CHAPTER TWO

LITERATURE REVIEW

2.1 ORIENTATION TO THE CHAPTER

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

2.2 APPROACHES TO THE TEACHING OF SCIENCE

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

2.2.1 Traditional teaching approaches

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

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

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

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

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

2.2.1.1 Traditional teaching approaches and learner performance

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

- **Traditional teaching and conceptual understanding**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2.2 Context-based teaching approaches

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

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

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

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

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

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

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

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

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

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

2.2.2.1 Models for developing context-based materials

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

Model 1: Context as the direct application of concepts

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

Model 2: Context as reciprocity between concepts and applications

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

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

Model 3: Context provided by personal mental activity

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

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

Model 4: Context as social circumstances

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

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

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

2.2.2.2 Development of context-based teaching materials

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

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

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

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

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

- ***Development of learning activities***

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

- ***Development of assessment tasks***

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

2.2.2.3 Approaches for implementation of context-based materials

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

Model 1: Traditional context-based teaching approaches

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

Model 2: More modern context-based teaching approaches

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

Model 3: Recent context-based teaching approaches

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

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

2.2.2.4 Implementation of context-based teaching materials in school science

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

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

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

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

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

- ***Salters' Projects***

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2.2.5 Context-based teaching approaches and learner performance

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

➢ Selection of contexts

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

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

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

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

- **Design of context-based materials**

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

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

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

Context-handling

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

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

Regulation of learning

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

Emphasis

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

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

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

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

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

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

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

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

2.2.3 Learning cycle instructional approaches

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

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

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

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

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

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

- **Principles underpinning learning cycle instructional approaches**

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

Herbart's instruction model

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

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

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

Dewey's models of reflective experience

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

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

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

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

Piaget's mental function model

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

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

Constructivism

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

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

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

2.3 CONCEPTUAL FRAMEWORK FOR THE STUDY

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

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

(i) Core component

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

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

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

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

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

(ii) Process component

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

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

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

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

(iii) Learning cycle

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

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

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

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

2.4 ASSESSMENT OF SKILLS ACQUISITION AND LEARNER ATTITUDE

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

2.4.1 Assessment of science inquiry skills

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

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

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

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

2.4.2 Assessment of problem-solving ability

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

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

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

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

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

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

2.4.3 Assessment of decision-making ability

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

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

2.4.4 Assessment of learners' attitude

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

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

2.5 SOME FACTORS AFFECTING PERFORMANCE IN SCHOOL SCIENCE

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

2.5.1 Gender and achievement in science

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

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

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

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

2.5.2 Learners' cognitive preferences and achievement in science

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

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

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

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

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

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

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

2.6 CHAPTER SUMMARY.

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

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