Are the numbers of males and females in the families equal? Which sex is predominant?

Narrative

Mr and Mrs Sizwe have been married for twenty years, and they have four daughters, but no son. This situation worries Mr Sizwe, because, according to his custom, having no son means that there will be nobody to take over as his heir when he dies. Mr Sizwe decided to consult his elders about the situation, and they advised him to marry a second wife, who could bear him a son. To his dismay, the second wife gave birth to a girl.

Phase 2 Interrogation of contexts

Ask learners to discuss and attempt to provide answers to the following questions.

1 Who is responsible for determining the sex of a child (the husband or wife)?
2 Why do some couples have only girls or only boys?
3 Is it possible for a couple to decide whether to have a girl or a boy?
4 What would you advise a friend with a problem similar to that of Mr and Mrs Sizwe to do for the sake of family stability?
5 How is the sex of a child determined?

Phase 3 Introduction of content

- Human karyogram
- X and Y chromosomes
- Segregation during meiosis
- Fertilisation of egg by the sperm
- Sex determination
- Monohybrid inheritance of characteristics

Phase 4 Linkage of content and context

Having learned the principles that govern sex determination, consider the questions in phase 2 (context interrogation phase), and attempt to answer them again. Discuss your answers with your group members, and agree on group answers.

1 Do you still maintain the answers given earlier?
2 If the answer is yes, explain why you think your original answers are correct.
3 If not, why have you decided to change your answers?
4 Do you have any questions which cannot be answered from the information provided?

Phase 5 Assessment of learning

1. How does the chromosome set of the human female differ from that of the male?
2. Explain why the offspring of a donkey and a horse are infertile?
3. Why is the chance of a human baby being a boy or a girl about 50% each?
4. A normal body cell of a certain organism has 38 chromosomes. How many chromosomes will be in the sex cells of this organism?
5. A child is born with both male and female reproductive organs. Explain what could have caused this anomaly?

<u>Lesson example 3</u>

9.3 TOPIC THREE: DETERMINATION OF BLOOD GROUPS

OBJECTIVES:

At the end of this theme, learners should be able to:
1 State the different blood types
2 Show an understanding of the phenomenon of multiple alleles
3 Show an understanding of the inheritance of blood types
4 Distinguish between antigens and antibodies
5. Explain the cause of agglutination (coagulation) during blood transfusion
6 Explain the need to match donor and recipient's blood during blood transfusion

Phase 1 Introduction of contexts

Mind capture

- Ask learners to give their blood groups if they know them.
- Ask them why people have different blood group**s**
- Inform learners that people's blood groups are divided into four categories, namely type A, type B, type AB and type O.

Narrative

Two baby girls were born in Baragwanath hospital, to Mrs Mathe and Mrs More. Unfortunately the nurses did not label the babies properly and they were mixed up. All the other babies born on that day were boys. The hospital staff is not sure which baby belongs to which parent. Both Mrs Mathe and Mrs More have blood type **A**. Mr Mathe's blood type is **AB**, whereas Mr More's blood type is **A**. The blood type of baby girl 1 is **O**, and that of the baby girl 2 is **B**. The parents want to know which baby is their real child. How can this situation be resolved?

Phase 2 Interrogation of context

What are your views about the following issues? (Discuss as a class or in groups).

1. Given the information above, how can you determine which baby belongs to which parent?
2. What are the reasons for your conclusion?
3. If Mrs Mathe had blood group O, would it be possible for baby girl 1 to be her child?
4. At the time of this confusion, baby girl 2 develops severe anaemia which requires blood transfusion. Would you advise the mothers to donate their blood to her?
5. Provide reason(s) for your answer.

Phase 3 Introduction of content

- Alleles – multiple alleles
- ABO blood types
- Antigen, A and B
- Antibodies
- Effects of blood donation (blood donation and agglutination)
- Universal donors and recipients

Practical 3 DNA structure and replication - (See the practical manual)

Phase 4 Linkage of content and context

Learners should use the information learned to attempt to answer the questions from phase 2. Find out from the learners whether:

1 There is any difference between their initial and current answers. Why?
2 They used new information in clarifying the questions.
3 They have any questions that could not be answered from the information provided?

Phase 5 Assessment of learning

1 A child has blood group AB, The parents

A must be A and B, but not AB.
B must both be blood groups AB.
C. can have different blood types, but neither can be blood type O.
D. can have any of the four blood types.

Explain your answer.

2 Susan, a mother with blood type B, has a child with blood type O. Susan claims that Graig, who has blood type A, is the father of her child. Graig says that he cannot possibly be the father of a child with blood group O. Susan sues Graig for child support. Further blood tests ordered by the judge reveal that Graig is homozygous A. The judge should rule that:

A Susan is right, and Graig must pay for child support.
B Graig is right, and must not pay for child support.
C Susan cannot be the real mother of the child. Her real child could have been swapped with another in the hospital when the child was born.
D It is impossible to reach a conclusion based on the limited information available.

Explain your answer.

<u>Lesson example 4</u>

9.5 TOPIC FIVE: GENETIC COUNSELLING, DECISIONS AND ETHICS

OBJECTIVES

At the end of this theme, learners should:

- Be able to work out genetic inheritance probabilities
- Show an understanding of the non-absolute nature of genetic predictions
- Demonstrate an understanding of the ethical implications of decisions based on genetic tests and probabilities
- Display an understanding of the medical importance of decisions based on genetic test results
- Reveal the ability to base decisions on facts

Phase 1 Introduction of contexts

Mind capture

Remind learners about the abnormalities, disorders or diseases that are common in their own communities, and ask them what they would do if they knew that they were expecting a child with one of the serious genetic abnormalities cited.

Narrative: The dilemma of Huntington's disease

(Adapted from Salters-Nutfield Advanced Biology, 2005. snab-cpd2-fac-9613)

Huntington's disease is a dominant genetic trait. Carriers of the affected allele will develop symptoms at some stage in their life. The typical age for the onset of the symptoms is between 35 and 45. Sick people develop involuntary tremors (shivers) of the limbs, and personality alterations, outbursts of crying, unexplained anger, memory loss, and sometimes schizophrenic behaviour. The severity of the symptoms at the various stages of the disease differs from one person to another. Death usually occurs at around the age of 50. In their final years of life, patients are in a vegetative state.

Sedibeng, Palesa's grandfather, became ill with Huntington's disease at the age of 45. He passed away when he was 51 years old. Palesa, who is now 22 years old, is about to get married. She would like to be tested in order to find out whether she is a carrier of the disease, so that she can plan her future. She has to decide whether she should continue with her studies for many years, so that she may acquire a profitable profession, or get married and enjoy the remaining years of her life. If she gets married, should she have children or give up the maternal experience.

Mpho, Palesa's father, does not want to find out whether he is a carrier of the Huntington's gene. He believes that if he finds out that he will soon be ill, like his father, he might not enjoy the few years that he could still live a healthy life. He therefore discourages his daughter, Palesa, from being tested.

Phase 2 Interrogation of contexts

You have been asked to advise Palesa on the following issues.

1. Should Palesa be tested for Huntington's genes or not? Why?
2. If Palesa decides not to undergo a Huntington's disease test, would you advise her to continue with her education for many years or would you suggest that she just gets married and enjoys life?
3. If Palesa decides to get married without being tested, would you advise her to have children or not.
4. If Palesa tests positive for Huntington's disease would you advise her to have children or not?

For each of the above questions, find out from the learners who are for the idea and those who are against it. Then let the two groups debate the issues, providing reasons to back up their views.

Phase 3 Introduction of content

- Monohybrid inheritance
- Genetic probabilities
- Autosomal disorders
- Information on the characteristics of Huntington disease (late onset, dominant trait)
- Genetic ethical issues

Phase 4 Linkage of content and context

Ask learners to sit according to the groups formed in phase 2, and ask them to review their answers to each question. If there are any changes to the original answers, ask them to explain why they decided to change their answers. Find out if learners are able to link the information in phase 3 to the context provided in phase 1.

Phase 5 Assessment of learning

Cystic fibrosis (CF) is a common autosomal recessive genetic trait. CF causes a deficient functioning of the external secretion glands, resulting in the production of salty sweat, digestion disorders, and the production of large quantities of mucus in the respiratory tracts. The excessive production of mucus causes frequent lung infections. Each lung infection adds to the long-term damage of the lungs. The disease is therefore lethal and patients rarely survive past the age of 40. There is no cure for cystic fibrosis. However, scientists are investigating the possibility of curing the disease using gene therapy.

(Adapted from Salters-Nutfield Advanced Biology, 2005. snab-cpd2-fac-9613.)

Learners should answer the following questions based on the above passage.

Claassen and Susan got married recently, and both have brothers who have cystic fibrosis (CF). Susan is now pregnant. Genetic tests show that Claassen and Susan are both carriers of a CF trait, and that the embryo is homozygous for the CF trait.

1. Given the knowledge of the genotypic status of the embryo, what would you advise Susan to do about the pregnancy?
2. If your friends disagree with your advice to Susan, how would you react to their alternative views?
3. What moral problems should the parents consider in making decisions about the embryo?

Lesson example 5

9.8 TOPIC EIGHT: IDENTIFICATION OF OFFENDERS USING GENETICS

OBJECTIVES

At the end of this theme, learners should be able to:

1. Appreciate the role of science in solving crime
2. Explain the different ways of using genetics to solve crime
3. Describe the process of DNA testing
4. Link fingerprinting to variations in characteristics

Phase 1 Introduction of contexts

Mind capture

Science is often used in communities to solve crimes, such as murder, armed robberies, drug trafficking, and road accidents. This kind of science is called forensic science. The evidence from forensic science may be used to convict criminals or to prove a suspect's innocence.

Narrative: Who killed granny? (Based on a real-life story)

A 65-year-old grandmother was found dead in her house in Makweng in Polokwane. A closer look at the body suggested that she had been strangled. A forensic investigator was assigned to investigate the murder. On inspecting the body he found bruises on her neck, which supported the suspicion that the cause of death was strangulation.

The forensic investigator noticed a bite mark on the forearm of the victim. He swabbed it to collect some saliva for testing. He also discovered some skin and blood under the fingernails of the victim's right hand, and brown a hair strand in the clenched fist of her left hand.

The investigator collected all these samples, together with the victim's blood, and fingerprints found on the victim's necklace. He sent these samples to the laboratory for analysis. The results from the samples showed that:

1 The victim's blood type was A
2 The blood found under her nails was type B
3 Some blood cells from the blood under the nails were sickled (deformed)
4 The hair found in her hand was brown in colour, while her hair was grey.
5 The cells found in the saliva showed that the perpetrator was a male.
6 The fingerprints were not clear

A week later the local detective brings four suspects, who were seen around the murder scene at the time of the crime, to the forensic investigator. He asks him to determine the likely murderer using forensic evidence. The forensic investigator asks for blood and hair samples from the four suspects. He labels these samples A, B, C, and D, and sends them to the laboratory for analysis.

The results from the suspects' samples show the following:

1 Suspect A is a woman with brown hair and blood type B
2 Suspect B is a man with red hair and blood type A
3 Suspect C is a man with black hair and blood type B
4 Suspect D is a man with blonde hair and blood type B

Phase 2 Interrogation of contexts

1. Which of the four suspects do you think is the prime murder suspect? Why?
2. Is the information sufficient to determine the murderer?
3. If not, what can you do to confirm or reject the evidence against the suspected murder?
4. Is it possible for another person to have exactly the same evidence as that of the murderer? Explain.
5. Is there any other information which could be used to determine the murderer?

Phase 3 Introduction of content

- Chromosome structure
- Protein synthesis
- Blood-typing
- Finger-printing
- DNA testing
- Permanent and changeable characteristics.

Phase 4 Linkage of content and context

Learners to use the information learned to answer the questions from the second phase.

1 Are there any differences between your initial and current answers?
2 What new information has been useful in clarifying or answering the questions?
3 What is your opinion on the use of forensic science to judge people?
4 Do you have any questions that could not be answered using the information provided in phase 3?

Phase 5 Assessment of learning

1. The study and application of scientific facts and techniques to solve crimes is called
   ____
2. A bank is robbed overnight and the security guard at the bank is tied up by the criminals. What sorts of things would a forensic expert look for or investigate as evidence for convicting the criminals?
3. A person was accused of assaulting another and causing grievous bodily harm. The victim's blood type was B, and the suspect was found with a lot of blood on his clothes, which was also type B.
   (i) What conclusions can you draw from this case?
   (ii) What forensic evidence would you need to convict the perpetrator?

Lesson example 6

PRACTICAL 5 CLONING OF ORGANISMS

(Adapted from: Salters-Nuffield Advanced Biology, 2005).

INTRODUCTION

New advances in genetics have resulted in the ability to produce several identical organisms using the genes of a single organism. All the organisms made from the donor organism have exactly the same characteristics as the donor organism. The production of identical organisms, tissues or cells that are derived from a single donor organism is called cloning. In this experiment we shall simulate the cloning of animals.

OBJECTIVES

- To demonstrate the cloning of animals
- To show how organisms with desired characteristics can be produced using genetic engineering.

CONTEXT

Mr Van Wyk is a farmer who produces sheep for sale. Some of Mr Van Wyk's sheep have better fur quality than others, and such sheep sell at a higher price. Mr Van Wyk wants to have more of the sheep with quality fur so that he could make more money. He asks you, as a professional genetics scientist, to help him produce more of the sheep with good fur using genes from the desired sheep. In this experiment, you are required to follow the procedure below, to simulate the process of cloning animals using model organisms called woolbes, made from cotton wool and other materials.

SAFETY WARNING

Learners should **NOT** in any circumstance taste any of the materials used in this experiment, as safety and hygiene conditions cannot be guaranteed in the laboratory.

REQUIREMENTS PER GROUP

	Materials	Quantity	
1.	Envelops with chromosomes sets	2	(surrogate and desired sets)
2.	Big balls of cotton wool	10	(Body segments plus head) x2
3.	Small balls of cotton wool	4	(for the breasts)
4.	A yellow bead and a silver heart shape		(for small and big noses)
5.	big silver and small red star shapes	2	pairs (for big and small ears)
6.	Pieces of pipe cleaners	20	(antennae, legs, breasts, tail)
7.	Eye shapes	2	pairs (for big and small eyes)
8.	Toothpicks segments)	4	(for joining the body
9.	Glue	1	tube

Note

(i) All materials **MUST** be kept by the educator at the front of the class.
(ii) Learners should collect **ONLY** the specific shapes and colours of materials required for the construction of the Woolbes as determined by the selected genotypes.
(iii) The surrogate and desired Woolbe chromosome sets should be of different colours, and they should not be mixed.
(iv) The chromosomes **must be cut** along the longitudinal lines, to separate them, before putting them into the envelopes.

Instructions

You are provided with two envelopes containing the genotypes of two Woolbes. One envelope contains the genotype of a surrogate Woolbe, and the other contains the genotype of a desired Woolbe. Each set of genotypes consists of eighteen (9 pairs) chromosomes, coding for nine different characteristics. The characteristics of the surrogate and desired Woolbes, which are based on these chromosomes, are shown in the figures below.

Figure 5.1 Characteristics of surrogate Woolbe

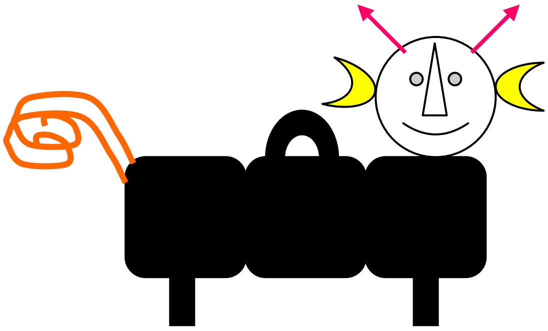
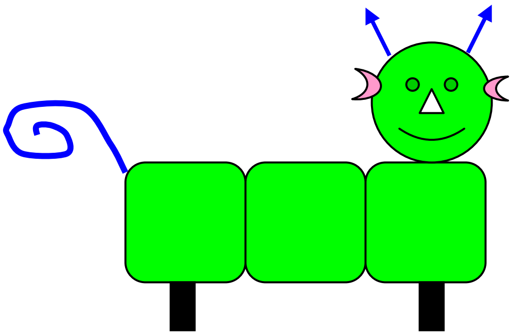


Figure 5.2 Characteristics of desired Woolbe



CONSTRUCTION OF SURROGATE, DESIRED AND CLONED WOOLBES

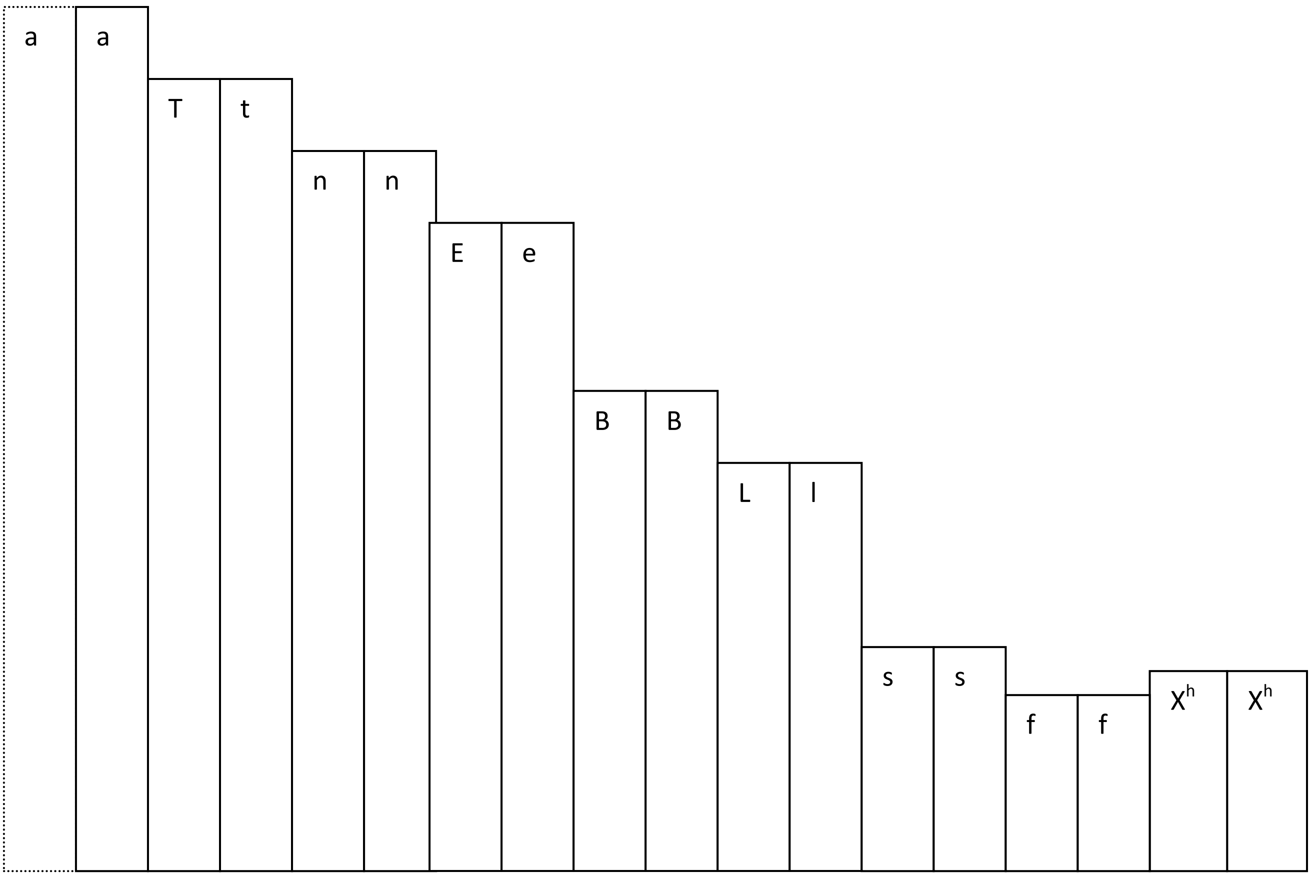
Construct the surrogate, desired and cloned Woolbes according to the following procedure.

INSTRUCTIONS

Stage one: Construction of the surrogate Woolbe.

1. Use the genotypes provided in figure 5.3, and the genetic information in table 5.1 below, to determine the genotype (genetic composition) and phenotype (characteristics) of the surrogate Woolbe, then complete table 5.2.

Figure 5.3 Genotype of surrogate Woolbe



The following table shows the genetic code for determining the characteristics of the Woolbes from their genotypes.

Table 5.1 Genetic code for Woolbe characteristics

Trait	Letter	Genotype and phenotype of Woolbes		
Antennae	**A**	AA = Red	Aa = White	aa = Blue
Tail	**T**	TT = Yellow	Tt = Yellow	tt = Orange
Forked tail	**F**	FF = normal tail	Ff = normal tail	ff = forked tail
Nose	**N**	NN = Big nose	Nn = Big nose	nn = small nose
Sex / Hump	**X & Y with H**	$X^H X^H$ or $X^H X^h$ = female without a hump	X^HY = male without a hump	X^hY or $X^h X^h$ = male or female with a hump
Body segments	**B**	BB = Green	Bb = Green	bb = Black
Eyes	**E**	EE = Big	Ee = Big	ee = small
Legs	**L**	LL = Black (Grey)	Ll = Black (Grey)	ll = green
Ear size	**S**	SS = Big (Gold)	Ss = Big (Gold)	ss = small (Red)

Table 5.2 Genotypes and phenotypes of surrogate woolbe

Trait	Genotype	Characteristic (phenotype) of surrogate Woolbe
Antennae		
Tail		
Forked tail		
Nose		
Sex/Hump		
Body segments		
Eyes		
Legs		
Ear size		

Using the information from table 5.2, construct the surrogate woolbe as shown in Figure 5.1 above.

Note Use **ONLY** the appropriate shapes and colours according to the characteristics (phenotype) of the Woolbe under construction.

Procedure for constructing woolbes

1. Stick three balls of Cotton Wool together using a toothpick, to represent body segments.
2. Using another toothpick, stick another ball of cotton wool on top of the third ball of cotton wool, to symbolize the head.
3. Cut three pieces of about 5 cm of a pipe cleaner. For each piece, curve one end, and trim (remove the wool) from the other end, then stick the trimmed ends of two of the pipe cleaners on the head, to indicate the antennae.
4. Stick the trimmed end of the third one on the last body segment, to serve as a tail.
5. For a forked tail (genotype of ff), twist trimmed ends of two pieces of pipe cleaner together, but leave the curved ends separate, then stick the twisted trimmed ends on the last body segment – the forked tail.
6. Cut four pieces of about 5 cm of a pipe cleaner. For each piece, bend one end to form a foot, and trim the other end (remove the wool). Insert two of the pipe cleaners into the lower part of the first segment of the body, and the other two pipe cleaners on the third segment of the body, to form the legs of the woolbe.
7. Use glue to stick two big or small eyes (depending on the genotype) on the front part of the head.
8. Use glue to stick a big or small nose (according to the genotype) just below the eyes.
9. Use glue to stick two small or big ears on either side of the head.
10. If you have a female genotype (XX), stick two small cotton balls on the lower side of the middle body segment, to represent the breasts.

Stage two: Formation of surrogate Woolbes'egg cell and extraction of nucleus

1. Turn the chromosome cards upside down, so that you do not see the letters on the cards.
2. Place the chromosomes of the surrogate Woolbe in pairs according to their length (diploid set).
3. Randomly select one chromosome from each pair (half of the chromosomes found in the diploid cell), and put them in an envelope, to form the genetic set of chromosomes found in her egg. (The envelope represents the egg cell).
4. Suck (remove) the genetic materials (nucleus) from the surrogate Woolbe's egg (the envelope), leaving the cell without any genetic materials.

Stage three: Construction of desired Woolbe

1, Use the genotype provided in figure 5.4 below and information from table 5.1 above, to determine the genotypes and phenotypes of the desired woolbe and complete table 5.3.

Figure 5.4 Genotype of desired Woolbe

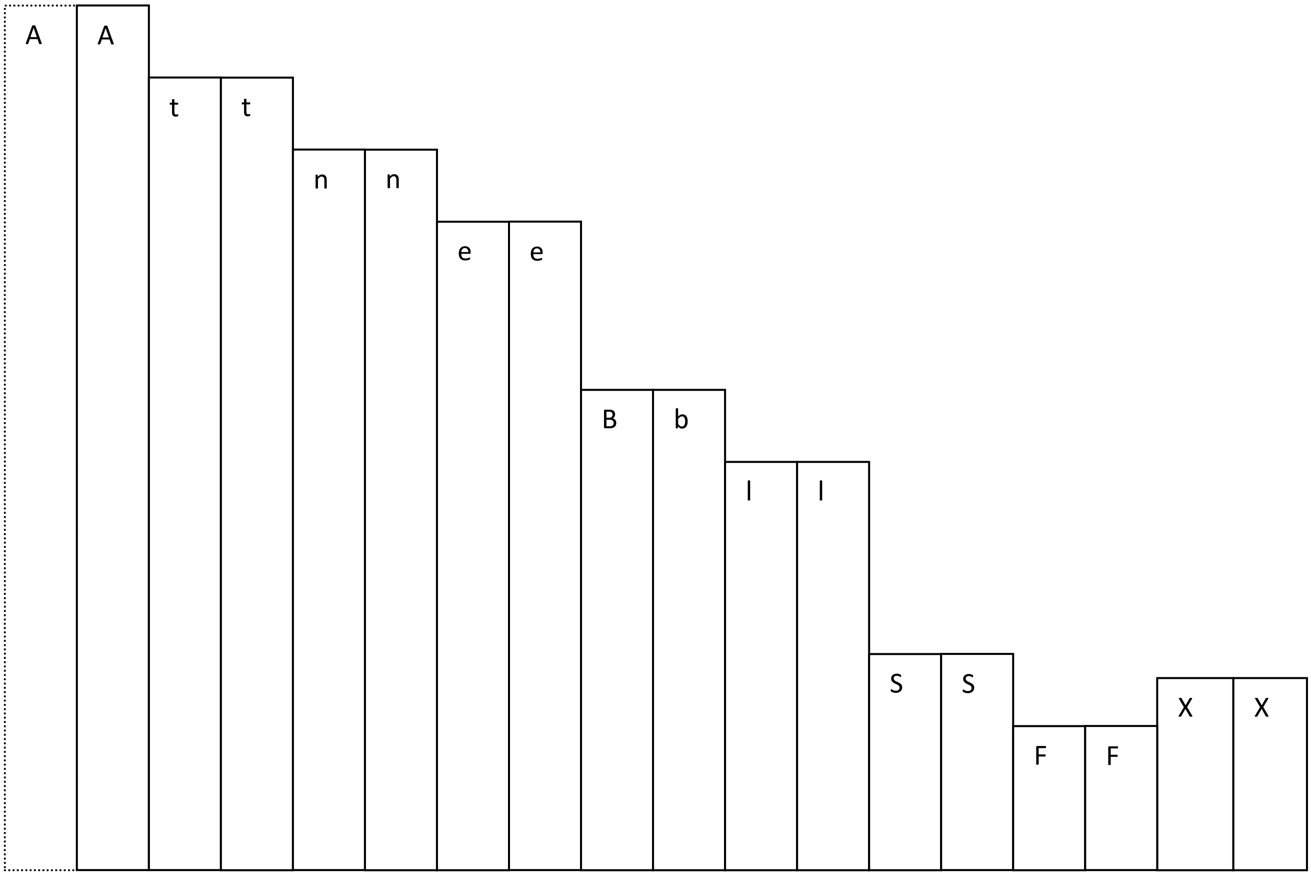


Table 5.3 Genotypes and phenotypes of desired woolbe

Trait	Genotype	Characteristic (phenotype) of desired Woolbe
Antennae		
Tail		
Forked tail		
Nose		
Sex/Hump		
Body segments		
Eyes		
Legs		
Ear size		

Using the phenotypes shown in table 5.3, construct the desired Woolbe as shown in Figure 5.2.

Stage four: Formation of the cloned Woolbe

1. Open the envelope containing the chromosomes of the desired Woolbe.
2. Suck out the diploid set of genetic materials(remove all the chromosomes) from the cell (envelope) taken from the desired Woolbe's body.
3. Inject (put) this genetic material from the desired Woolbe into the empty egg cell (empty envelope) of the surrogate Woolbe, created under stage 2. **This action results in an embryo whose genetic material was came from the desired Woolbe.**
4. Using the genetic materials from the embryo's cell (figure 5.4), and the information in Table 5.1, to compete table 5.4. Use the information from table 5.4 to construct the cloned Woolbe, as shown in Figure 5.5 below.

Figure 5.5 Characteristics (phenotypes) of the cloned baby Woolbes

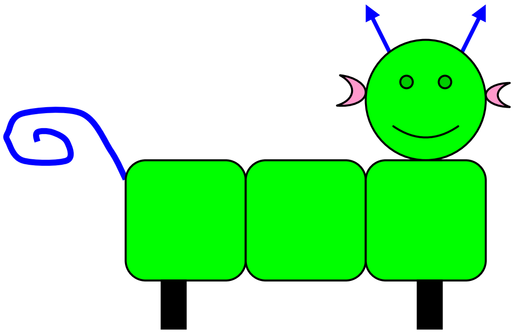


Table 5.4 Genotypes and phenotypes of cloned woolbe

Trait	Genotype	Characteristic (phenotype) of cloned Woolbe
Antennae		
Tail		
Forked tail		
Nose		
Sex/Hump		
Body segments		
Eyes		
Legs		
Ear size		

Questions

Place your cloned baby Woolbes together in a nursery and answer the following questions.

1. Do all the cloned Woolbes show features of a typical Woolbe? Explain.
2. Do the cloned woolbes have characteristics from both the surrogate and the desire woolbe?

3. Are the cloned Woolbes identical (similar to each other in every way) or are their some differences? Explain.
4. Are there any characteristics present in the cloned Woolbes that do not appear in the desired Woolbe? Explain.
5. Are there any characteristics in the cloned Woolbes which could be considered abnormal? Explain.
6. Were the cloned Woolbes formed from genes coming from two parents? Explain.
7. Is there any difference in the sex(es) of the cloned baby Woolbes? Explain.

REFERENCE

University of York Science Education group (2005). Salters-Nuffield Advanced Biology (SNAB). New York, UK.

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Appendix VII: Genetics Content Knowledge Test (GCKT)

Learner code ☐

Age ☐

Grade ☐

Gender ☐

DURATION: 1 Hour

TOTAL MARKS: 55

INSTRUCTIONS AND INFORMATION

Read the following instructions carefully before answering the questions.

1. **Answer ALL the questions.**
2. **Write ALL the answers in the spaces provided for each question.**
3. **Present your answers according to the instructions of each question.**
4. **ONLY draw diagrams or flow charts when asked to do so.**
5. **Non-programmable calculators, protractors and compasses may be used**
6. **Write neatly and legibly.**

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SECTION A [9]

QUESTION 1 [5]

For the following questions, various options are provided as possible answers. Choose the correct answer by marking a cross on the letter that represents the correct answer.

For example: Which of the following is a province found in South Africa?

A. Pretoria
B. Cape Town
~~C.~~ Gauteng
D. Polokwane

Answer the following questions in the same way.

1.1 Down's syndrome occurs when

A. a male sex cell undergoes mitosis.
B. every cell of an organism has an extra pair of chromosomes.
C. all somatic cells have an extra chromosome.
D. a female sex cell undergoes mitosis.

1.2 Indicate which one of the following crosses will result in a ratio of 50% homozygous black to 50% heterozygous.

A. Bb X bb
B. BB X bb
C. BB X Bb
D. Bb X Bb

1.3 The possible genotypes for an individual with blood group A are

A. I^AI^A; I^AI^B
B. I^AI^A; ii
C. I^Ai; I^Bi
D. I^AI^A; I^Ai

1.4 The phenotypic ratio in the offspring resulting from the cross Tt x Tt is:

A. 1:2:1.
B. 3:1.
C. 1:1.
D. 9:3:3:1.

1.5 A father has blood type B and a mother has blood type O. They have three children of their own and one adopted child. Sipho has blood type B, Thandiwe has blood type AB. Thuli has blood type O and Bongiwe has blood type B. Which child is adopted?

A. Sipho
B. Thandiwe
C. Thuli
D. Bongiwe

QUESTION 2 [4]

Give the correct biological term for each of the following descriptions in the spaces provided.

2.1 Genes in the same position on homologous chromosomes (1)

____

2.2 A pair of identical chromosomes found in diploid cells (1)

____

2.3 A change in the chemical structure of a gene (1)

____

2.4 An individual with alleles for a dominant characteristic on both chromosomes of a homologous pair (1)

____

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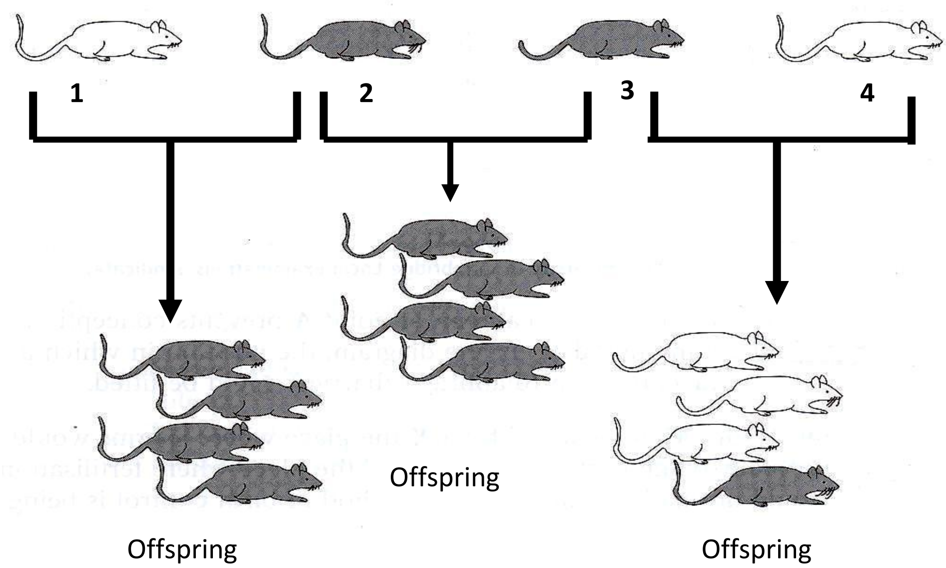
SECTION B [46]

Answer all the following questions in the space provided for each question. Show your working where necessary.

QUESTION 3 [6]

Study the diagram below, which shows some breeding experiments on mice. A single pair of alleles showing complete dominance controls coat colour (white or grey) in these mice.



Results of breeding experiments

3.1 If mouse **1** is a female, state the sex chromosomes that would be present in the gametes of parent mouse **2** and mouse **3** respectively. (2)
Answer: Parent mouse 2 _____________. Parent mouse 3______________

3.2 If mice **3** and **4** had a second set of offspring, what is the percentage chance that the first mouse born would be female? (1)
Answer: ____

3.3 Which of the parent mice (**1, 2, 3** or **4**) is likely to be homozygous dominant for coat colour? (1)
Answer: ____

3.4 State why mouse **3** can only be heterozygous for coat colour. (2)
Answer:____

QUESTION 4 [11]

Read the passage below and answer the questions that follow.

GENETICALLY MODIFIED PIG BRED WITH 'GOOD FAT'

Scientists in South Africa have produced genetically modified pigs with fat containing omega-3 fatty acids. These fatty acids, which are usually found in certain types of fish, are thought to be responsible for a number of benefits, from combating heart disease to improving intelligence. Researchers from the University of Pretoria's School of Medicine created piglets capable of converting less useful omega-6 fatty acids into omega-3 fatty acids. They implanted 1 800 embryos into 14 female pigs. Ten live offspring, which were able to make high levels of omega-3 fatty acids, were born.

[Adapted from: *Cape Argus*, 27 March 2006]

4.1 What percentage success did the scientists have with the implanted embryos in forming a clone of pigs capable of producing omega-3 fatty acids? Show ALL working. (3)

Answer: ____

4.2 To produce genetically modified pigs, the gene that produces omega-3 fatty acids is inserted into the pig embryos. Describe the steps in forming, and introducing many copies of the desirable gene (using bacteria) into the pig embryos. (4)

Answer:

____
____
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4.3 Give TWO reasons why:

(a). Some people may support the use of genetically modified pigs to produce omega-3 fatty acids (2)

Answer

(i) ____

(ii) ____

(b) Some people may be against the use of genetically modified pigs to produce omega-3 fatty acids. (2)

Answer

(i) ____

(ii) ____

QUESTION 5 [12]

A body of a young woman was found on an open plot. She had been allegedly assaulted and murdered. DNA specimens were taken at the scene.

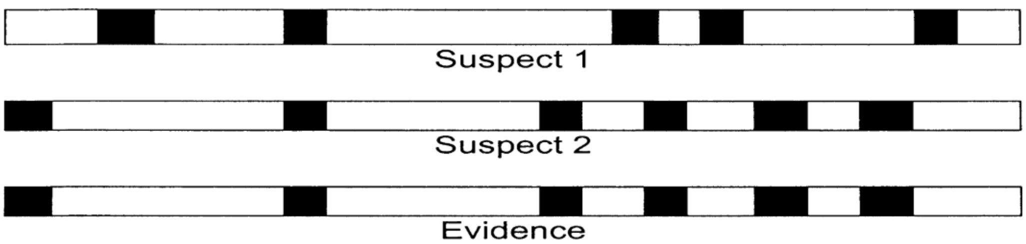
5.1 What is the purpose of taking DNA specimens at the scene? (2)

Answer: ____

5.2 What other purpose, (not those mentioned in question 5.1) can DNA fingerprinting also be used for? (1)

Answer ____

The DNA fingerprints below were used as evidence in a court case in order to convict the crime suspect. A fraction of DNA finger-print was derived from dry blood that was found on the victim's belt (with which she was strangled). Study the DNA finger-prints and answer the questions that follow.



5.3 Which suspect is most probably the murderer? (1)

Answer: ____

5.4 Give a reason for your answer to question 5.3. (1)

Answer:____

5.5 Is there any way in which the suspect can prove his innocence? Explain (3)

Answer:____

5.6 In what way do you think the forensic team can prove this claim wrong? (2)

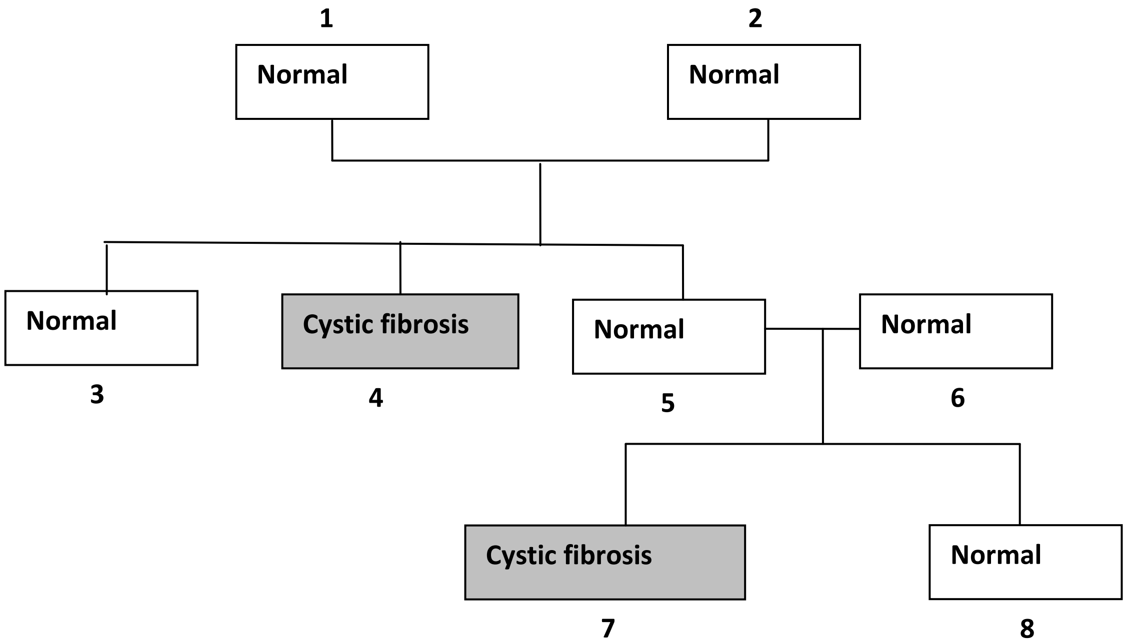
Answer:____

5.7 If one of the suspects refused to give his DNA for testing, should he be forced to do so? Explain. (2)

Answer:____

QUESTION 6 [12]

The diagram below shows a family tree for cystic fibrosis. This condition is produced by a recessive allele, f, while the normal condition is controlled by the dominant allele, F.



6.1 What are the possible genotypes of individuals 1, 4, and 5 respectively? (3)

Answer:

____

6.2 Briefly explain TWO symptoms of cystic fibrosis. (2)

(i) Answer:____

(iii) Answer:____

6.3 If individual 8 is heterozygous, what are the chances of individuals 7 and 8 having a NORMAL child? Show this by means of a Punnet diagram. (5)

Answer:____

6.4 Is cystic fibrosis a sex-linked disease? Briefly explain your answer.

Answer:____

____

____

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____

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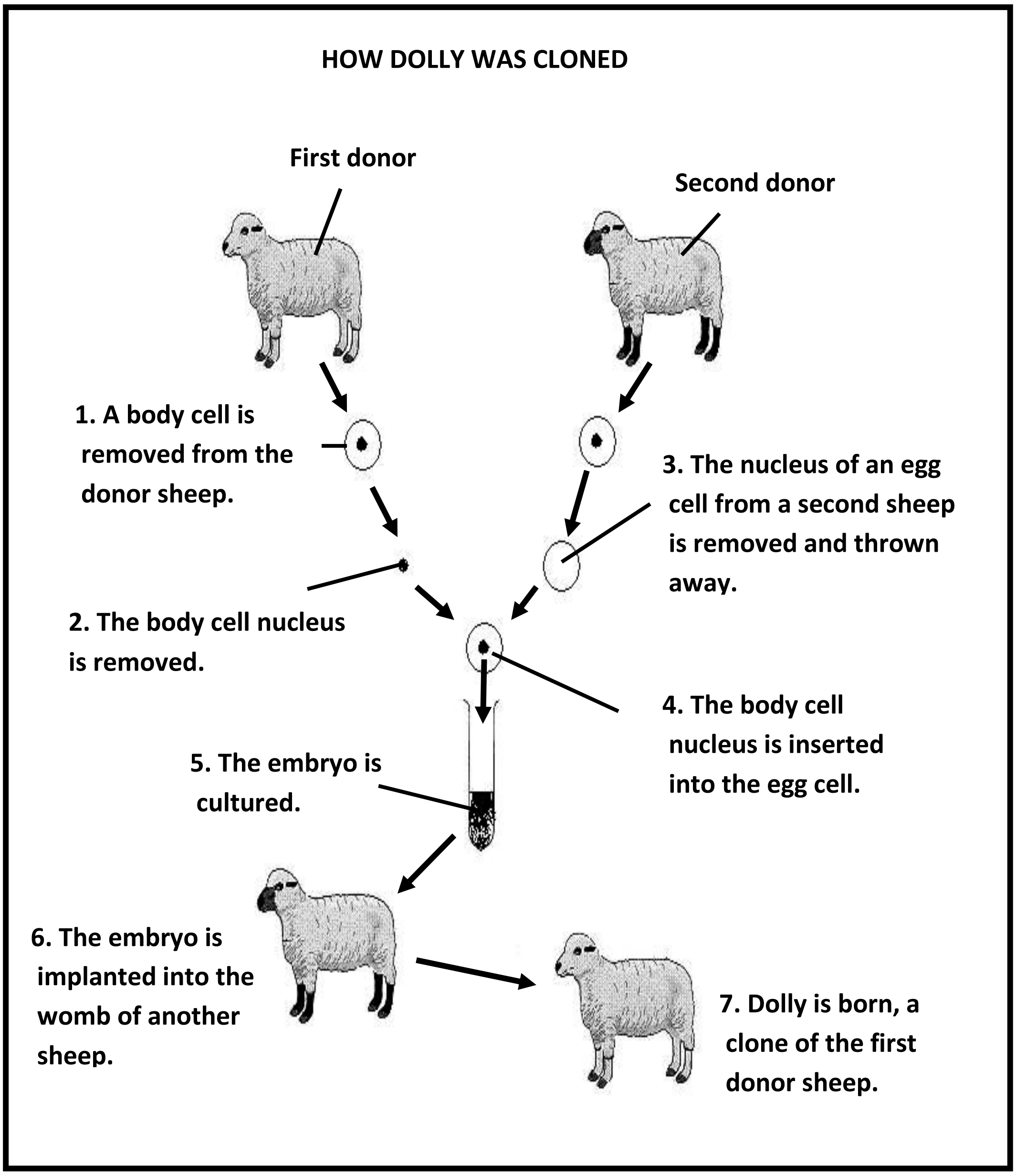
(2)

QUESTION 7 [5]

Study the diagram below that shows the cloning of a sheep named Dolly.



7.1 Why was it necessary to remove the nucleus from the egg cell of the second donor before the sheep could be cloned? (1)

Answer:____

7.2 Would Dolly have any characteristics of the second donor sheep? (1)

Answer: ____

7.3 Explain your answer to **question. 7.2** (2)

Answer:____

____

____

____

7.4 Number 5 on the diagram states that 'the embryo is cultured'. Through which process of cell division does the embryo develop? (1)

Answer: ____

TOTAL MARKS **[55]**

THE END

****

MEMORANDUM FOR GENETICS CONTENT KNOWLEDGE- (GCKT)

SECTION A [9]

QUESTION 1 [5]

For the following questions, various options are provided as possible answers. Choose the correct answer by putting a cross on the letter that represents the correct answer.

For example: Which of the following is a province found in South Africa?

E. Pretoria
F. Capetown
~~G.~~ Gauteng
H. Polokwane

Answer the following questions in the same way.

1.1 Down's syndrome occurs when

A. a male sex cell undergoes mitosis.
B. every cell of an organism has an extra pair of chromosomes.
C. <u>all somatic cells have an extra chromosome.</u>
D. a female sex cell undergoes mitosis.

1.2 Indicate which one of the following crosses will result in a ratio of 50% homozygous black to 50% heterozygous.

A. <u>Bb X bb</u>
B. BB X bb
C. BB X Bb
D. Bb X Bb

1.3 The possible genotypes for an individual with blood group A are

A. I^AI^A; I^AI^B
B. I^AI^A; ii
C. I^Ai; I^Bi
D. <u>I^AI^A; I^Ai</u>

1.4 The phenotypic ratio in the offspring resulting from the cross Tt x Tt is:

A. 1:2:1.
B. <u>3:1.</u>
C. 1:1.
D. 9:3:3:1.

1.5 A father has blood type B and a mother has blood type O. They have three children of their own and one adopted child. Sipho has blood type B, Thandiwe has blood type AB. Thuli has blood type O and Bongiwe has blood type B. Which child is adopted?

A. Sipho
B. Thandiwe
C. Thuli
D. Bongiwe

QUESTION 2 [4]

Give the correct biological term for each of the following descriptions, in the spaces provided.

2.1 Genes in the same position on homologous chromosomes (1)
_____Alleles_____________

2.2 A pair of identical chromosomes found in diploid cells (1)
____Homologous pair of chromosomes_______

2.3 A change in the chemical structure of a gene. (1)
____Mutation_______

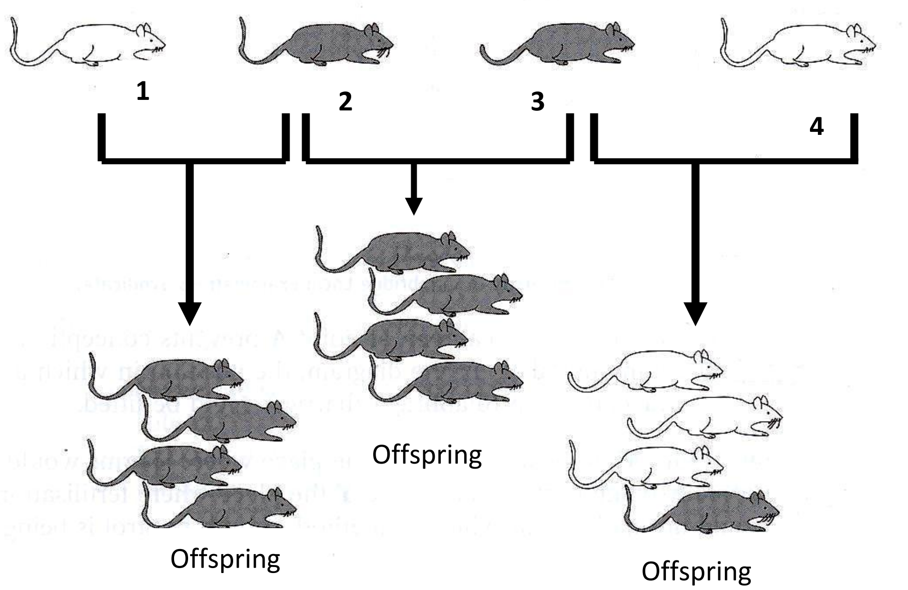
2.4 An individual with alleles for a dominant characteristic on both chromosomes of a homologous pair.
___Homozygote/Homozygous______ (1)
[4]

SECTION B

Answer all the following questions in the space provided for each question. Show your working where necessary.

QUESTION 3

Study the diagram below, that shows some breeding experiments on mice. A single pair of alleles showing complete dominance controls coat colour (white or grey) in these mice.



Results of breeding experiments

3.1 If mouse **1** is a female, state the sex chromosomes that would be present in the gametes of parent mouse **2** and mouse **3** respectively. (2)
Answer: Parent mouse 2 __**XY**__. Parent mouse 3__**XX**__

3.2 If mice **3** and **4** had a second set of offspring, what is the percentage chance that the first mouse born would be female? (1)

	X	Y
X	XX	XY
X	XX	XY

Answer: ______ **50%** ______

3.3 Which of the parent mice (**1, 2, 3** or **4**) is likely to be homozygous dominant for coat colour? (1)

	C	c
C	CC	Cc
C	CC	Cc

Answer: ______ **Mouse 2** ______

3.4 State why mouse **3** can only be heterozygous for coat colour. (2)
Answer: **A cross between mouse 3 and mouse 4 produced offspring with white/recessive coat colour√, and white/recessive coat colour only shows up when both parents have at least one recessive gene√**

[6]

QUESTION 4

Read the passage below and answer the questions that follow.

GENETICALLY MODIFIED PIG BRED WITH 'GOOD FAT'

Scientists in South Africa have produced genetically modified pigs with fat containing omega-3 fatty acids. These fatty acids, which are usually found in certain types of fish, are thought to be responsible for a number of benefits, from combating heart disease to improving intelligence. Researchers from the University of Pretoria's School of Medicine created piglets capable of converting less useful omega-6 fatty acids into omega-3 fatty acids. They implanted 1 800 embryos into 14 female pigs. Ten live offspring, which were able to make high levels of omega-3 fatty-acids were born. [Adapted from: *Cape Argus*, 27 March 2006]

4.1 What percentage success did the scientists have with the implanted embryos in forming a clone of pigs capable of producing omega-3 fatty acids? Show ALL working. (3)

$$\frac{10\,\surd \times 100\surd}{1800}$$

= 0.55%√

Answer: ______________________________

4.2 To produce genetically modified pigs, the gene that produces omega-3 fatty acids is inserted into the pig embryos. Describe the steps in forming and introducing many copies of the desirable gene (using bacteria), into the pig embryos. (4)

Answer: **The gene responsible for producing omega 3 is located √**
In DNA of salomon /fresh mackerel/ tuna √
This gene is cut/removed from the donor organism √
It is inserted into the plasmid of a bacterium √
Recipient bacterium replicates to form many copies of the gene √
These genes are inserted into the cells of the zygote/embryo of a pig/organism.(Any four correct responses)

4.3 Give TWO reasons why
(a). Some people may support the use of genetically modified pigs to produce omega-3 fatty acids (2)

Answer**(i)** **Healthier for humans to eat √, combat heart disease √**
(ii) **Mass production of healthy fats √**
Improves intelligence

(b) Some people may be against the use of genetically modified pigs to produce omega-3 fatty acids. (2)

Answer **(i)** **Cultural/religious objections to eat meat from pigs/pork √**

(ii) **Very low success rates √**

Expensive procedure √

No value for vegetarians √

Objections to eating genetically modified foods √ **[11]**

QUESTION 5

A body of a young woman was found on an open plot. She had been allegedly assaulted and murdered. DNA specimens were taken at the scene.

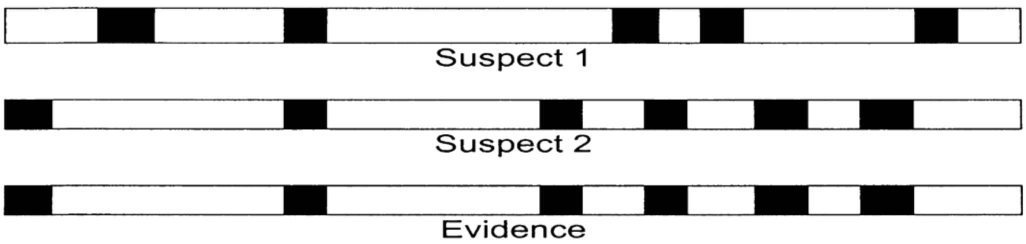
5.1 What is the purpose of taking DNA specimens at the scene? (2)

Answer: _**To identify the victim √ / To identify the murderer/perpetrator/rapist** √

5.2.1 What other purpose, (not those mentioned in question 5.1) can DNA fingerprinting also be used for? (1)

Answer: _**To determine paternity / paternity tests**_

The DNA fingerprints below were used as evidence in a court case in order to convict the crime suspect. A fraction of a DNA finger-print was derived from dry blood that was found on the victim's belt (with which she was strangled). Study the DNA finger-prints and answer the questions that follow.



5.3 Which suspect is most probably the murderer? (1)

Answer: _____**Suspect 2** √______

5.4 Give a reason for your answer to question 7.3. (1)

Answer: _**The bar code pattern of suspect 2 correlates exactly with that of the documentary evidence**_ √_

5.5 Is there any way in which the suspect can prove his innocence? Explain (3)

Answer: **Yes** √**, He/she can argue that the dry blood came from the victim himself.**√√

5.6 In which way do you think the forensic team can prove this claim wrong? (2)

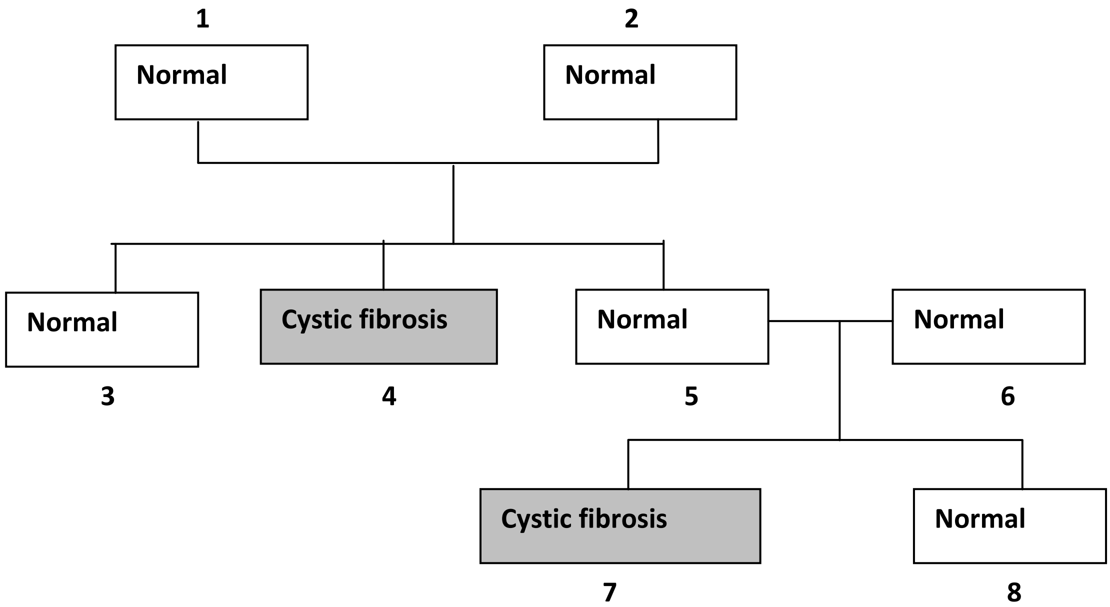
Answer: ___**The forensic team should have made a DNA print of the victim's DNA**√**, in order to compare it with the evidence** √__

5.7 If one of the suspects refused to give his DNA for testing, should he be forced to do so? Explain. (2)

Answer: _**<u>Yes √, If he/she knows he/she is innocent, he/she would not have a problem giving his DNA, so the suspect is most probably guilty, and should therefore be forced to give his/her DNA sample √. By committing murder, you take away another person's life, and therefore surrender your own rights to privacy√.</u>**_OR **<u>No √, His right to privacy should not be violated √, He cannot be forced to do anything against his will √.</u> [12]**

QUESTION 6

The diagram below shows a family tree for cystic fibrosis. This condition is produced by a recessive allele, f, while the normal condition is controlled by the dominant allele, F.



6.1 What are the possible genotypes of individuals 1, 4, and 5 respectively? (3)
Answer: **<u>1 – Ff √; 4 – ff √; 5 – Ff √.</u>**

6.2 Briefly explain TWO symptoms of cystic fibrosis. (2)
(i) Answer: **<u>Body produces an abnormally thick sticky mucus √.</u>**
<u>- that accumulates in the lungs √.</u>
(ii) Answer: **<u>Certain enzymes are not produced √</u>**
<u>leading to digestive problems √</u>
<u>Produce sweat with high salt content / salty sweat √</u>
<u>Low immunity √</u> (Any two correct responses).

6.3 If individual 8 is heterozygous, what are the chances of individuals 7 and 8 of having a NORMAL child? Show this by means of a Punnett diagram. (5)

	f	**f**√
√**F**	Ff	Ff √
f	ff	ff √

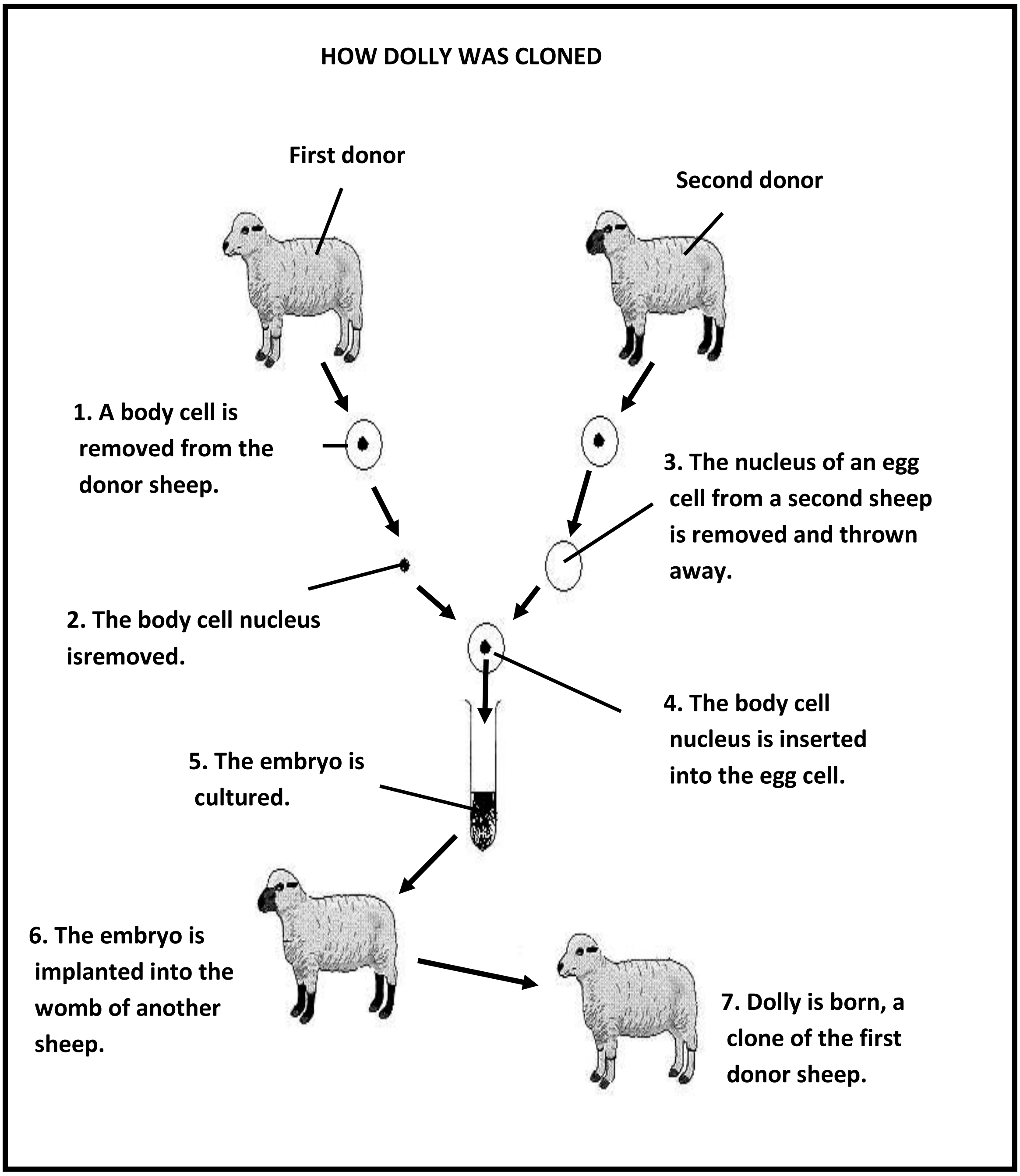
Answer: **<u>= 50%</u>** √ **<u>Chance of Cystic fibrosis</u>**

6.4 Is cystic fibrosis a sex-linked disease? Briefly explain your answer. (2)
Answer: **No √, Both males and females can get the disease √.**

[12]

QUESTION 7

Study the diagram below that shows the cloning of a sheep named Dolly.



7.1 Why was it necessary to remove the nucleus from the egg cell of the second donor before the sheep could be cloned? (1)

Answer: **To insert the DNA / nucleus √ of the sheep that you want to clone √**

7.2 Would Dolly have any characteristics of the second donor sheep? (1)
Answer: **No √**

7.3 Explain your answer to **question 10.2** (2)

Answer: **Dolly will have exactly the same DNA as the first donor sheep √, because the DNA of the second donor sheep was removed √ and replaced.**

7.4 Number 5 on the diagram states that 'the embryo is cultured'. Through which process of cell division does the embryo develop? (1)

Answer: **Mitosis√,**

[5]

TOTAL MARKS **[55]**

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Appendix VIII: Test of Science Inquiry Skills (TOSIS)

Learner code ☐

Age ☐

Grade ☐

Gender ☐

DURATION: 30 Minutes

TOTAL MARKS: 20

INSTRUCTIONS AND INFORMATION

Read the following instructions carefully before answering the questions.

1. **Answer ALL the questions.**
2. **Write ALL the answers in the spaces provided for each question.**
3. **Present your answers according to the instructions of each question.**
4. **ONLY draw diagrams or flow charts when asked to do so.**
5. **Non-programmable calculators, protractors and compasses may be used.**
6. **Write neatly and legibly.**

1. Read the following passage carefully and choose the best answer from the options given after each question, by putting a cross [X] on the letter that represents your choice. After making your choice, give a reason(s) for choosing the option.

Mpho discovered that his bread was covered with bread mould (fungi that grows on bread). He wondered whether temperature had anything to do with the presence of bread mould on his bread. He decided to grow bread mould in nine similar containers with temperature regulators. Three containers were kept at 0^{o}c, three were kept at 90^{o}c, and three were kept at room temperature (about 27^{o}c). He put the same amount of bread, and bread mould in each of the containers and kept all of them in the same cupboard. Mpho measured the amount of the bread mould in each container after four days.

1.1 In this experiment Mpho was trying to test whether ____________________

A. bread mould will cover the bread in the three containers, after four days.
B. growth of bread mould is affected by the temperature of the environment.
C. the amount of bread mould is determined by the amount of bread available.
D. the type of container used determines the amount of bread mould produced.

Give a reason for your choice.

____

____

1.2 The factor that was expected to change in this experiment was:
A. the amount of the bread mould in each container.
B. the amount of bread in each container
C. the temperature of each container
D. the number of containers at each temperature

Give a reason for your choice

____

____

1.3 Which factor was changed (manipulated) in this experiment?
A. The number of containers at each temperature
B. The amount of bread in each container
C. The presence of bread mould in the containers
D. The temperature of the containers

Give a reason for your choice

____

____

2. Read the following passage adapted from the National Geographic news. Retrieved on 32/02/2010, from: http://en.wikipedia.org/wiki/Colony_collapse_disorder

Then answer the questions that follow.

Mystery Bee Disappearances

Without a trace, something is causing bees to disappear (vanish) by the thousands. A phenomenon called Colony Collapse Disorder (CCD), in which worker bees from a <u>beehive</u> abruptly disappear is affecting bee colonies in the United States. The cause(s) of the Colony Collapse disorder are not yet fully understood, although many authorities think that the problem is caused by <u>biotic</u> factors such as *<u>Varroa</u>* mites and insect diseases. Other proposed causes include environmental change-related stresses, <u>malnutrition</u>, pesticide use, and migratory beekeeping. More speculative possibilities have included both <u>cell phone</u> radiation and <u>genetically modified (GM) crops</u> with <u>pest control</u> characteristics. Up to now, no evidence exists for any of these suggestions (assertions). It has also been suggested that it may be due to a combination of many factors, and that no single factor is the cause.

Colony collapse is economically significant because <u>many agricultural crops, worldwide, are pollinated by bees</u>. For example an estimated 14 billion U.S. dollars in agricultural crops in the United States is dependent on bee pollination. A lot of people think that honeybees are only important for the honey they produce, but much, much more important are their pollination services.

Imagine that you are a scientist who is interested in knowing the cause(s) of the bee colony collapse disorder. You decide to investigate the effect of pesticides on the disappearance of the bees.

2.1 Which of the following ideas would you test in your investigation? (Put a cross [☒] on the letter that represents your choice).

A. Bees are disappearing by the thousands in Colony Collapse Disorder.
B. Understanding the different causes of the Colony Collapse Disorder.
C. Stresses, malnutrition, pesticides, migratory beekeeping, cell phone radiation, and genetically modified crops are the causes of the Colony Collapse Disorder.
D. Pesticides cause Colony Collapse Disorder.

2.2 Tell us how you would conduct your investigation.

____
____
____
____
____

3. A life sciences educator wanted to show her class the relationship between light intensity and the rate of plant growth. She carried out an investigation and got the following results.

Light intensity (candela)	250	650	1100	1300	1600	2000	2400	2800	3100	3200
Plant growth rate (cm/week)	2	5	9	11	12	15	13	10	5	0

Table 1. The relationship between light intensity and plant growth rate

3.1 You are one of the learners in the life sciences class, and your educator asks you to draw a Figure using the above results (Table 1), to show the relationship between light intensity and plant growth. Use the grid below to draw the Figure.

3.2 Which factors (variables) were being investigated by the educator?

A________________________________ B ____________________________

3.3 From the results of this investigation, we may say that

A. An increase in plant growth increases light intensity.
B. An increase in light intensity decreases plant growth.
C. An increase in plant growth increases light intensity to a certain point then it decreases.
D An increase in light intensity increases plant growth to a certain point then it decreases.

4. Read the following passage carefully and answer the questions that follow, by choosing the best answer from the options given after each question. Put a cross [E] on the letter that represents your choice.

   A farmer received special food from the government, for helping his cows to produce more milk. He wants to find out whether the special food could indeed increase his cows' milk production. He therefore gives the special food to 20 cows for a period of one month. He gives the same amount of normal (usual) food to 20 other cows for the same period of time. He carefully records the amount of milk produced by each of the 40 cows for a month. At the end of the month his results are as follows:

   - **18 of the cows that were <u>not</u> given the special food produced just as much milk as usual, while 2 of them produced more milk.**
   - **16 of the cows that were given the special food produced more milk, while 4 of them produced just as much milk as usual.**

4.1 What was the farmer trying to find out in the above investigation?

A. Whether the amount of milk produced by each of the 40 cows can be recorded
B. Whether the special food he received from the government was not poisonous
C. Whether the special food he received from the government increased milk production
D. Whether the cows feed on special food would be fatter than those feed on normal food

4.2 From the results of this investigation, we may conclude the following:

A. The special food does not help cows to produce more milk.
B. The special food helps cows to produce more milk.
C. The usual food helps cows to produce more milk.
D. Both the special food and the usual food help cows to produce more milk.

Give a reason for your choice

____

____

5. Read the following passage carefully and answer the questions that follow by choosing the best answer from the options given after each question. Put a cross [E] on the letter or number that represents your choice.

   A learner wants to investigate the effect of acid rain on fish. She takes two jars and fills them with the same amount of fresh water. She adds fifty drops of vinegar (weak acid) to one jar, and adds nothing to the other. She selects four similar live fish, and puts two in each jar. Both pairs of fish are provided with the same amount of all their requirements (e.g. oxygen, food, etc.). After observing the fish for one week, she draws her conclusion.

5.1 Which of the following would you suggest for this experiment in order to improve it?

A. Prepare more jars with different amounts of vinegar (weak acid).
B. Add more fish to the two jars already in use.
C. Add more jars with different types of fishes.
D. Add more vinegar (weak acid) to the two jars already in use.

5.2 Select a suitable explanation for your answer to the above question from the following explanations.

1. When more fish are added to the two jars the effect of the acid will no longer be felt.
2. More jars with different types of fishes will show you a variety of effects of the acid on the fishes.
3. Preparing more jars with different amounts of vinegar will show the effect of different concentrations of acid.
4. Adding more vinegar to the two jars will produce a greater effect on the fishes and make the acid effect clearer.

THANK YOU FOR YOUR PARTICIPATION. YOUR CONTRIBUTION IS HIGHLY APPRECIATED.

THE END

****

MEMORANDUM

SCHOOL.____

INSTRUMENT: TEST OF SCIENCE INQUIRY SKILLS (TOSIS)
TOTAL MARKS: 20

ITEM SPECIFICATION:

	Inquiry skills	Items	Total scores
1	Formulation of hypotheses	1.1, 2.1, 4.1	3
2	Identification of variables	1.2, 1.3, 3.2	3
3	Experimental design	2.2, 5.1, 5.2	5
4	Graphing skills	3.1	6
5	Drawing conclusions from results	3.3, 4.2	3
	Total score		20

QUESTION 1 [3] (*1 mark each*)

1.1 B
1.2 A
1.3 D

QUESTION 2 [4]

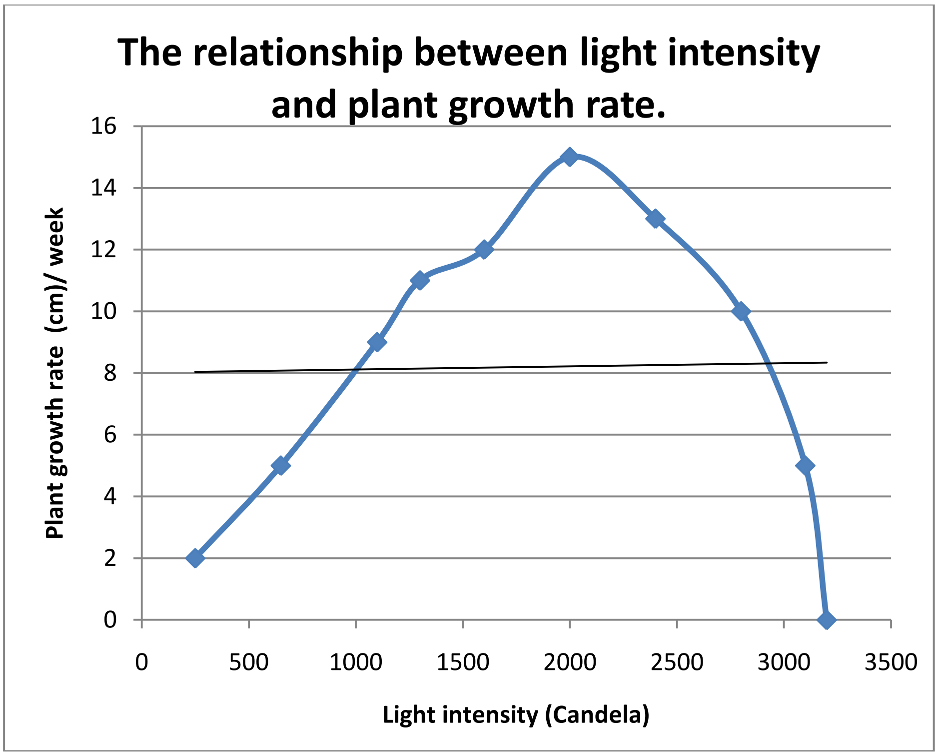
2.1 D *(1mark)*

2.2 - evidence of correct procedure (steps = *1mark)*
- indication of use of a control (*1 mark*)
- indication of some replication of the experiment *(1 mark)*

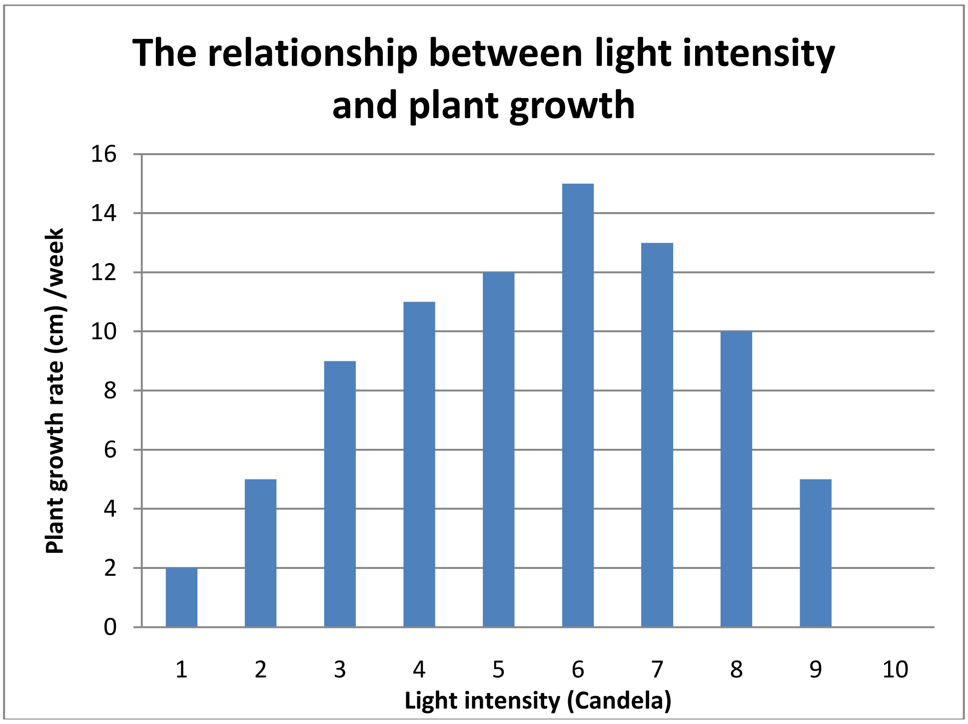
QUESTION 3 [8]

3.1 Figure *[6 marks]*

	Marks
Correct Figure	1
Appropriate scale used	2
Axis correctly placed and labelled	2
Correct title of the Figure	1
Total marks for Figure	6



OR A CORRECT HISTOGRAM WITH APPROPRIATE LABELS



3.2 Light intensity and plant growth rate *[1mark; ½ mark each]*

3.3 D *[1 mark]*

QUESTION 4 [3] THE EFFECT OF SPECIAL FOOD ON MILK PRODUCTION

4.1 C *[1 mark]*
4.2 D *[1 mark]*

Reason: More cows given the special food more produced milk than usual, and few cows given normal food produced more milk than usual (Or any similar response) *[1 mark.]*

QUESTION 5 [2]

5.1 **A** *[1mark]*For experimental design
5.2 **3** [*1 marks*] Reason for a chosen design

TOTAL MARKS = 20

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Appendix IX: Decision-Making Ability Test (DMAT)

Learner code ☐

Age ☐

Grade ☐

Gender ☐

DURATION: 20 Minutes

Total Marks: 10

INSTRUCTIONS AND INFORMATION

Read the following instructions carefully before answering the questions.

1. **Answer ALL the questions.**
2. **Write ALL the answers in the spaces provided for each question.**
3. **Present your answers according to the instructions for each question.**
4. **ONLY draw diagrams or flow charts when asked to do so.**
5. **Non-programmable calculators, protractors and compasses may be used.**
6. **Write neatly and legibly.**

THANK YOU FOR YOUR PARTICIPATION

QUESTION 1 **Read the following passage carefully and answer the questions that follow it.**

Tsego has been taking care of her 50-year-old father who has been suffering from a genetic disease called Huntington's disease for the past five years. When Tsego became pregnant outside marriage, she feared that her unborn child might be a carrier of Huntington's disease. She decided to go for genetic tests, which confirmed her fear. Tsego did not want her child to suffer the way her father did. She therefore wondered whether she should abort the baby or not. Tsego decided not to tell her boyfriend about the unborn baby's condition.

	FACTS ABOUT HUNTINGTON'S DISEASE
1	Huntington's disease is a dominant genetic trait, but symptoms show later in life.
2	Sick people develop involuntary tremors (shivers) of the limbs, and personality alterations, outbursts of crying, unexplained anger, memory loss and sometimes schizophrenic behaviours.
3	The seriousness of the symptoms at the various stages of the disease differs from one person to another.
4	A person may lead a normal life until the age of 50.
5	In their final years of life, patients are in a vegetative state.
6	Death usually occurs after the age of 50.
7	The average life expectancy of a healthy human being is about 75 years.
8	Abortion of an embryo at an early stage of the pregnancy is legal in South Africa.
9	Every human being has a right to life.

For question 1.1, choose the correct option by putting a cross [E] on the letter representing the correct answer.

1.1. What is the problem that needs to be considered in the story above?
   A. Whether Tsego should tell the boyfriend about the condition of the baby or not.
   B. Tsego became pregnant outside marriage.
   C. Whether the unborn child is a carrier of Huntington's disease or not.
   D. Whether Tsego should abort the baby of not.

1.2. How could Tsego handle this problem?

____

____

1.3. What would you advise Tsego to do? Explain.

____

____

____

1.4. If your friends have views that differ from yours, would you listen to their opinions before settling on a final decision, or would you give reasons to defend your view?

Answer ____

Explain____

____

1.5. Should Tsego inform her boyfriend about her baby's condition and get his opinion before she makes a decision or not?

Answer ____

Explain____

____

QUESTION 2 **Read the following case carefully and answer the questions that follow it.**

You are given the responsibility of managing a school library. The roof of the school library has a lot of bats which scare some learners who want to use the library. The following table shows some facts about bats.

	FACTS ABOUT BATS
1	Bats are small flying mammals.
2	Bats can hide behind bookshelves and small spaces.
3	Bats are considered to be an endangered species (they are likely to become extinct).
4	Anyone caught killing or harming a bat may be fined up to R2000.00.
5	Bats are active at night and sleep during the day.
6	A bat can bite a human being.
7	Some bats carry rabies virus which can be transmitted to human beings through a bite.
8	Vampire bats found in Europe suck blood from warm-blooded animals.
9	Most bats eat insects including vectors such as mosquitoes, which can spread diseases.
10	Bats are good pollinators.
11	Bats help in seed dispersal.
12	Bats prefer living in natural habitats. They only live in houses when their natural habitat is destroyed.
13	Bats move very fast in an erratic (random) pattern.

For question 2.1, choose the correct option by putting a cross [☒] on the letter representing the correct answer.

2.1 What problem does the presence of the bats in the library roof present?

A. Bats are considered to be an endangered species.
B. The bats make the library look dirty.
C. Some learners are scared to use the library.
D. The R2000.00 fine for killing bats.

2.2 How would one deal with the bats?

____

____

2.3 Being the person responsible for managing the library, what would you do about the bats?

Answer ____

Explain____
____

2.4 Your assistant comes up with a suggestion which is different from yours. How would you react to this suggestion?

Answer ____

Explain____
____

2.5 The nature conservation board is responsible for taking care of wild life. Would you consult them before implementing your final decision?

Answer ____

Explain____
____

THE END

****

MEMORANDUM

CRITERIA FOR ASSESSING DECISION-MAKING ABILITY (DMAT)

Total marks: 10

CRITERIA

1	Ability to identify/state the problem in a given situation
2	Ability to consider/identify alternative options
3	Use of facts to evaluate/eliminate options and select a viable option
4	Consideration of stakeholders in making a decision.

QUESTION 1 (5 Marks)

1.1. (Criterion 1): 1 mark
A. Should Tsego tell the boyfriend about the condition of the baby or not?
B. Tsego became pregnant outside marriage.
C. Is the unborn child a carrier of Huntington's disease or not?
D. Should Tsego abort the baby of not?
1.2. (Criterion 2): 1 mark (at least 4 options; 3 or 2 options, ½ mark; 1 option, no mark)

Examples
Seek medical advice.
Abort the baby.
Keep the baby and wait to see if the problem occurs.
Keep the baby and pray for healing.
Keep the baby and be prepared to take care of it. Etc.

1.3. (criterion 3): 1 mark
Explanation - reflects ability to use facts to select a viable option among alternative options.

1.4. (Criterion 3): 1 mark
Explanation based on ability to consider alternative options and use facts to select a viable option.

For example:
Agree to consider the optional suggestion and use available facts to either accept or reject it.

1.5. (Criterion 4): 1 mark
Explanation relates to concern for stakeholders (baby, father, mother)

QUESTION 2 (5 Marks)

2.1 (Criterion 1): 1 mark

A. Bats are considered to be an endangered species.
B. The bats make the library look dirty.
C. Some learners are scared to use the library.
D. The R2000.00 fine for killing bats.

2.2 (Criterion 2): 1mark (at least 4 options; 3 or 2 options, ½ mark; 1 option, no mark)

Examples:

- Kill the bats
- Ignore them
- Allow them to escape
- Prevent them from escaping
- Seek help from wild-life specialist

2.3 (Criterion 3): 1mark

Decision and explanation based on available facts

For example:

- Fear of: being fined, making the bats extinct.
- Bats; are good pollinators, help in seed dispersal; destroy vectors.
- Bats may bite people and learners are scared of using the library.
- Bats may transmit disease to people.
- Natural habitat destroyed (therefore bats may not leave)

2.4 (criterion3): 1mark

Explanation based on ability to consider alternative options and use facts to select a viable option.

For example: Agree to consider the optional suggestion and use available facts to either accept or reject it.

2.5 (criterion 4): 1mark

Explanation relates to concern for stakeholders and consideration of available facts:

For example: Consideration for future generations, the nature conservation board, the environment, etc.

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Appendix X: Problem-Solving Ability Test (PSAT)

Learner code	☐
Age	☐
Grade	☐
Gender	☐

DURATION: 30 Minutes

Total Marks 10

INSTRUCTIONS AND INFORMATION

Read the following instructions carefully before answering the questions.

1. **Answer ALL the questions.**
2. **Write ALL the answers in the spaces provided for each question.**
3. **Present your answers according to the instructions of each question.**
4. **Non-programmable calculators, protractors and compasses may be used.**
5. **Write neatly and legibly.**

Problem 1: (adapted from Reeff, Zabal and Blech - DIE, 2006)

John would like the members of his family to meet for a family reunion, at his home in Pretoria. These family members live in different parts of South Africa. John wants to treat his family to a big braai during the family get-together. He is likely to get the money for the braai from his salary, which he gets on the 15th of every month. In order to involve everyone in the family, the date for the reunion should be suitable for all. Some of John's relatives go to school, and they have a month-long holiday in July. John is the only one in the family who is good at planning parties.

Imagine yourself to be John. Your appointments in July are shown in Table 1, while the appointments of your relatives in the same month are shown in Table 2.

Table 1 John's important appointments in July

Day	Date	Appointment
Thursday	1	
Friday	2	
Saturday	3	
Sunday	4	
Monday	5	
Tuesday	6	
Wednesday	7	
Thursday	8	
Friday	9	
Saturday	10	
Sunday	11	Thanks-giving at his youth club.
Monday	12	
Tuesday	13	
Wednesday	14	
Thursday	15	
Friday	16	
Saturday	17	
Sunday	18	
Monday	19	Meet with his boss.
Tuesday	20	
Wednesday	21	
Thursday	22	
Friday	23	Attend a friend's wedding.
Saturday	24	
Sunday	25	
Monday	26	
Tuesday	27	
Wednesday	28	Attend a workshop at work.
Thursday	29	Attend a workshop at work.
Friday	30	
Saturday	31	

NOTE!! John works for eight hours every day, from Monday to Friday. However, he could negotiate for leave on any day, apart from a Wednesday.

Table 2 John's family's appointments in July

Mpho	Nolwazi	Thomas	Maria	Nelisa	Ayanda
Attend a conference on July 12; See a doctor on July 26.	Any day of the week is okay, except Thursdays and on July 16.	Business appoint-ments on July 2, July 13, and July 27.	No important appointments, but has to attend youth club every Saturday.	Cannot attend the re-union on July 5, July 20 and July 24.	Will be abroad during the second week of July. Starting from the 4^{th} of July.
Mpho and Nelisa need to use a plane to come for the reunion, while Nolwazi, Maria, Thomas and Ayanda could use their own cars or public transport.					
John's wife, Lerato, has to be at the reunion. However, she might attend a women's meeting at youth club, on the 25^{th} of July.					

Answer the following questions concerning the family reunion.

1. What is the problem that needs to be solved in the situation described above?

____

____

2. What do you think you need to consider for you to solve the problem?

____

____

____

____

3. Which date in July is **most suitable** for John's family reunion?

____

4. Tell us how you arrived at this date (the steps you followed)?

____

____

____

____

____

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____

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____

5. How would you make sure that this date is suitable for everyone in Johns' family?

____

____

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____

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____

Problem 2: (adapted from PISA – OECD, 2004)

A youth club is organizing a five-day children's camp. Forty-six (46) children (26 girls and 20 boys) have signed up for the camp, and 8 adults (4 men and 4 women) have volunteered to attend and organise the camp. The names of the adults who volunteered to attend the camp are; Mrs Thomson, Mrs Modiba, Ms Vyk, Ms Sanders, Mr Kiviet, Mr Neil, Mr Zulu and Mr Williams. Seven dormitories with differed number of beds are available at the camp site, as shown on the table below.

Name of dormitories	Number of beds
Red	12
Blue	8
Green	8
Purple	8
Orange	8
Yellow	6
White	6

All the people involved need to be accommodated at the camp, and the rules of the camp must be observed. The following table shows the names of the available dormitories and the number of beds in each dormitory.

Dormitory rules:

1. Males and females are **not** allowed to sleep in the same dormitory.
2. At least one adult **must** sleep in each dormitory.

Answer the following questions concerning the camp.

1. What is the problem that needs to be solved in the situation described above?

____

____

____

____

____

____

2. Complete the table below by allocating the 46 children and 8 adults to the dormitories.

Name of dormitory	**Number of boys**	**Number of girls**	**Name(s) of adult(s)**
Red			
Blue			
Green			
Purple			
Orange			
Yellow			
White			

THANK YOU FOR YOUR PARTICIPATION. YOUR CONTRIBUTION IS HIGHLY APPRECIATED.

THE END

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MEMORANDUM

CRITERIA FOR ASSESSMENT OF PROBLEM-SOLVING ABILITY
Total Marks: 10

1	Ability to define / state / clarify the problem
2	Ability to reason / explore / analyse / forecast the problem
3	Ability to plan / devise a strategy / investigate / implement the possible solution.
4	Ability to evaluate / reflect on the problem

QUESTION 1 Family reunion

1. **Problem accurately defined**: To set an appropriate date for the re-union, 1 mark.

2. **Ability to explore the problem:** date should be in July, John's appointments, relatives' appointments and commitments, John's pay date, transport needs, time for relatives to return home. **1 mark**; for three or more considerations, ½ mark; for one or two considerations, 0 mark; for no consideration.

3. **Ability to plan:** 18th of July, 1 mark; 30th of July, ½ mark; any other, 0 mark.

4. **Ability to explore the problem:** consider appointments and commitments of people involved, time when John is likely to have money, transport needs, etc. 1 mark for 3 or more steps; ½ mark for 1 or 2 steps, and 0 for no steps.

5. **Ability to evaluate the problem:** Ensure that no appointment or commitments on selected day; John is likely to have money; it meets transport needs.1 mark for 3 or more reflections, ½ mark for 1 or 2 reflections, 0 mark for no reflection.

Total marks = 5

QUESTION 2 Children's camp

1. Problem accurately defined: To set an appropriate date for the reunion, 1 mark.

2. Conditions to be satisfied for full credit = 4 marks.
   i. Total number of girls = 26.
   ii. Total number of boys = 20.
   iii. Total number of adults = 8 (4 males and 4 females).
   iv. Total number of individuals in each dormitory is within the limit for each dormitory.
   v. Individuals in each dormitory are of the same gender.
   vi. At least on adult in each dormitory.

Example of full credit response for children's camp question

Dormitory		Number of boys	Number of girls	Name(s) of adult(s)	Totals
Name	Bed capacity				
Red	12	8	0	Mr Zulu and Mr Neil	10
Blue	8	0	7	Mrs Thomson	8
Green	8	0	7	Ms Sanders	8
Purple	8	0	7	Ms Vyk	8
Orange	8	7	0	Mr Kiviet	8
Yellow	6	0	5	Mrs Modiba	6
White	6	5	0	Mr Williams	6
Totals	56	20	26	8 adults	54

Conditions for partial credits

i. Violation of 1 or 2 conditions - subtract 1 mark.
ii. Exclusion of adult (s) in the total number of individuals in each dormitory – subtract 1 mark.
iii Number of girls and boys exchanged (i.e. girls = 20 and boys = 26) - subtract 1 mark.
iv. Correct number of adults in each dormitory but names (or gender) not given – subtract 1 mark.
v. No response or other responses given - 0 mark.

NOTE:

Question 2.1 tested learners' competence in criterion 1; ability to define / state the problem. Full credit in question 2.2 demonstrates competence in three of the four criteria for problem-solving ability: Ability to reason, plan and evaluate the problem, through the allocation of the correct number of individuals to dormitories, according to complicated specified interrelated variables and relationships. That is, relationships of, male – female, child – adult, different dormitory sizes, and the fact that there were 8 adults and only seven dormitories. A partial credit showed violation of one of more of the specified conditions, thus indicating a deficiency in one or more of the stated criteria for problem-solving ability.

Appendix XI: Life Sciences Attitude Questionnaire (LSAQ)

Learner code

Age

Gender

School code

Duration: 15 minutes

INSTRUCTIONS

Please indicate how you feel about the statements shown below, by choosing (SD) for Strongly Disagree, (D) for Disagree, (U) for Undecided, (A) for Agree and (SA) for Strongly Agree. Indicate your choice by marking a cross under the option which you think best represents your feelings about the statement given, as shown in the example below.

Example

		SD	D	U	A	SA
0	My school is the best in South Africa					X

In the above example, the person put a cross under the option (SA), which indicates that he/she strongly agrees that his/her school is the best in South Africa.

Indicate on the following table, how you feel about each of the statements, by marking in the box representing the option which you think best represents your feelings, as shown in the above example.

	Statement	SD	D	U	A	SA
1	Genetics is an interesting topic to study					
2	Without the study of life sciences, it would be difficult to understand life.					
3	Performing practical activities in genetics helps me to understand genetics concepts and ideas better.					
4	Life sciences are more difficult than other science subjects.					
5	I admire people who are knowledgeable about life sciences.					
6	I like studying life sciences because of its importance in understanding life and the environment.					
7	Genetics is a difficult topic.					
8	What is taught in genetics cannot be used in everyday life.					
9	I enjoy studying genetics					
10	My future career/profession has nothing to do with genetics, so I don't study it a lot.					
11	There are too many concepts (ideas) to learn in genetics, and as a result, I have lost interest in the topic.					
12	I do not bother about what we learn in genetics because I do not understand them.					
13	Genetics will be very useful in my future career/ profession. I therefore want to study it very well.					
14	I usually feel like running out of the class during life sciences lessons.					
15	I enjoy studying life sciences.					
16	Studying life sciences is a waste of time.					
17	Ideas in genetics are not related to human needs.					
18	I do not understand how the study of genetics is related to my daily life.					
19	I do not agree with many ideas (concepts) in life sciences.					
20	I feel quite happy when it is time for genetics lessons.					
21	I hope to study genetics and life sciences further, because I want to take up a life science-related career.					
22	I really enjoy the life sciences lessons which deal with my daily life experiences.					
23	I don't like studying genetics.					
24	What is learnt in life sciences can be applied to our daily lives.					
25	I think I will have fewer job opportunities if I study genetics and life sciences.					
26	Life science is an easy subject.					
27	Discoveries in life sciences and genetics have improved human life.					
28	Life science is not my favourite subject.					
29	I sometimes avoid studying life sciences.					
30	I like setting difficult tasks for myself when studying genetics.					

THANK YOU FOR YOUR PARTICIPATION.

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LIFE SCIENCES ATTITUDE QUESTIONNAIRE (LSAQ) SCORING FRAMEWORK

LEARNER CODE ☐ **GENDER** ☐

#		SD	D	U	A	SA	Rating
1	+	1	2	3	4	5	
2	+	1	2	3	4	5	
3	+	1	2	3	4	5	
4	-	5	4	3	2	1	
5	+	1	2	3	4	5	
6	-	5	4	3	2	1	
7	+	1	2	3	4	5	
8	+	1	2	3	4	5	
9	+	1	2	3	4	5	
10	-	5	4	3	2	1	
11	-	5	4	3	2	1	
12	-	5	4	3	2	1	
13	+	1	2	3	4	5	
14	-	5	4	3	2	1	
15	+	1	2	3	4	5	
16	-	5	4	3	2	1	
17	+	1	2	3	4	5	
18	-	5	4	3	2	1	
19	-	5	4	3	2	1	
20	+	1	2	3	4	5	
21	+	1	2	3	4	5	
22	-	5	4	3	2	1	
23	-	5	4	3	2	1	
24	+	1	2	3	4	5	
25	+	1	2	3	4	5	
26	+	1	2	3	4	5	
27	+	1	2	3	4	5	
28	-	5	4	3	2	1	
29	-	5	4	3	2	1	
30	-	5	4	3	2	1	
	Total score						

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AN EXAMPLE OF A SCORE SHEET FOR THE LIFE SCIENCES ATTITUDE QUESTIONNAIRE (LSAQ)

LEARNER CODE 03 **GENDER** F

NO.	CAT		SD	D	U	A	SA	Rating
1	**E**	+	1	2	3	~~4~~	5	**4**
2	**A**	+	1	2	3	4	~~5~~	**5**
3	**B**	+	1	2	3	~~4~~	5	**4**
4	**D**	-	5	~~4~~	3	2	1	**4**
5	**D**	+	1	2	3	4	~~5~~	**5**
6	**A**	-	5	~~4~~	3	2	1	**4**
7	**E**	+	1	~~2~~	3	4	5	**2**
8	**A**	+	1	2	3	~~4~~	5	**4**
9	**E**	+	1	2	3	~~4~~	5	**4**
10	**C**	-	~~5~~	4	3	2	1	**5**
11	**B**	-	5	~~4~~	3	2	1	**4**
12	**B**	-	~~5~~	4	3	2	1	**5**
13	**C**	+	1	2	3	4	~~5~~	**5**
14	**B**	-	5	~~4~~	3	2	1	**4**
15	**D**	+	1	2	3	~~4~~	5	**4**
16	**D**	-	~~5~~	4	3	2	1	**5**
17	**A**	+	1	~~2~~	3	4	5	**2**
18	**A**	-	5	~~4~~	3	2	1	**4**
19	**D**	-	5	~~4~~	3	2	1	**3**
20	**E**	+	1	~~2~~	3	4	5	**2**
21	**C**	+	~~1~~	2	3	4	5	**1**
22	**A**	-	5	~~4~~	3	2	1	**4**
23	**E**	-	5	~~4~~	3	2	1	**4**
24	**A**	+	1	2	3	4	~~5~~	**5**
25	**C**	+	1	2	3	~~4~~	5	**4**
26	**D**	+	1	2	3	~~4~~	5	**4**
27	**A**	+	1	2	3	~~4~~	5	**4**
28	**D**	-	5	~~4~~	3	2	1	**4**
29	**E**	-	5	~~4~~	3	2	1	**4**
30	**E**	-	5	4	~~3~~	2	1	**3**
		Total score						**116**

Appendix XII: Science Cognitive Preference Inventory (SCPI)

Learner code

Age

Grade

Gender

DURATION: 10 Minutes

INSTRUCTIONS

In this inventory we are **NOT** testing your ability. We want to find out about some of the things you like in Science. Each item in this inventory begins with some information about science. An item is followed by four statements which **all** contain **correct** information. You are asked to rank the statements according to the way you like them, by assigning numbers 4 to 1 as follows:

4. for the statement that you like most (the most interesting to you).
3. for the statement that you like second best.
2. for the statement that you like third best.
1. for the statement that you like the least (the least interesting to you).

PLEASE NOTE:

Read all four statements for each item before you start ranking them. Remember that **ALL** statements are **CORRECT**, which means that there is no correct or wrong answer. You just need to rank the statements, starting with the one you like most up to the one you like the least, by assigning them the numbers 4, 3, 2, and 1, accordingly.

EXAMPLE

It is a bright cold Saturday afternoon.		
A	Swimming conditions are excellent	4
B	A field trip to the forest will be good	1
C	There is a nice new movie starting at the cinema	3
D	A basketball match is being shown on the television	2

For the person who filled in this table, the most liked activity on a bright cold Saturday afternoon is swimming (4thranking), followed by watching a new movie at the cinema (3rd ranking), then watching a basketball match being shown on the television (2nd ranking), and a field trip to the forest is the least liked activity on a cold Saturday afternoon (1st ranking).

Select the following statements as explained in the example above.

1.	**A function of a stem of a plant is to bear leaves, flowers and later on fruits.**	
A	Fibres used in cloth are made of the stems of certain plants.	
B	The maximum height of a plant depends on the shape and the amount of wood in the stem.	
C	Some stems are soft, others are woody.	
D	How do old trees with hollow trunks remain alive?	

2.	**Bacteria are important for the living world.**	
A	Bacteria are used in the food industry in the production of foods such as cheese, yoghurt, and certain types of prickles.	
B	What would become of the carbon in dead organisms if there were no bacteria at work?	
C	Some bacteria break down dead plants and animals into their elements. By doing so, they help maintain the cycle of necessary elements.	
D	Bacteria are organisms so small that they can be seen only with the aid of a microscope.	

3.	**Living organisms may be divided into producers and consumers.**	
A	There is always a larger number of producers than consumers.	
B	What will happen to the producers if all consumers on earth disappeared?	
C	Green plants provide food and energy for most other living organisms and so they make animal and human life possible.	
D	Most producers are green plants.	

4.	**Algae are simple plants that can produce oxygen (by photosynthesis).**	
A	Algae are primary producers and fundamental to the survival of most water animals.	
B	Certain algae can be used as indicators of the conditions in fish ponds and aquaria.	
C	According to geological findings, blue algae were the first plants on earth. There could possibly be a special reason for this.	
D	Algae are classified into green, blue, brown and red algae.	

5.	**Heredity (genetics) is a topic in biology.**	
A	Genetics is used extensively (a lot) in the breeding of horses.	
B	Parents with blue eyes are likely to have children with blue eyes.	
C	Organisms (people, animals, plants) have many features in common with their parents.	
D	I wonder whether girls inherit more traits (characteristics) from their mothers than from their fathers.	

THANK YOU FOR YOUR PARTICIPATION.

ITEM SPECIFICATION FOR EACH COGNITIVE PREFERENCE MODE FOR SCPI

ITEM	OPTION	OPTION STATEMENT
APLICATION MODE (A)		
Q1	A	Fibres used in cloth are made of stems of certain plants.
Q2	A	Bacteria are used in the food industry in the production of foods such as cheese, yoghurt, and certain types of prickles.
Q3	C	Green plants provide food and energy for most other living organisms and so they make animal and human life possible.
Q4	B	Certain algae can be used as indicators of the conditions in fish ponds and aquaria.
Q5	A	Genetics is used extensively (a lot) in the breeding of horses.
PRINCIPLE MODE (P)		
Q1	B	The maximum height of a plant depends on the shape and the amount of wood in the stem.
Q2	C	Some bacteria break down dead plants and animals to their elements. By doing so, they help maintain the cycle of necessary elements.
Q3	A	There is always a larger number of producers than consumers.
Q4	A	Algae are primary producers and fundamental to the survival of most water animals.
Q5	B	Parents with blue eyes are likely to have children with blue eyes.
RECALL MODE (R)		
Q1	C	Some stems are soft, others are woody.
Q2	D	Bacteria are organisms so small that they can be seen only with the aid of a microscope.
Q3	D	Most producers are green plants.
Q4	D	Algae are classified into green, blue, brown and red algae.
Q5	C	Organisms (people, animals, plants) have many features in common with their parents.
QUESTIONING MODE (Q)		
Q1	D	How do old trees with hollow trunks remain alive?
Q2	B	What would become of the carbon in dead organisms if there were no bacteria at work?
Q3	B	What will happen to the producers if all consumers on earth disappeared?
Q4	C	According to geological findings, blue algae were the first plants on earth. There could possibly be a special reason for this.
Q5	D	I wonder whether girls inherit more traits (characteristics) from their mothers than from their fathers.

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FRAMEWORK FOR DETERMINING LEARNERS' COGNITVE PREFERENCE MODES

Learner code ☐ Age ☐ Gender ☐ Cognitive preference mode ☐

	Item number	1	2	3	4	5	Total rating
A	Application	A	A	C	B	A	
	Ratings						
P	Principle	B	C	A	A	B	
	Ratings						
R	Recall	C	D	D	D	C	
	Ratings						
Q	Questioning	D	B	B	C	D	
	Ratings						
Highest total rating				Mode			

AN EXAMPLE OF LEARNERS' COGNITVE PREFERENCE SCORE SHEET

Learner code ☐ Age ☐ Gender Cognitive preference ☐

	Item number	1	2	3	4	5	Total rating
A	Application	A	A	C	B	A	
	Ratings	*4*	*4*	*4*	*2*	*1*	*15*
P	Principle	B	C	A	A	B	
	Ratings	*2*	*3*	*2*	*3*	*2*	*12*
R	Recall	C	D	D	D	C	
	Ratings	*1*	*1*	*3*	*1*	*3*	*9*
Q	Questioning	D	B	B	C	D	
	Ratings	*1*	*2*	*1*	*4*	*3*	*11*
Highest total rating		*15*	Mode			*Application*	

* Entries in italics are examples of possible ratings
* The highest total rating is considered to be the cognitive preference mode which the learner is more inclined to use.

Appendix XIII: Educator individual interview schedule

Interviewee code: ☐

Introduction:

- Thank you for agreeing to participate in this discussion on the study of genetics. My name is ...., and I work at .... I am a researcher in the life sciences, and I am currently researching the study of genetics in schools.

- You have just finished teaching genetics, and we would like to know your views and experiences concerning the topic. It is alleged that learners find the study of genetics to be difficult. We would therefore like to find out how learners feel about the study of genetics, so that we may have a better understanding of this matter.

- In this discussion there are no wrong or right answers. Everything you say will be treated in confidence by the research team for the purpose of the research. Your views will remain anonymous, and will not be used against you in any way. You are therefore requested to feel free to say what you really think and how you really feel. You may decline from participating in the discussion at any time, and there will be no consequences for you.

- The discussion will take approximately 30 minutes, and it will be video-recorded so that I may be able to listen to our discussion at a later stage, to make sure that I capture your views correctly. The materials on the tape will not be reproduced or used anywhere else. Do you have any questions or comments before we start?

Questions:

1. How would you describe learners' performance in the genetics topic that you just taught?
2. In your opinion, what do you think could be the reason for this performance?
3. Tell me about learners' attitude towards the study of genetics and life science as a subject?
4. What do you think the cause of this attitude could be?
5. Tell me what you think about the relevance of genetics to learners' daily life experiences? Why do you think so?
6. According to your experience, how would you describe learners' perception of genetics in relation to its relevance to their daily lives?
7. In your opinion, what is the most effective way of teaching genetics?
8. Is there anything else that you would like to add?

Thank you very much for your participation and patience. Your contribution is highly appreciated.

Educator individual interview themes

Educator interviews focused on

- Opinions concerning learner performance in genetics and life sciences.
- Educators’ opinion on the approach(es) used to teach genetics.
- Opinions on the relevance of the study of genetics to learners.
- Opinions concerning learners’ attitude towards the study of genetics and life sciences.

Appendix XIV: Learner focus group interview schedule

Focus group Number: ☐

Introduction:

- I am very grateful to you all for sparing the time to take part in discussions on the study of genetics. My name is ...., and I work at .... I am a researcher in the life sciences, and I am currently researching the study of genetics in schools.

- You have just completed the study of genetics, and we would like to know how you feel about it. The reason for our discussion is to try to understand what learners think about the study of genetics, so that we may find effective ways of teaching the topic.

- Your views and feelings will be treated in confidence amongst the research team, for the purpose of the research. Anything you say will remain anonymous, and will not be used against you in any way, including assessing or judging you. There are no wrong or right answers. Everyone's contribution is important, welcomed and encouraged. You are therefore requested to feel free to say what you really think and how you really feel. You are free to decline from participating at any time if you so wish, and there will be no consequences for you.

- The discussion will take approximately 30 minutes, and it will be video-recorded so that we may be able to listen to it at a later stage, to make sure that we capture your views correctly. The materials on the tape will not be reproduced or used anywhere else. Do you have any questions or comments, before we start?

Questions:

1. Let's talk about your experience of the study of genetics, did you like it or not? Tell me why you feel that way.
2. In your opinion, do you think the study of genetics relates to your daily life? Why do you say so?
3. How do you feel about the way genetics was taught? Would you have liked it to be taught in a different way? Tell me more.
4. Tell me what you think about the study of genetics? Do you consider the study of genetics to be easy or difficult to learn? Tell me why you think so.
5. After studying genetics, you wrote a test to assess your understanding of the topic. Tell me what you think of your performance in the test?
6. Imagine that the minister of education has asked you to make suggestions on how you would like genetics to be taught. What would you say to him/her?
7. Is there anything else regarding the study of genetics that you would like to share with us?

Thank you very much for your participation and patience. Your contribution is highly appreciated.

THE END

Learner focus group interview themes

Learner focus group interviews were based on the following themes:

- Opinions on performance in genetics.
- Opinions on the way genetics was taught.
- Opinions on the relevance of the study of genetics to learners' lives.
- Opinions on interest in the study of genetics.

Appendix XV: Pilot study results.

Learner code	Gender	SCPI Modes		TOSIS Scores (%)		DMAT Scores (%)		PSAT Scores (%)		GCKT scores (%)		LSAQ Scores (/150	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
p1	F	A	A	10	15	35.0	35.0	10.0	15.0	7	9	98	100
p2	F	P	A/P	10	15	40.0	30.0	30.0	25.0	14	16	106	112
p3	F	R	R	15	20	40.0	45.0	20.0	25.0	11	13	113	112
p4	M	A	A	25	30	30.0	35.0	20.0	30.0	22	23	101	105
p5	F	A	A	30	35	35.0	30.0	25.0	25.0			104	102
p6	M	R	R	25	30	65.0	70.0	15.0	20.0	6	9	91	98
p7	F	P/R	P	15	15	10.0	20.0	20.0	25.0	3	3	90	90
p8	M	R	R	50	45	10.0	15.0	25.0	30.0	11	10	107	109
p9	F	Q	Q	20	25	50.0	40.0	15.0	10.0	10	11	97	100
p10	M	Q	P	25	30	10.0	20.0	40.0	35.0	20	22	97	99
p11	M	P	P	20	35	20.0	25.0	30.0	30.0	15	18	116	103
p12	F	Q	Q	10		30.0		10.0		21		111	
p13	F	Q	Q	35	40	30.0	40.0	15.0	15.0	14	17	115	114
p14	M	R	R	25	30	50.0	55.0	20.0	20.0	15	16	109	107
p15	F	Q	Q	20	25	50.0	45.0	15.0	15.0	14	16	89	93
p16	M	P	P	25	30	65.0	70.0	15.0	20.0	11	15	84	85
p17	M	R	R	25	20	10.0	10.0	20.0	20.0	9	15	107	107
p18	M	P	P	35	30	10.0	20.0	20.0	20.0	22	27	106	104
p19	M	R	R	10	10	50.0	60.0	30.0	15.0	15	16	91	97
p20	F	R	R	15	20	10.0		15.0		17	16	106	111
p21	M	P	P	20	30	10.0	15.0	45.0	45.0	13	19	91	95
p22	F	P	P	25	25	50.0	55.0	35.0	40.0	18	14	106	103
p23	F	P	Q	35	40	30.0	30.0	20.0	25.0	11	13	118	116
p24	M	Q	Q	30	25	60.0	55.0	25.0	35.0	11	14	73	84
p25	F	P	P	25	25	20.0	30.0	10.0	15.0	15	18	113	
p26	F	R/Q	Q	15	20	20.0	15.0	20.0	30.0	11	10	82	90
p27	M	A	A	15	15	50.0	50.0	10.0	10.0	16	18	85	87
p28	F	R	R	15	10	30.0	30.0	25.0	20.0	20	22	103	100
p29	M	R	R	40	30	10.0	15.0	15.0	15.0	16	17	114	113
p30	F	Q	Q	10	20	50.0	50.0	10.0	10.0	18	18	115	113
p31	M	P	P	35	30	10.0	10.0	25.0	35.0	11	13	102	107
p32	M	Q	Q	20	20	10.0	15.0	15.0	20.0	18	20	96	98
p33	F	P/R	P	5		10.0	10.0	25.0	20.0	14	14	117	114
p34	F	Q	Q	25	25	30.0	25.0	15.0	15.0	16	17	97	101
p35	F	R	R	20	25	30.0	25.0	20.0	20.0	13	20	100	98
p36	F	R	R	25	25	60.0	65.0	10.0	10.0	15	17	101	105
*Reliability Coefficient		P =0.001		0.83		0.95		0.82		0.88		0.93	
Duration		10 minutes		30 minutes		20 minutes		30 minutes		1 hour		15 minutes	

*A chi-square test of was used to determine the association between the cognitive preferences in the 1st and 2nd administrations of the SCPI instrument.

*Reliability coefficients for the other instruments (GCKY, TOSIS, DMAT, PSAT, and LSAQ) were determined using Pearson correlation coefficient.

Appendix XVI: Comparison of pre-test control and experimental mean scores ($\bar{x}$) for LSAQ items according to attitude categories

Item Code	Item statement	N	Control MEAN ($\bar{x}$) ± SD	N	Experiment MEAN ($\bar{x}$) ± SD	p-value
CATEGORY (ATT 1): APPLICATION OF LIFE SCIENCES / GENETICS TO EVERYDAY LIFE						
RA2	Without the study of life sciences, it would be difficult to understand life.	99	4.000 ± 1.088	86	3.906 ±1.013	0.550
RA6	I like studying life sciences because of its importance in understanding the environment.	99	4.081 ± 0.899	86	4.000 ±1.147	0.593
RA8	What is taught in genetics cannot be used in everyday life.	99	4.252 ± 0.982	86	4.209 ±0.855	0.752
RA17	Ideas in genetics are not related to human needs.	99	4.353 ± 0.799	86	4.400 ±0.710	0.679
RA24	What is learnt in life sciences can be applied to our daily lives.	99	4.545 ± 0.558	86	4.465 ±0.730	0.399
RA27	Discoveries in life sciences and genetics have improved human life.	99	4.181 ± 0.719	86	4.127 ±0.823	0.635
CATEGORY (ATT 2): LEARNERS' PERCEPTION OF LIFE SCIENCES/GENETICS LESSONS / CLASSES						
RA3	Performing practical activities in genetics helps me to understand genetics concepts and ideas better.	99	4.494 ± 0.690	86	4.523 ±0.681	0.780
RA11	There are too many concepts (ideas) to learn in genetics, as a result, I have lost interest in the topic.	99	3.515 ± 1.521	86	3.541 ±1.350	0.903
RA12	I do not bother about what we learn in genetics because I do not understand them.	99	4.222 ± 1.064	86	4.209 ±0.971	0.932
RA14	I usually feel like running out of the class during life sciences lessons.	99	4.494 ± 0.660	86	4.313 ±1.008	0.146
RA18	I do not understand genetics lessons.	99	4.141 ± 0.903	86	4.209 ±0.841	0.599
RA20	I feel quite happy when it is time for genetics lessons.	99	3.858 ± 0.958	86	3.930 ±0.992	0.618
RA22	I really enjoy the life sciences lessons which deal with my daily life experiences.	99	4.464 ± 0.836	86	4.372 ±0.920	0.475
CATEGORY (ATT 3): LEARNERS' PERCEPTION OF LIFE SCIENCES CAREER PROSPECTS						
RA10	My future career/profession has nothing to do with genetics, so I don't study it a lot.	99	4.050 ± 1.163	86	4.151 ±1.090	0.546
RA13	Genetics will be very useful in my future career/ profession. I therefore want to study it very well.	99	4.121 ± 1.189	86	4.081 ±1.019	0.809
RA21	I hope to study genetics and life sciences further, because I want to take up a career in medicine.	99	4.080 ± 0.944	86	3.988 ±0.999	0.519
RA25	I will have fewer job opportunities if I study genetics and life sciences.	99	4.222 ± 0.909	86	4.162 ±0.794	0.639
CATEGORY (ATT 4): LEARNERS' OPINION OF GENETICS AS A TOPIC						
RA1	Genetics is an interesting topic to study.	99	4.464 ± 0.812	86	4.337 ±0.876	0.306
RA7	Genetics is a difficult topic.	99	3.474 ± 1.043	86	3.477 ±1.092	0.989
RA9	I enjoy studying genetics.	99	3.656 ± 1.070	86	3.895 ±1.052	0.129
RA23	I don't like studying genetics.	99	4.121 ± 1.003	86	4.360 ±0.796	0.077
RA30	I like setting difficult tasks for myself when studying genetics.	99	3.222 ± 1.129	86	3.477 ±0.979	0.106
CATEGORY (ATT 5): LEARNERS' OPINION OF LIFE SCIENCES AS A SUBJECT						
RA4	Life science is more difficult than other science subjects.	99	4.101 ± 1.025	86	4.105 ±0.908	0.979
RA5	I admire people who are knowledgeable about life sciences.	99	4.060 ± 0.901	86	3.756 ±1.073	0.037*
RA15	I enjoy studying life sciences.	99	4.323 ± 0.902	86	4.314 ±0.885	0.944
RA16	Studying life sciences is a waste of time.	99	4.666 ± 0.622	86	4.663 ±0.696	0.968
RA19	I do not agree with many ideas (concepts) in life sciences.	99	3.868 ± 1.036	86	3.930 ±0.918	0.672
RA26	Life science is an easy subject.	99	3.353 ± 1.145	86	3.186 ±1.153	0.324
RA28	Life science is not my favourite subject.	99	4.151 ± 1.081	86	4.221 ±1.045	0.659
RA29	I sometimes avoid studying life sciences.	99	4.354 ± 0.799	86	4.400 ±0.710	0.610

* Indicates a significant treatment effect at α = 5% significance level.

Appendix XVII: Summary of post-test statistics on the interactive influence of gender on specific categories of science inquiry skills

Inquiry skills Component	Treatment	Gender	N	mean ($\bar{x}$)	SD	F-value	p-value
OT1	E	F	44	3.977	2.040	0.00	0.9989
		M	41	3.902	2.095		
	C	F	50	5.880	2.624		
		M	30	5.833	1.895		
OT2	E	F	45	5.222	4.258	2.59	0.0552
		M	41	4.927	3.349		
	C	F	50	4.100	3.872		
		M	30	4.167	3.495		
OT3	E	F	45	7.778	6.619	0.90	0.3440
		M	41	7.195	8.066		
	C	F	50	7.100	5.632		
		M	30	8.667	8.503		
OT4	E	F	45	7.778	7.654	1.22	0.2703
		M	41	4.878	7.201		
	C	F	50	6.200	4.468		
		M	30	5.667	3.651		
OT5	E	F	45	3.778	4.542	0.03	0.8595
		M	41	3.049	4.312		
	C	F	50	5.700	4.739		
		M	29	4.828	4.721		

KEY:
OT1 = ability to formulate hypotheses
OT2 = ability to identify variables
OT3 = ability to design experiments
OT4 = competence in Graphing skills
OT5 = ability to draw conclusions from results
E = experimental group
C = control group
F = female learners
M = male learners

Appendix XVIII: Summary of post-test ANCOVA statistics for the interactive influence of cognitive preferences and treatment for the different components of science inquiry skills

Inquiry skills variables	Cognitive preference	CONTROL			EXPERIMENTAL			F Value	p-value
		N	**Mean**	**SD**	**N**	**Mean**	**SD**		
OT1	A	14	3.57142857	2.34403615	15	6.33333333	2.96808420	0.41	0.7470
	P	25	4.60000000	1.38443731	26	6.53846154	2.35339362		
	Q	15	4.66666667	3.99404318	18	5.00000000	1.71498585		
	R	22	3.40909091	2.38365647	10	5.50000000	2.83823106		
OT2	A	14	4.28571429	4.32218911	15	4.66666667	3.99404318	0.00	0.9998
	P	25	3.80000000	3.89444048	26	4.23076923	3.65849906		
	Q	15	4.66666667	3.99404318	18	4.44444444	3.79197639		
	R	23	3.26086957	4.15842399	10	4.00000000	3.94405319		
OT3	A	14	7.14285714	7.26273039	15	7.00000000	6.21059003	0.31	0.8215
	P	25	8.40000000	6.87992248	26	7.50000000	6.20483682		
	Q	15	6.66666667	6.98638131	18	7.77777778	7.32084498		
	R	23	6.95652174	7.64840008	10	9.00000000	9.94428926		
OT4	A	14	12.1428571	10.1364320	15	6.0000000	2.8030596	1.84	0.1420
	P	25	5.8000000	6.0690472	26	6.3461538	4.8078462		
	Q	15	6.0000000	7.6063883	18	6.6666667	4.8507125		
	R	23	4.7826087	6.6534784	10	4.5000000	2.8382311		
OT5	A	14	1.78571429	3.72473172	15	4.33333333	5.62731434	0.13	0.9450
	P	25	5.00000000	4.78713554	26	6.53846154	4.18789464		
	Q	15	3.00000000	4.55129495	17	5.58823529	4.28746463		
	R	23	3.04347826	3.91359241	10	4.00000000	5.16397779		

KEY:
- OT1: Ability to formulate hypotheses
- OT2: Ability to identify variables
- OT3: Ability to design experiments
- OT4: Graphing skills
- OT5: Ability to draw conclusions from results
- A: Application mode
- P: Principle mode
- Q: Questioning mode
- R: Recall mode
- SD: Standard deviation

Appendix XIX: Summary of post-test ANCOVA statistics for the interactive influence of gender, cognitive preferences and treatment on learning outcomes

Dependant variable	Cognitive preference	Gender	CONTROL			EXPERIMENTAL			F Value	p-value
			N	Mean	SD	N	Mean	SD		
GCKT	A	F	7	16.1038961	5.7905187	11	27.1074380	10.0067595	1.98	0.1199
		M	8	15.4545455	7.8954203	5	30.1818182	7.8834485		
	P	F	13	16.7832168	9.3051674	20	27.5454545	9.8580618		
		M	13	13.8461538	5.4816730	7	34.5454545	7.7138922		
	Q	F	9	19.7474747	11.3707049	10	29.2727273	13.3457243		
		M	6	15.7575758	8.0220083	9	28.6868687	13.8998120		
	R	F	16	13.9659091	6.6054385	8	22.7272727	8.7467316		
		M	12	14.3560606	5.7996163	3	11.5151515	4.5756572		
TOSIS	A	F	7	32.8571429	17.5254916	10	30.5000000	10.3949774	0.74	0.5278
		M	7	25.0000000	19.5789002	5	24.0000000	7.4161985		
	P	F	12	33.7500000	9.5643752	20	30.5000000	11.3439063		
		M	13	21.9230769	11.4634313	6	33.3333333	8.7559504		
	Q	F	9	25.5555556	12.6106216	8	30.6250000	8.2104028		
		M	6	21.6666667	11.6904519	10	28.0000000	11.5950181		
	R	F	13	21.5384615	16.8800444	7	22.8571429	7.5592895		
		M	10	21.0000000	9.6609178	3	36.6666667	22.5462488		
DMAT	A	F	7	61.4285714	27.3426233	11	70.0000000	20.4939015	0.96	0.4122
		M	8	50.0000000	20.0000000	5	80.0000000	23.4520788		
	P	F	13	50.0000000	26.1406452	20	67.5000000	20.4874801		
		M	13	53.0769231	22.5035610	7	72.8571429	14.9602648		
	Q	F	8	63.7500000	25.0356888	10	73.0000000	16.3639169		
		M	6	46.6666667	31.4112506	10	74.0000000	17.1269768		
	R	F	13	53.0769231	29.8285700	8	73.7500000	15.0594062		
		M	9	50.0000000	21.2132034	3	53.3333333	11.5470054		
PSAT	A	F	7	25.7142857	24.3975018	11	38.1818182	23.1595258	0.49	0.6905
		M	8	42.5000000	14.8804762	5	52.0000000	26.8328157		
	P	F	13	41.9230769	21.5579125	20	53.5000000	25.8079955		
		M	13	34.2307692	16.6890875	7	48.5714286	24.1029538		
	Q	F	9	31.6666667	20.0000000	10	55.0000000	26.7706307		
		M	6	33.3333333	25.0333111	10	41.0000000	26.0128174		
	R	F	14	24.6428571	15.1231211	8	53.7500000	28.7538817		
		M	9	37.2222222	22.2361068	3	46.6666667	40.4145188		
LSAQ	A	F	6	115.333333	20.5491281	11	130.636364	9.7187728	0.38	0.7659
		M	7	119.714286	23.9563094	5	129.200000	12.8918579		
	P	F	10	127.800000	19.6061215	17	129.470588	7.8749416		
		M	12	119.750000	12.6284311	7	126.142857	10.6681547		
	Q	F	9	113.777778	18.8399693	7	127.428571	5.9681695		
		M	6	110.166667	12.8750405	9	128.666667	7.6157731		
	R	F	14	109.000000	20.9321247	6	122.166667	11.8053660		
		M	10	121.500000	13.8343373	3	131.333333	20.8166600		

KEY
GCKT: Genetics Content Knowledge test
TOSIS: Test Of Science Inquiry Skills
DMAT: Decision-Making Ability
PSAT: Problem-Solving Ability
LSAQ: Life sciences Attitude Questionnaire
A: Application mode
P: Principle mode
Q: Questioning mode
R: Recall mode
SD: Standard deviation
F: Female
M: Male

Appendix XX: Chi-square test for the correlation of pre- and post-intervention cognitive preferences for the experimental group.

Pre-test	Post-test				Total
	A	P	Q	R	
A	7 (3.15)	2 (4.33)	3 (3.74)	1 (1.77)	13
P	3 (5.09)	14 (7.00)	1 (6.05)	3 (2.86)	21
Q	2 (4.61)	3 (6.33)	12 (5.47)	2 (2.59)	19
R	4 (3.15)	3 (4.33)	3 (3.74)	3 (1.77)	13
Total	16	22	19	9	66
Exact p-value = 0.0003					

Appendix XXI: Interview protocols

(A) FOCUS GROUP INTERVIEWS

Key: ES = Experimental group learner
CS = Control group learner

Experimental groups

ET (School code)

Table 1 Learners' perception of performance in the study of genetics

ES3	When I wrote the first test (pre-test), it was difficult, but after studying genetics, I felt more excited, and it became easy. I think I passed the second test (post-test).
ES26	I think genetics is an easy topic and I passed the test (post-test).
ES15	I think genetics was interesting and fun, except the cloning part, but I think I passed the test (post-test).
ES20	If all educators taught us the way sir did, we would never fail any subject. I enjoyed looking back at my original ideas.
ES23	The topic of genetics is too long. It should be shortened, because you can easily forget what you learnt earlier.
ES15	The way our educator taught us made it easy. We talked about things that happen to us, so it was easy to understand. I especially enjoyed the part on diseases and the inheritance of features from our parents.

Table 2 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

ES28	The stories made the study of genetics easy because we managed to understand what was happening, and we were able to explain the situations.
ES3	We would like to be taught other subjects the way we were taught genetics.
ES20	I would suggest that they include the genetics topic in Grades 10, 11 and 12, because it is very interesting.
ES26	They should train educators on how to teach genetics so that the results of the learners could be better.
ES26	Mr "X" should teach other educators how to teach life sciences.
ES15	Some learners like studying on their own. Then it becomes difficult, but when we study in groups like we did in this programme, it becomes easy to understand because we help and learn from one another.
ES20	"Some educators are too lazy to explain to learners what is happening. They just give you notes from the textbook or tell you to go home and read from 'page 159', and tell you to explain what you read to the class. It was difficult to understand. But in the method used in this project, it was not like that. We understood what we were learning.

Table 3 Learners' perception of the relevance of the study of genetics

ES3	Genetics consists of many terms and principles, but it is easy and important because it teaches us about how we are related to our parents and ancestors, and it shows us how we pass our genes to the generations still to come.
ES23	It was easy because it was all about everything that was happening in our lives.

Table 4 Learners' opinions on their interest in the study of genetics

ES15	I found genetics to be interesting. The more you study, the more interesting and easy it became.
ES9	I am interested in genetics because it helps me understand many things in life, such as how we look alike with our siblings, and how we pass genes to other generations
ES26	The practical activities in genetics were very interesting, because we were able to see the things that we study in theory.
ES9	The cloning topic was very interesting.
ES16	It was fascinating and interesting at the same time. I liked and understood the part which talked about how genes determine my appearance.
ES23	Genetics was more interesting than other topics.

EU (School code)

Table 5 Learners' perception of performance in the study of genetics

ES39	The study of genetics was easy because we were able to link it to what happens in our homes
ES57	The practical lessons made the study of genetics easy.
ES45	If the things we learn are put to us as stories, it becomes easier to understand, rather than just give us past questions which we do not know how they relate to our lives
ES53	After learning genetics the way we did, I am sure we will pass the examination with distinctions. If we don't, it will be because of the other topics in life sciences, not genetics.
ES53	I feel that we will perform better in genetics than in other topics.

Table 6 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

ES55	I liked the stories before each lesson because they made me understand what we were learning.
ES44	The genetics programme that we followed should be compulsory so that everyone can benefit from it, because those who missed the programme are disadvantaged.
ES48	The method we used to learn genetics should be used in other topics in life sciences and other science subjects, not just in genetics, so that we may understand what we learn.
ES57	The way we normally learn other topics is through theory, where we are asked to just read from a text book. At the end of the day nothing makes sense.

Table 7 Learners' perception of the relevance of the study of genetics

ES39	After studying genetics, I understand most of the things that happen in our societies, like why we have albinos.
ES44	The study of genetics was easy because we were able to link it to what happens in our homes.
ES54	We can catch criminals using genetics, and even men who refuse the responsibility of a child.
ES51	The study of genetics is good for us because we know how it affects us, and we understand some of the issues we hear on TV.

Table 8 Learners' opinions on their interest in the study of genetics

ES42	Genetics was very interesting and fun. I used to look forward to the lessons.
ES55	I liked the fact that we were not just learning genetics in theory, but we were also doing practical activities.
ES42	The fact that we were dealing with things that happen in our lives made the study of genetics very interesting.
ES53	The study of genetics was interesting because we did it practically, which made it easier to understand.
ES57	When we learnt genetics, our educator allowed us to give our views, but with the other topics, we are usually not given an opportunity to say what we think.
ES34	Because of the way we were taught genetics, I am now interested in genetics, because it helped me to understand many things in life, such as how we happen to look alike with our brothers and sisters.

EV (School code)

Table 9 Learners' perception of performance in the study of genetics

ES82	I think the practical activities helped me to understand the concepts better.
ES64	The stories made me realize the myths which I had, and by studying genetics I managed to know the truth.
ES68	The discussions made me to understand genetics concepts very well.
ES70	It was easy to understand the terms and ideas because we worked in groups and we learnt from one another. If you are wrong, your friends explained the reasons to you.
ES77	It was more exciting and fun, and it is easy to remember what we learnt.
ES68	It was fun to learn genetics by using our own experiences. It just makes genetics so easy. I am sure I have passed the test.

Table 10 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

ES69	The way sir taught us was different. In other classes, learners do not understand exactly what the educators teach us, because it is mostly theory.
ES60	In other classes, there is no interaction between us and the educators, but here we are allowed to say what we think, even to argue with others or disagree with the educator.
ES68	Other educators come and stand in front and talk and talk and talk, telling you things that you see in the textbooks. They just tell us what to do and we follow. It is not fun.
ES79	The method used to teach genetics in this project was more practical, but other educators teach us theory only, which we don't understand.
ES77	Everything about the topic was perfect. The practical activities and the stories made the topic fun.
ES64	The nice thing about the lessons was that we were talking about things that happen in our homes. I now understand why my brother looks so different from all of us.

Table 11 Learners' perception of the relevance of the study of genetics

ES65	The study of genetics helps us improve our daily lives and deal with the challenges that we have in our lives.
ES77	Genetics, it is good to study it. It teaches us a lot of things about ourselves.
ES65	Genetics is easy because it is about things that happen to us.
ES69	We learnt about things that happen in our lives. It was interesting to know what happens in your own life, and it was easy to remember what we learnt.

Table 12 Learners' opinions on their interest in the study of genetics

ES60	Genetics is interesting because it explains things that we see in our lives. For example, we used to think that people with disabilities were bewitched, but now we understand that it could have been the result of genetic mutations.
ES68	It was interesting to learn that most genetic diseases are incurable, so it means that when you marry you have to be careful and know whether your husband is carrying the genes that cause the disease or not.
ES65	I enjoyed the practical activities because they were about things that we see and that we hear from people.
ES79	It was very interesting. At first I thought it was difficult. I really enjoyed the part on cloning of animals.
ES82	It was interesting because I learnt about things which I did not understand before, especially about my own body.

CONTROL GROUPS - CW (School code)

Table 13 Learners' perception of performance in the study of genetics

CS108	Genetics was interesting, but when it comes to tests and examinations, we get scared or panic and fail, or we don't pass the way we expect to pass.
CS120	Genetics is difficult because it is just rules and terms which are difficult to understand
CS97	I found the study of genetics to be difficult, because some of the terms, I cannot put them in my mind, especially the definitions, they are very confusing.
CS112	Genetics is challenging because some of us do not understand what it is based on.
CS123	Genetics is difficult because we do not understand it, and the educators don't allow us to ask too many questions.
CS100	I think we find genetics to be difficult, because we don't study it and we don't apply what we learn outside the classroom.

Table 14 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

CS126	If we are given more time to study genetics, we might perform well, because when we get to the examination, we don't remember what we studied.
CE105	I think that if our educators can teach us extra strategies for studying genetics. Then we may understand it better and perform well.
CS102	I would like to see more practical activities in our genetics lessons.
CS120	We should be going to places like museums so that we can see the issues we learn about.
CS116	They should make DVDs which we can watch at home, so that we may understand
CS123	The problem is that we do not do any practical activities in genetics. We would like to do practical activities so that we may understand genetics.
CS100	Educators must be active because the lessons are sometimes boring.
CS100	I think genetics should be taught early in Grade 11 so that when we reach Grade 12, we will understand it better.

CS97	Some of our educators just read from the textbook or give us questions from past examination papers, so we don't understand what is going on.
CS116	Educators must be able to communicate with learners, not just get angry when we ask questions.
CS115	Our educators should organize trips to places where we can see what we learn in class.
CS123	The way our educators teach us, makes us fail, because we find it boring. They just read from textbooks, then they give us many exercises, so we just 'cram' *(memorize*) the work because we don't understand.

Table 15 Learners' perception of the relevance of the study of genetics

CS116	I think genetics is important to our lives, but we do not know how to apply it to our lives.
CS112	The study of genetics and life sciences helps us to know how to take care of ourselves.
CS97	Genetics makes us aware of how gene mutations can cause disabilities and disorders in our bodies.

Table 16 Learners' opinions on their interest in the study of genetics

CS106	Genetics is interesting because we learn about ourselves, how we are made, and how certain characteristics come about.
CS102	Some of us do not understand what genetics is all about.

CX (School code)

Table 17 Learners' perception of performance in the study of genetics

CS131	For me it was difficult because the terms used were difficult for me to understand
CS145	The study of genetics was fine, it wasn't easy or difficult.
CS142	Genetics needs a lot of interpretations and a clear understanding.
CS130	It is not that easy because it requires a lot of time for us to understand.
CS156	I would say it was difficult because the way we learn genetics is different from the way the questions are asked in the examination.
CS132	What makes it difficult is that we can't really see the things which we learn about.

Table 18 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

CS130	I think genetics could be easier if we can be shown videos which show how the genetics processes take place.
CS141	We should be using microscopes to see what really happens in the cells.
CS130	The use of games might also help us understand genetics better.
CS139	If we can put the genetics terms in a song, it will help us remember them because music is liked by many young people.
CS156	Genetics should be taught very early, say in Grade 7 and we should continue learning it until Grade 12, so that we may understand it better.
CS131	I think the use of practical activities can help us understand genetics better.
CS146	They should organize field trips to places where genetics is practised so that we may see for ourselves what goes on.
CS131	We want to be involved in the lessons. Our educators talk and talk and talk, and we get bored, and at times feel sleepy.
CS145	We should be allowed to participate in lessons so that we can know where we are wrong or right.

Table 19 Learners' perception of the relevance of the study of genetics

CS145	Genetics is important, because it helps us to know whether a child belongs to you or to somebody else.
CS132	In genetics we study what happens in our bodies, so I think it is relevant.
CS130	It can be relevant if we talk about things which we can see, not just things we imagine in our minds.

Table 20 Learners' opinions on their interest in the study of genetics

CS132	Genetics was interesting because it deals with things that affect our lives.
CS145	I found it interesting because of the way the educator framed the question about genetics.
CS106	Genetics is interesting because we learn about ourselves, how we are made, and how certain characteristics come about.

CY (School code)

Table 21 Learners' perception of performance in the study of genetics

CS168	Learners forget what they have learnt because biological terms are too difficult to understand.
CS181	Learners forget what they have learnt because genetics has many things to learn about and some of the terms are similar, so it is not easy to remember them.
CS167	Some learners learn by cramming (memorization) without interest, and without thinking about what they have crammed. They just want to pass the examination. They don't think about why these things happen.
CS188	Learners do not read to understand the things that they have been taught. Life sciences need people who read a lot.
CS173	I think the problem is our perspectives. We tend to think that the topic is difficult just because the terms used are not familiar to us.
CS188	Learners fail genetics because they do not understand the biological terms. You have to know the terms for you to understand the topic.

Table 22 Tell us how you experienced the teaching of genetics and how you like to be taught genetics

CS173	People fail genetics because of the methods used by educators to teach genetics.
CS181	Some educators start teaching genetics without us knowing where it comes from, where it is situated and how it affects us.
CS181	Educators should be trained on how to teach properly.
CS167	They (educators) should use practical activities and examples which should include things like diseases that are caused by genetics. It will be easier to understand, because we would be able to apply what they teach us in our lives.
CS188	The educators are the ones that make the study of genetics difficult, because most of them pretend to know genetics, but just follow what is written in textbooks, and they do not help us understand what is going on.
CS173	I think after learning something, we should answer a lot of questions individually so that we can know our weaknesses.
CS167	Theory should be balanced with practical activities.
CS188	More time should be provided for the study of genetics.
CS188	Learners should be more involved in science lessons.
CS168	Educators should always relate what we learn to real-life issues, and give more examples of how the things we learn can be applied in life.

Table 23 **Learners' perception of the relevance of the study of genetics**

CS173	Yes, genetics is important, because it teaches us about what is happening in our bodies.
CS188	If educators can show us how the genetics processes really happen, it would be very important, because we would know how the study of genetics helps us.
CS167	I think most life sciences topics are important to us, because we learn about the different processes that take place in our bodies.
CS173	Some of the things are relevant, but others are not.

Table 24 **Learners' opinions on their interest in the study of genetics**

CS167	If we can go to places where they deal with genetics, to observe what happens, then the study of genetics would be easy and interesting.
CS173	Some learners are stereotyped. They think that genetics is difficult, so they lose hope and put little effort in trying to understand it, and they end up failing.

EDUCATOR INTERVIEWS: Key – ET = Experimental group educator
CT = Control group educator

ET (School code)

Table 25 **Educators' opinions on learners' performance in the study of genetics**

ET1	The performance of learners in life sciences, especially genetics is usually not good. I think it is because learners prefer hands-on activities for them to understand the content, but educators normally don't do practical activities, because of large classes and lack of resources, so they just teach theory.
ET1	In the examination it is assumed that learners can apply what they were taught, and they end up asking practical questions so the learners end up failing the subject.
ET1	During our normal classes, it is like Greek to the learners. They don't understand most of the things, and they end up getting confused.
ET1	The learners who were involved in this programme are advantaged because they really understood the concepts.
ET1	What made them understand genetics was the teaching method of starting the lesson with real-life issues (*narratives*), and then relating the concepts to those issues. Then the lessons made sense to them.
ET1	Learners who were taught using the new method really understood the lessons, because they were able to relate everything they did in class to what happens in real life.

Table 26 **Educators' opinions on their ability to identify and address learners' preconceptions**

ET1	It was very interesting. Learners have so many ideas about genetics related issues
ET1	What surprised me is that some learners could explain genetics related issues even before they were given the content.
ET1	When you listen to their arguments, you could easily pick out the wrong explanations and the correct ones, and during the content introduction, most learners corrected themselves, and I also emphasized the ideas which they misunderstood.
ET1	This teaching method is a good way of knowing what to stress and where to explain more in the lessons.
ET1	The method also helped me to know what learners misunderstand in genetics.

Table 27 Educators' opinions on the most appropriate and effective way of teaching genetics

ET1	The use of real-life examples made the study of genetics more interesting and easier to understand.
ET1	If you link real-life issues with the syllabus, they become more meaningful and clearer to the learners.
ET1	Most educators do not usually link their lessons to issues happening outside the classroom. They rush to finish the syllabus by just presenting theory. In the end the learners do not understand anything, that's why we have high failure rates.
ET1	Most of the teaching in our normal classes is educator-centred, whereas the genetics programme we had was learner-centred.
ET1	I think the learners really appreciated the teaching method used in the programme. They even ask me why I don't teach them using the same method, but it is not possible for me to use it in a large class where there are no resources.
ET1	I think the best way of teaching genetics is to link the lessons to learners' real-life experiences just as we did in the programme.
ET1	When learners are able to relate their lessons to real-life experiences, they won't memorize, because they answer the questions with understanding.
ET1	The only problem with this method is that we cannot apply it now because we do not have the enough resources for practical activities.
ET1	What I liked is that, in the content introduction phase when you 'touch' on issues where learners had alternative conceptions, they would ask for clarification.

Table 28 Educators' opinions on the relevance of studying genetics, to learners' lives

ET1	Yes, I think genetics has an impact on learners' lives, because they learn about nature.
ET1	And I know that the learners who were involved in this programme saw how genetics impacts on our lives. What they learnt will be useful throughout their lives.

Table 29 Educators' opinions on learners' interest and participation in the study of genetics

ET1	The learners were very interested in the lessons. They all wanted to say something and convince the others about their views.
ET1	They enjoyed the practical activities a lot. They could easily see the processes that are explained in theory. Frankly, I did not know that there were such interesting practical activities in genetics.
ET1	They were always looking forward to the stories at the beginning of the lesson and the practical activities which showed them what they had learnt in theory.
ET1	At times, you would hear them discussing and arguing about the issues outside the classroom. It was nice to see them so excited about their lessons.
ET1	You know, even other learners who were not part of the programme wanted to join us, but it was too late for them.

ET (School code)

Table 30 Educators' opinions on learners' performance in the study of genetics

ET2	The learners who were exposed to the new teaching approach performed much better when compared with my previous learners' performance.
ET2	One outstanding aspect of the new approach is that the learners become very active during lessons, and therefore the learners understood the lessons better.

Table 31 Educators' opinions on their ability to identify and address learners' preconceptions

ET2	With the new method of teaching, it was easy to know what the learners know and what they did not know, because they were given the opportunity to express their views before being taught.
ET2	Learners have many ideas and opinions on scientific issues. When asked where they got the answers from, they said they just heard from other people.
ET2	In the content introduction phase when you 'touch' on some of their misconceptions, they would ask for clarification.
ET2	Some learners had correct information about issues related to genetics even before the topic was taught. Such learners were usually excited when the genetics concepts confirmed their ideas.

Table 32 Educators' opinions on the most appropriate and effective way of teaching genetics

ET2	Genetics topics usually pose a lot of teaching challenges for educators and comprehension difficulties for learners, but the teaching method used in this programme made it easier for learners to understand.
ET2	In traditional teaching approaches, learners feel intimidated by the educators, and they do not have the opportunity to relate their thoughts and daily life experiences with what is learnt in class, so that they may become inquisitive and want to learn more.
ET2	The lessons highlighted situations and problems, and then provided explanations and possible solutions as they unfolded in the various stages.
ET2	What I really like about this approach is that it encourages team work, develops problem-solving skills, communication skills, tolerance and understanding of diverse cultures.
ET2	Learners were attentive and receptive to the information at all stages, which really helps in making them understand the topic even better when they review their previous answers to the questions.
ET2	The context interrogation stage allows for interaction and discussion, and it paves the way for the information stage where the content relating to that scenario is presented by the educator.
ET2	Other learning areas can easily and effectively be integrated into the context and content.
ET2	It also forces educators to relate what they teach to what happens in real-life.
ET2	The teaching approach used in this programme turned out to be an exciting and interesting experience to teach learners. This is because situations and problems, which relate to their everyday lives are used.
ET2	To me, as an educator, context based method, when followed correctly, will always achieve the expected objectives. All life sciences learning outcomes can be addressed, when you use the new teaching method.
ET2	Each lesson, compared to the traditional way of teaching, requires more time to complete.
ET2	The educator needs to be well prepared and collect sufficient information for content, because there will be lots of questions to answer.
ET2	I would say it requires time, careful selection of content load, selection of relevant comprehensible context for the lesson and the following of the stages systematically, with a lot of discussion and writing for the learners.
ET2	My area of concern is that in most traditionally black schools, there is overcrowding in classes, and since this method required grouping of learners, total effectiveness of this approach may somehow to an extent be compromised.
ET2	I had the opportunity to use this technique to teach genetic topics and personally feel it can work very well in teaching other Life Sciences topics, especially other controversial topics, like evolution, organ donation.
ET2	I have all the confidence that Life Sciences performance will improve, and educators will find it very exciting.

Table 33 Educators' opinions on the relevance of studying genetics, to learners' lives

ET2	I believe everyone knows that most of the topics in life sciences are relevant to everyone including learners. We study life.
ET2	Genetics is the basis of life itself. Without genes, there is no life, so the study of genetics is relevant to the learners.
ET2	It makes the learning of life sciences relevant to their everyday life.

Table 34 Educators' opinions on learners' interest and participation in the study of genetics

ET2	Learners were very enthusiastic and motivated to learn more.
ET2	The new teaching approach turned out to be an exciting and interesting experience to teach learners. This is because situations and problems which relate to their everyday lives are used.
ET2	The learners are kept interested throughout the lesson,
ET2	It helps learners construct their own knowledge and always keeps them actively involved.
ET2	Learners enjoyed the practical activities a lot. They could easily see the processes that are explained in theory. Frankly, I did not know that there were such interesting practical activities in genetics.

ET3 (School code)

Table 35 Educators' opinions on learners' performance in the study of genetics

ET3	When learners see and relate to what the educator is saying, they understand things better and faster, hearing and listening skills are lacking in our learners.
ET3	The use of contexts in the lessons helped learners to quickly remember the things learnt, because they can relate the concepts to situations which they are familiar with.
ET3	Once you tell them what happens in real life, and then teach them the relevant genetics concepts, it becomes easier for them to understand.
ET3	The hands-on activities also helped the learners to understand the genetics concepts well.

Table 36 Educators' opinions on their ability to identify and address learners' preconceptions

ET3	Certainly, and most of the misconceptions were related to their cultural beliefs, such as witchcraft. If you start a lesson by saying to the learners, tell me something, then they feel free to tell you what they know, and then you can pick up misconceptions and correct them.
ET3	Yes, learners have very interesting and strange ideas about life. They came up with uninformed answers, solutions, myths, and beliefs, before the information stage.
ET3	What is good is that during the information phase, you have the opportunity to explain, and emphasize those issues where you noted the misconceptions.

Table 37 Educators' opinions on the most appropriate and effective way of teaching genetics

ET3	The approach (used in the study) involves a two way interaction between the educator and the learners. It is a two-way form of communication. In our schools, it is always a one-way communication where the educator says, and the learners have to accept what the educator has said. Learners do not ask questions because what the educator says is considered right.
ET3	The approach (used in the study) is practical in nature, which is lacking in traditional approaches.
ET3	Probing learners to give you what they understand about the topic makes them think broadly. It therefore increases their thinking capacity, and makes them want to know more.
ET3	The involvement of learners in the lessons made them feel appreciated, because they felt that the little they knew from home was integrated in the lessons.
ET3	In traditional teaching approaches, learners feel intimidated by the educators, and they do not have the opportunity to relate their thoughts and daily life experiences with what is learnt in class, so that they may become inquisitive and want to learn more.
ET3	I would like to mention that the context-based approach is also helpful to the educator. It is a fact that most educators do not understand what they teach. This approach forces educators to understand what they teach because they know that the learners are likely to ask questions which they might not know how to answer.
ET3	I did not know that one could conduct interesting experiments in genetics. It was very difficult to come up with genetics experiments which learners could be interested in, and which made sense. This method of teaching is really good.
ET3	It was time consuming. Adequate time is required to get information from learners and to correct their misconceptions.
ET3	However the disadvantage of time may not be an issue if the approach is used well, because if the learners understand very well, then you can move faster. But if they don't understand then you may have to repeat the topic many times for them to eventually understand.

Table 38 Educators' opinions on the relevance of studying genetics, to learners' lives

ET3	The advantage of the way genetics was taught in this programme is that learners know that what is taught in class is actually happening in their own communities.

Table 39 Educators' opinions on learners' interest and participation in the study of genetics

ET3	For the first time, I did not have to force my learners to talk. In fact I had to control them at times. Everyone wanted to say something.
ET3	The learners were very excited during lessons, especially during phase 4 (*where learners were required to link the content learnt to the context previously explored*). At times it was difficult to control them, because they came up with so many questions and suggestions.
ET3	The teaching method used kept learners interested throughout, and it stimulated in the learners the need to want to know more or research more on the topic.
ET3	The use of real-life situations in the lessons helped learners to quickly remember the things learnt, because they can relate the concepts to situations which they are familiar with.
ET3	The exploration of contexts stage allows for interaction and discussion, and it paves the way for the information (concept) stage where the content relating to that scenario, is presented by the educator.

Control groups

CT4 (School code)

Table 40 Educators' opinions on learners' performance in the study of genetics

CT4	I would say they fail because they believe that genetics is very complex, so they just shut down.
CT4	I can't pick up exactly where the problem lies, it's probably the way we teach genetics, or the type of resources that we use, because we normally use the chalk board, posters, textbooks, old models, and they don't seem to be effective in enhancing learners' achievement in genetics.
CT4	Probably learners are just lazy to study.

Table 41 Educators' opinions on their ability to identify and address learners' preconceptions

CT4	Because they are usually quiet, it is difficult to know what they think, or what they know or don't know.
CT4	Our learners are scared or shy to express themselves and reveal what they think. I think they are also scared that their friends will laugh at them if they speak broken English, because as you know, English is not their mother tongue, and they are not good at it.

Table 42 Educators' opinions on the most appropriate and effective way of teaching genetics

CT4	I normally teach genetics lessons by giving an introduction, involving some background to the lesson, and then I speak more about the lesson and give them content from the textbook, and then some exercises to do.
CT4	I think the way we teach genetics is limited to the sense of hearing. Our learners are not good at exploring issues on their own. They are very much reliant on the educator.
CT4	Some learners are afraid of giving the wrong answer, because they are not confident about what they say.
CT4	I think practical activities may help learners to understand genetics and life sciences as a subject.
CT4	I really think that genetics is a very interesting subject. If we find out what the problem is, then our learners might perform better in genetics.

Table 43 Educators' opinions on the relevance of studying genetics, to learners' lives

CT4	I believe that genetics is relevant and important to learners' lives, because it teaches them about the inheritance of diseases and certain abnormalities.

Table 44 Educators' opinions on learners' interest and participation in the study of genetics

CT4	Learners like genetics because it is an interesting topic.
CT4	Learners are usually curious during lessons. They are inquisitive, and have some interest in the lessons, but then they do not seem to understand the concepts.
CT4	I think there should be more courses to train educators on how to teach genetics.

CT5 (School code)

Table 45 Educators' opinions on learners' performance in the study of genetics

CT5	I think most learners have problems with the application of genetics.
CT5	At times what makes learners get lost during the study of genetics is the way educators present the lessons as abstract concepts.
CT5	Generally, I would say learners understand certain part of genetics, but not others.
CT5	I also think that the main problem with the study of genetics is that the application parts were just introduced in the syllabus recently, so most educators struggle to understand those parts, especially those who have decided not to study further.

Table 46 Educators' opinions on their ability to identify and address learners' preconceptions

CT5	We know the parts that confuse learners and some of their beliefs, so if you are a good educator, you can easily address them.
CT5	At times when you ask them a question, they just stare at you without saying anything, so it is difficult to know what they are thinking.

Table 47 Educators' opinions on the most appropriate and effective way of teaching genetics

CT5	The best way to teach genetics is by linking it to what happens in learners' lives.
CT5	I think experts should teach educators on how to teach genetics properly, so that learners can understand what they are taught.

Table 48 Educators' opinions on the relevance of studying genetics, to learners' lives

CT5	Of course genetics is very relevant to learners, but they need to understand it for them to appreciate it.
CT5	The teaching of genetics should be linked to real life, then it becomes relevant to learners.

Table 49 Educators' opinions on learners' interest and participation in the study of genetics

CT5	I would say learners generally like the study of genetics, but not all the different concepts of genetics.
CT5	What I know is that learners always enjoy topics which they find easy to understand. If they think that something is difficult, they won't like it.
CT5	Even some educators are not comfortable with some parts of genetics, so how can they arouse learners' interest and improve performance in those parts?

CT6 (School code)

Table 50 Educators' opinions on learners' performance in the study of genetics

CT6	Probably they are not just good at mastering the genetics concepts. I really don't know why they can't grasp the concepts.
CT6	What I notice with my classes is that they seem to understand the lessons when we start the study of genetics, but as we get deeper into the processes and applications of genetics, they get lost, and become bored.
CT6	Learners' performance in genetics is very poor. The average mark is around 30%.

Table 51 Educators' opinions on their ability to identify and address learners' preconceptions

CT6	At times, learners say things which are not scientifically true, then we correct them.
CT6	When learners don't understand, they usually keep quiet. Therefore you can't really know what they are thinking. Even if you ask them a question about that part, they won't answer.

Table 52 Educators' opinions on the most appropriate and effective way of teaching genetics

CT6	I believe that the way I normally teach is the best way of teaching genetics, because I always strive to do the best in whatever I do.
CT6	I usually start with a mind capture, like something that happened somewhere, to capture their attention. Then I teach them the concepts, and give them an assessment to see if they have followed the lesson.
CT6	I think practical activities can help to clarify the theory, but the problem is that, there are very few practical activities in genetics, and the materials are expensive, so we end up teaching the theory.

Table 53 Educators' opinions on the relevance of studying genetics, to learners' lives

CT6	Yes I think that learners realize the importance of genetics to their lives, although there are some topics which they think are not important to their lives, such as the study of plants.

Table 54 Educators' opinions on learners' interest and participation in the study of genetics

CT6	Most learners don't like the application parts because they find them difficult. They are only interested in the parts which they understand.
CT6	At times they appear to have some kind of fear of the topic, because they think it is difficult.
CT6	Some educators are very strict, and some of them use corporal punishment to make the learners respect them, so the learners are afraid of saying something that may annoy the educator, and end up being afraid to say anything in class.

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Appendix XXII: Permission from the University of Pretoria to conduct research

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FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
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Fax: +27 12 420-5621

TO THE DISTRICT DIRECTOR
DEPARTMENT OF EDUCATION

HEAD OF DEPARTMENT
Science, Mathematics and
Technology Education

DATE; 31st AUGUST 2009.

Dear sir/Madam

RE: PERMISSION TO CONDUCT A RESEARCH PROJECT – Ms. M.M.. Kazeni

The above mentioned is a PhD student at the University of Pretoria, and we would like to request your permission to allow her to conduct a research relating to the "Effectiveness of context-based teaching approaches in Life sciences, in South African schools." She would like to conduct the research in four schools randomly selected from the Tshwane South Educational district. As part of her research, she would like to compare the effectiveness of context-based and traditional teaching approaches in enhancing learners' performance in Life sciences. In order to conduct the research, she will need to develop context-based teaching materials and expose them to learners as an enrichment program (outside the normal learning time). Performance of learners using the context-based teaching approach will be compared with that of learners using the traditional (usual) teaching approach for the same Life sciences topic(s).

The successful completion of this research is likely to provide insights into the effectiveness of context-based teaching approaches (which form part of the OBE curriculum) on learners performance and attitudes towards the study of life sciences, and the relevant contexts. It will also enable Ms Kazeni to complete her PhD study.

The researcher will need to satisfy and adhere to the highest ethical standards as required for research projects of this nature, and prescribed by the University of Pretoria, which include as far as possible anonymity and confidentiality of participants and participating schools. The outcomes of the study will be made available to the participating schools upon request.

Your cooperation will be highly appreciated.

Regards

Prof. G.O.M. Onwu
Supervisor

Ms. M.M. Kazeni
Researcher.

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Appendix XXIII: Permission from the provincial Department of Education to conduct research

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries: Nomvula Ubisi (011)3550488

Date:	**05 November 2009**
Name of Researcher:	**Kazeni Monde Monica**
Address of Researcher:	**54 Chantepark**
	Poligoon Street
	Meyerspark
Telephone Number:	**0124205734/0835186515**
Fax Number:	**0124205621**
Research Topic:	**The Relative Effectiveness of Context-based and Traditional Teaching Approaches on Learners' Performance in Life Sciences, in some South African Schools**
Number and type of schools:	**10 Secondary Schools**
District/s/HO	**Tshwane South**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

Permission has been granted to proceed with the above study subject to the conditions listed below being met, and may be withdrawn should any of these conditions be flouted:

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*

Office of the Chief Director: Information and Knowledge Management
Room 501, 111 Commissioner Street, Johannesburg, 2000 P.O.Box 7710, Johannesburg, 2000
Tel: (011) 355-0809 Fax: (011) 355-0734

4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher must supply the Director: Knowledge Management & Research with one Hard Cover bound and one Ring bound copy of the final, approved research report. The researcher would also provide the said manager with an electronic copy of the research abstract/summary and/or annotation.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

Pp Nomvula Ubisi
Martha Mashego
ACTING DIRECTOR: KNOWLEDGE MANAGEMENT & RESEARCH

The contents of this letter has been read and understood by the researcher.	
Signature of Researcher:	[signature]
Date:	10/11/2009

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Appendix XXIV: Permission from principals of participating schools

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DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5734
Fax: +27 12 420-5621
http:// www.up.ac.za

Natural sciences building
Office no. 208.

Date: 4th December, 2009

Dear Sir/Madam,

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN YOUR SCHOOL, ON THE USE OF CONTEXT-BASED TEACHING APPROACH IN LIFE SCIENCES

My name is Ms. Kazeni, Monde, M.M., a registered PhD student at the University of Pretoria. I wish to refer to the above mentioned subject and inform you that in accordance with permission granted by the Gauteng Department of Education to conduct research in some schools in Tshwane South Educational district, your school has been selected to participate in the research.

The performance of learners in sciences including the Life Sciences in South African schools has been declining since 2003, despite concerted efforts by the government and other stake holders to remedy the situation. Life Sciences are becoming increasingly relevant in dealing with health, environmental and economic issues in our societies. It therefore becomes necessary to investigate different ways (including teaching approaches) of addressing the problem of poor performance of learners in the Life Sciences. In this research, a teaching approach which relates the teaching of Life Sciences to learners' daily experiences (context-based teaching) will be investigated. This approach attempts to emphasize the relevance of Life Sciences education to learners' lives. The research involves exposing grade 11 Life Sciences learners to either a context-based teaching approach, for the experimental group, or to a traditional/normal teaching approach, for the control group, on the same topic(s). Thereafter, the performance of both groups of learners on the topic(s) taught will be assessed and compared.

The research will be undertaken during the second term in 2010, and it will take the form of an enrichment programme, envisaged to take place after school hours. Therefore, the normal teaching and learning of participants will not be affected. Educators involved with the experimental groups will be trained on how to use the context-based teaching approach. After the intervention and assessment, a sample of participating learners will be selected to take part in a focus group discussion, in order to establish their perceptions on the use of the context-based teaching approach. Participating educators will also be interviewed to get their views on the effectiveness of the context-based teaching approach. The likely benefits of the study will include:

1. Gaining some insights into the range of contexts which learners feel could facilitate the understanding and enjoyment of some topics in the Life Sciences.
2. An indication of the effectiveness and efficiency of context-based teaching (which is part of the OBE system) in improving learner performance in, and attitude towards the study of Life Sciences.
3. Professional development of participating educators in context-based teaching.

I undertake to maintain confidentiality, and that neither the school nor the participants will be identified in the study report. The school and participants will be free to withdraw from the study anytime without any repercussions. In line with the departmental (DoE) regulations, a letter of informed consent will be given to participating learners and educators to indicate their willingness to participate in the research, as it is important that their participation is voluntary.

Your school may participate in the study as one of the experimental or control schools. I therefore request your consent to participate in this research project on a voluntary basis. Your assistance in this matter will be highly appreciated by myself and the University of Pretoria. Kindly indicate your willingness to grant the requested permission by signing in the space provided below.

Yours faithfully

Kazeni Monde, M.M. (Researcher) ---------------------- (Signature of the researcher) Date 04/12/09

Prof G.O.M. ONWU (Supervisor) ---------------------- (Signature of the supervisor) Date 4/12/09

Prof M. Braun (Head of Department) ---------------------- (Signature of the head of Department) Date 4/12/09

HEAD OF DEPARTMENT
Science, Mathematics and
Technology Education

CONFIRMATION OF PERMISSION TO CONDUCT RESEARCH AT THE SCHOOL

I Prof/ Dr/Mr/Mrs/Ms, ------------------------------ the principal of ------------------------
--(name of school)
hereby grant Ms. Kazeni M, M.M., permission to conduct research at this school on the above stated topic.

-- Date-----------------

(Signature of the Principal)

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Appendix XXV: Letter of consent to participating educators

LETTER OF INFORMED CONSENT FOR EDUCATORS.

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FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5734
Fax: +27 12 420-5621

Date: 4th February 2010.

Dear Educator:

RE: <u>REQUEST TO PARTICIPATE IN A RESEARCH PROJECT.</u>

You may be aware that the performance of South African high school learners in sciences, including life science, has been declining for almost a decade now. You are invited to participate in a research project which attempts to address the problem of poor performance in life science. In this project, we will try to see how different teaching approaches may help in improving the performance of learners in genetics, a topic which learners are said to find difficult to understand.

If you are interested in participating in the research project, your role will involve helping in teaching learners using either a context-based teaching approach, or the traditional (normal) way of teaching. Educators involved in teaching the context-based materials, will be thoroughly trained on how to use them. Teaching sessions will take place after school, as enrichment lessons. Therefore, your involvement in the project is not likely to affect your normal teaching schedule.

The researcher will make occasional visits to your class during lessons, for the purpose of identifying any challenges related to the implementation of the approaches, **NOT** for assessing you. We hope to videotape some of the lessons in order to capture the learning atmosphere. Also, some of the participating educators will be interviewed at the end of the project, to determine their perceptions of the use of the particular teaching approach in enhancing learner performance.

We would appreciate if you could participate in this project, as we believe that it will contribute to furthering our knowledge on how to significantly improve learner performance in life science. You have the right to decline, or withdraw from participation any time, without any repercussions. Your participation or non participation in the project, and the outcomes of the study will have **NO** consequences whatsoever, on your profession as an educator, or on your personal reputation. All data collected during the project will be treated confidentially by using pseudonyms.

If you are willing to participate in this research, please kindly write your name and sign on the line below.

Name of educator.. **Signature**................

Date:.........................

Yours sincerely

Name of researcher: Kazeni Monde. M. M. **Signature**..............

Date:18/02/10....

Supervisor: Prof G.O.M. Onwu:.............................. **Signature**..................

Date:24/02/10........

Appendix XXVI: Letter of informed consent to parents

LETTER OF INFORMED CONSENT FOR A MINOR CHILD.

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Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5734
Fax: +27 12 420-5621

Date: 4th February 2010

Dear Parent(s)/Guardian(s):

RE: REQUEST FOR PERMISSION TO INVOLVE YOUR CHILD IN A RESEARCH PROJECT.

I am writing to ask your permission for your child to participate in a research project aimed at addressing the problem of poor performance in life science. In this project, we will teach your child genetics, a topic that is considered difficult to learn. Different teaching approaches will be used in order to determine which one is more effective in improving learner performance in genetics.

In this project, lessons will be presented after school, as part of the learner after school enrichment project, offered by the University of Pretoria. Your child's school is already part of this after school enrichment project. This means that your child's participation in the research project is not likely to change her/his daily schedule. Your child will have the opportunity of studying genetics again when it will be taught during normal school lessons.

The research project is expected to be an enjoyable and beneficial experience for your child, and will **NOT** require any additional costs or responsibilities from you. We are hoping that your child will benefit from the project by improving her/his knowledge in genetics. We do not anticipate any risks or harm to your child during the research project.

Any information obtained from assessments done during the project will be used for this research only. Individual children's results will not be shared with the school staff. Participation in this study will therefore not affect the assessment of your child by the teachers, and will not be in the school records.

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Participation in this research is voluntary. Both you and your child have the right to decline, and you can withdraw your child from participating in the project any time, without any repercussions. Only learners who volunteer to participate, and whose parents/guardians willingly permit them to do so, will be considered for the project. We will appreciate if you could allow your child to take part in this study.

Should you have any concerns or questions regarding your child's participation in this project, please contact Ms Kazeni, M.M. at telephone number: 012 420 5734 or e-mail address: monde.kazeni@up.ac.za. If you have any questions about the rights of your child as a participant, you may contact the University of Pretoria, Faculty of Education, Ethics Committee, at 012 420 3751.

If you are willing to allow your child to participate in the study, please kindly write your name and sign on the lines below, and return the letter to the school as soon as possible.

Name of parent/guardian…………………………………**Signature**………………..

Date:………………………

Yours sincerely

Name of researcher: Kazeni Monde. M. M. **Signature**……………..

Date: 18/02/10………..

Supervisor: Prof G.O.M. Onwu **Signature**…………..

Date: 24/2/10…………

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Appendix XXVII: Permission from the University of Pretoria Ethics Committee to conduct research

UNIVERSITEIT VAN PRETORIA
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Faculty of Education

Faculty of Education

Ethics Committee

21 April 2010

Dear Ms Kazeni

REFERENCE: SM10/03/02

Your application was carefully considered and discussed during a Faculty of Education Ethics Committee meeting on 20 April 2010 and the final decision of the Ethics Committee is:

Your application is approved.

This letter serves as notification that you may continue with your fieldwork. Should any significant changes to the study occur after approval was given, it is your responsibility to notify the Ethics Committee immediately.

Please note that this is **not a clearance certificate**. Upon completion of your research you need to submit the following documentation to the Ethics Committee:

1) Investigator(s) Declaration that you adhered to conditions stipulated in this letter (D08/01).
2) Investigator(s) Declaration for the storage of research data and/or documents (Form D08/02).
3) Supervisor's Declaration for the storage of research data and/or documents (Form D08/03).

On receipt of the above-mentioned documents you will be issued a clearance certificate. Please quote the reference number SM10/03/02 in any communication with the Ethics Committee.

Best wishes,

Prof Liesel Ebersohn
Chair: Ethics Committee
Faculty of Education