

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; Taasobshirazi & 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; Taasobshirazi & 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				Average %	Rank
	Educators		Learners			
	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 ranking 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 ($\leq 50\%$) 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-retest 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 (OECD, 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 $p = 0.83$, 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 assessed using ANOVA and ANCOVA, while qualitative data were transcribed, coded and analysed. The ethical measures taken in the study were discussed.