THE RELATIONSHIP BETWEEN LIFE SCIENCES TEACHERS' KNOWLEDGE AND BELIEFS ABOUT SCIENCE EDUCATION AND THE TEACHING AND LEARNING OF INVESTIGATIVE PRACTICAL WORK

By

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Supervisor: Dr Edith R. Dempster

DECLARATION

I, Prithum Preethlall declare that:

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Prithum Preethlall

2015

Supervisor: Dr Edith R. Dempster

DEDICATION

To my loving parents Saras and Lallie:

Your limited primary school education and the hardships that you endured did not prevent you from securing the best education for your children. This has been a constant source of inspiration and determination to undertake and accomplish this study. This thesis is one of the fruits of your untiring hard work and labour.

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ABSTRACT

The advent of democracy in South Africa in 1994 resulted inter alia in the transformation of its education system. Revision of the school curriculum was an important component of the total transformation of education. The resulting *National Curriculum Statement (NCS)* required not only a change in educational or subject specific content, but also a change in educational processes. The ultimate purpose or goals of education are the Critical Outcomes (COs) and Developmental Outcomes (DOs) which reflect the beliefs, needs and aspirations of the people of South Africa. Learners are expected to relate to and use the knowledge and skills that they acquire in everyday life. Also, the learner is expected to use cognitive and social strategies such as reasoning, researching, collaborating, and expressing opinions and debating. The learning environment required to achieve the COs and DOs therefore necessitates active learners as well as teachers who use various strategies to promote learning that will result in understanding.

In South Africa reform in Life Sciences education is articulated via a policy framework referred to as the *National Curriculum Statement (NCS)* for Life Sciences in Grades 10 – 12 The *NCS* asserts that investigations as part of inquiry teaching and learning should feature prominently in science teaching and learning. This is an attempt to ensure that scientific content is not the only focus of science teaching and learning but that some understanding of the methods or processes of science are also involved. In order to accomplish this in the South African Life Sciences curriculum investigations feature as part of the prescribed practical work. It prescribes two types of practical work as part of the continuous assessment (CASS) or school-based assessment (SBA). Practical activities can take the form of 'hands-on' and/or 'hypothesis testing' tasks for the purposes of formal assessment. The 'hands-on' type of practical work is highly structured with a sequence of step-by-step procedures laid out by the teacher or text book to be followed by learners while the 'hypothesis testing' type of tasks has a leaning towards authentic, open-ended inquiry with minimal guidance and is learner directed or driven and was the subject of this study. Within the context of this study the 'hypothesis testing' type of activity is referred to as investigative practical work (IPW).

IPW is an example of inquiry-based teaching and learning. Many teachers do not readily appreciate the implementation of inquiry teaching and learning because of the many challenges or barriers that they encounter. One such challenge is teachers' beliefs about

classroom management that interfere with learning about 'doing' inquiry. Another is their knowledge base for implementing inquiry. Hence, this study focused on establishing the relationship of teachers' knowledge and beliefs about science education and the teaching and learning of IPW in the Life Sciences.

A qualitative, multiple case study approach was followed in executing this research. Data was collected through a questionnaire, a structured interview, lesson observations and study of documents which included tasks completed by the participating teachers, teacher and learner artefacts, as well as the different South African Biology and Life Sciences curricula.

The findings of the study shows that there are consistencies as well as inconsistencies between teachers' knowledge and teachers' beliefs regarding some aspects of teaching and learning. It also found consistencies and inconsistencies between knowledge and practice and between beliefs and practice. The strongest influence on teachers' practice is their previous experiences and knowledge, which have resulted in deep seated beliefs about the practice of IPW.

For the successful implementation of the transformed curriculum and more especially, IPW several recommendations have been provided. These recommendations involve strategies to be implemented from a micro (school) level to the macro level (National Department of Basic Education). If teachers' knowledge and beliefs are not taken into account, efforts to reform science education will have difficulty in succeeding.

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LIST OF ACRONYMS

C2005:	Curriculum 2005
CASS:	Continuous Assessment
CAPS:	Curriculum and Assessment Policy Statements
CO:	Critical Outcome
DBE:	Department of Basic Education
DO:	Developmental Outcome
DoE:	Department of Education.
FET:	Further Education and Training
GET:	General Education and Training
GPK:	General Pedagogical Knowledge
LO:	Learning Outcome
NCS:	National Curriculum Statement
NQF:	National Qualifications Framework
PCK:	Pedagogical Content Knowledge
PCxtK:	Pedagogical Context Knowledge
PD:	Professional Development
SA:	Specific Aim
SAG:	Subject Assessment Guideline
SBA:	School Based Assessment

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CHAPTER ONE

OVERVIEW OF THE STUDY

1.1 INTRODUCTION

The chapter provides an overview of the study which is embedded within the science inquiry teaching and learning perspective. It introduces the requirements of the transformed South African curriculum. In addition, it provides an elaboration of practical work as a component of science education and affords a brief motivation for the location of Investigative Practical Work (IPW) within the context of practical work and the inquiry approach to teaching and learning. The focus of the study, broad problems to be investigated, aims and objectives of the study and the key research questions are then elaborated on. The motivation and rationale for the study and how the findings will contribute to the body of knowledge then follows. It further highlights the context of the study, and subsequently provides a brief description of the design and methodology of the research limitations of the study. The outline of the structure of the thesis is finally given.

1.2 IMPERATIVES OF THE TRANSFORMED SOUTH AFRICAN CURRICULUM

The advent of democracy in South Africa in 1994 resulted inter alia in the transformation of its education system. Revision of the school curriculum was an important component of the total transformation of education. The resulting *National Curriculum Statement (NCS)* (Department of Education (DoE), 2003a) required not only a change in educational or subject specific content, but also a change in educational processes. The ultimate purpose or goals of education are the Critical Outcomes (COs) and Developmental Outcomes (DOs) (DoE, 2003a), which reflect the beliefs, needs and aspirations of the people of South Africa as contained in the Constitution of the Republic of South Africa (1996). Learners are expected to relate to and use the knowledge and skills that they acquire in everyday life. Also, the learner is expected to use cognitive and social strategies such as reasoning, researching, collaborating, and expressing opinions and debating. The learning environment required to achieve the COs and DOs therefore necessitates active learners as well as teachers who use various strategies to promote learning that will result in understanding.

In South Africa reform in science education is articulated via a policy framework referred to as the *Revised National Curriculum Statement (RNCS)* for Natural Sciences in Grades R – 9 (Department of Education (DoE), 2002a), and separate *National Curriculum Statement*

(NCS) for Life Sciences and Physical Sciences in Grades 10 – 12 (DoE, 2003b). The *NCS* (DoE, 2003b) asserts that investigations as part of inquiry teaching and learning should feature prominently in science teaching and learning. This is an attempt to ensure that scientific content is not the only focus of science teaching and learning. Some understanding of the methods or processes of science such as, recognising the strategies by which inquiries are conducted and knowing about the established procedures and routines used in carrying out investigations are also involved. In order to accomplish this in the South African Life Sciences curriculum investigations feature as part of the prescribed practical work. In this regard, the South African Life Sciences curriculum prescribes two types of practical work as part of the continuous assessment (CASS) or school-based assessment (SBA). The two types are namely, 'hands-on' and 'hypothesis testing'.

According to the Subject Assessment Guideline (SAG) document (DoE, 2005b) practical activities/tasks can take the form of 'hands-on' or 'hypothesis testing' tasks. In addition, it indicates that for the 'hands-on' practical activities learners will be assessed on their ability to: follow instructions, make accurate observations, work safely, manipulate and use apparatus effectively, measure accurately, handle materials appropriately, gather data, and record data appropriately (p. 8).

While the SAG document (DoE, 2005b; 2008) does not provide a description of what a 'hands-on' practical task is, except for an example of a task, it does articulate the nature of a 'hypothesis-testing' task together with an example. The reason for the details with respect to the hypothesis-testing task is because "this approach to assessment has not commonly been used in teaching Life Sciences" (p. 17). It further states that, "the knowledge, skills and values which feature in the Life Sciences curriculum, however, encourage tasks that call for higher level of knowledge and skills than those required in a 'hands-on' practical" (p. 17).

The following broad skills will be assessed for the 'hypothesis testing' tasks: accurately describe nature or a phenomenon; identify and state causal relationships; recognise, generate and state alternative hypotheses; generate logical predictions; plan and conduct controlled experiments to test hypothesis; collect, organise, and analyse relevant data and draw and apply reasonable conclusions (DoE, 2005b). These skills and abilities are reflective of 'The Scientific Method' (DoE, 2005b).

While the two types of activities may seem to be exclusive to each other, the information offered in the SAG (DoE, 2005b) does not indicate this. A hypothesis testing task includes

conducting an investigation, which may require the handling and manipulation of apparatus and equipment. Similarly, a hands-on task does not imply that hypotheses for example, cannot be generated and tested. The difference between these types of practical activities lies in the extent of guidance that is provided to the learners and therefore, the cognitive demand of the task. Hands-on tasks are generally 'scripted' tasks. That is, detailed step-by-step procedure may be provided for the learners to follow and execute. It involves activities that are highly structured with a great deal of information. Examples of such tasks are: 'Dissection of a sheep heart' or 'conducting an experiment' where the aim and procedure is provided and the results and conclusion could be verified using text-books or the teacher. This type of task focuses on the development and assessment of separate skills, such as following instructions, and handling and manipulating apparatus. It is therefore possible that activities in this format could result in learners missing out on any sense of an 'investigation' as a whole experience – that which brings it closer to the 'authentic scientific inquiry'. The hypothesis testing tasks are more open-ended allowing learners to reach a solution via multiple routes.

According to Chinn and Malhotra (2002) the hands-on tasks may be classified as simple inquiry activities and the hypothesis-testing tasks as authentic inquiry. Hypothesis testing type of activity leans towards authentic, open-ended inquiry and is the subject of this study. Hypothesis testing practical work is intended to develop and assess not just process skills but how these skills are threaded together as a whole investigative experience. It leans towards tasks that are more open-ended and towards authentic inquiry with a greater degree of learner autonomy. However, for this study the concept Investigative Practical Work (IPW) is used. A more detailed description is provided in Chapter Three.

1.3 PRACTICAL WORK AS A SIGNIFICANT COMPONENT OF SCIENCE EDUCATION

Practical work is a distinct feature of science education. There are various reasons for this. One of the aims of science is to increase our understanding of the natural world for instance, what it is made up of, and how it works. Furthermore, a crucial commitment of science is that claims or arguments and explanations must be supported by evidence. Science education aims to increase learners' knowledge of the natural world, and help them develop an understanding of the ideas and models that scientists use to explain its behaviour. It is therefore, natural that science teaching involves showing learners certain things, or putting them into situations where they will see things for themselves. Merely telling them is unlikely to lead to understanding (Millar, 2010). According to the House of Commons Science and Technology

Committee (2006) and SCORE (2008), practical work helps learners to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if learners are to pursue careers in science. Therefore, learners should be given opportunities to do exciting and varied experimental and investigative tasks. In addition, Roberts' (2002) report on the supply of people with science, technology, engineering, and mathematics skills highlights the quality of school science practical work as a key concern. Practical work, it argues, is a very important part of students' learning experiences. Hence, practical work should play a significant role in giving learners confidence to study science at higher levels (Roberts, 2002). Unfortunately, the House of Commons Science and Technology Committee (2006) as well as Roberts (2002) do not elaborate on the type or nature of practical work that could achieve what they claim.

Some science educators have questioned the value of practical work. For example, Hodson (1991) argues that, in spite of the large amount of time set aside for practical work it often offers little of real educational value. He goes on to state that in many countries school science practical work is "ill-conceived, confused and unproductive and for many children, what goes on in the laboratory contributes little to their learning of science or to their learning about science and its methods" (p176). Osborn (1998) expresses similar sentiments in that practical work offers little of educational value and plays a limited role in learning science. The claim that practical work influences learner's motivation to study science has also been challenged by Abrahams and Millar (2008).

These three authors are justified in their criticisms if they are referring to the common type of practical activities, which require learners to follow a step-by-step procedure laid out by the teacher or the text book. In addition, such practical activities may not emphasise the nature of science as a way of knowing, or where the nature of the practical activities do not require their learners to "explain and justify their work to themselves and to one another" (NRC, 1996, p. 33).

The above introductory remarks refer to practical work in general. However, this study however, focuses on one type of practical work, namely, investigative practical work (IPW) which is an example of inquiry–based teaching and learning and which conforms to what is referred to as 'hypothesis testing' within the South African Life Sciences curriculum. Chapter Three of this study locates IPW within the context of practical work in greater detail.

One of the goals of science education is to help learners to reason scientifically (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996; 2000; Department of Education (DoE), 2002; 2003). In this regard, schools usually engage learners in scientific inquiry tasks such as observation and experimentation. Hence, inquiry is an integral part of the teaching and learning of science. Investigative practical work (IPW) as a category of practical work is an example of inquiry-based teaching and learning which has received much attention in school curriculum transformation processes around the world, with South Africa being no exception (DoE, 2002a; 2003b). For example, in the United States, the AAAS (1993) and the NRC (1996; 2000) endorse inquiry-based science curricula that actively engage learners in practical investigations. In the United Kingdom, Attainment Target 1 for Science in the National Curriculum has devoted much priority to investigations (Department for Education and Employment, 1999). In the transformed South African curriculum, the critical outcomes (COs) as well as the learning outcomes (LOs), particularly learning outcome 1 (LO1) in the Life Sciences emphasises investigations (DoE, 2003a; 2005b).

In the original formulation of the *NCS*, the COs and developmental outcomes (DOs) were achieved through Learning Outcomes (LOs), written specifically for each subject in the Further Education and Training (FET) Phase of Education (Grades 10-12) (DoE, 2003b). In the Life Sciences, three learning outcomes were prescribed. LO1 which is the focus of this study is related to investigations and is stated as follows:

"The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem-solving, critical thinking and other skills" (DoE, 2003a; 2005b).

LO1 is a clear formulation of inquiry–based teaching and learning in the Life Sciences curriculum. LO1 may be achieved through the development of the following assessment standards (ASs):

- Identifying and questioning phenomena and planning an investigation
- Conducting an investigation by collecting and manipulating data
- Analysing, synthesising, evaluating data and communicating findings

(DoE, 2003a; 2005b).

The pursuance of these Assessment Standards (ASs) begins with appropriate guidance to tasks which lean towards authentic inquiry in Grades 10 and 11 and with minimal guidance to

open-ended tasks, in Grade 12. Table 3.2 in Chapter Three illustrates this increasing complexity in the implementation of LO1.

Learning outcome 2 (LO2) relates to the accessing, interpretation and construction of Life Sciences knowledge while Learning outcome 3 (LO3) encompasses the inter-relationship of science, technology, indigenous knowledge and the environment.

(DoE, 2003b)

Table 2.4 in Chapter Two shows the relationship between LO1 and the COs and DOs.

Implementing IPW in the teaching and learning Life Sciences provides a suitable vehicle for creating an appropriate active, learner-centred, learner-directed and activity based environment, as required to achieve LO1 and therefore some of the COs.

Chinn and Malhotra (2002) contend that scientific inquiry tasks carried out by school-based learners do not reflect the core attributes of authentic scientific reasoning. They refer to authentic scientific inquiry as the research that is conducted by scientists and simple inquiry tasks as those carried out by school-based learners. Within the context of this study, on a continuum between simple inquiry to authentic inquiry, IPW in a school environment falls closer to the authentic inquiry end. It refers to degrees of open-ended inquiry tasks with learner autonomy and some uncertainty of outcome. The notion of learner autonomy indicates that it is the learner who is at the centre of the scientific enterprise, in that he/she will identify the problem, generate questions and hypotheses, plan and design the investigation, conduct the investigation, collect, record, and analyse data, and articulate the findings and conclusions. It further excludes detailed guidance by following highly structured, step-by-step, instructions provided by the teacher or the text book. In addition, the term IPW is preferred to terms such as, ‘discovery’, ‘exploratory’, ‘experiments’, ‘problem solving’, ‘practical investigations’, ‘inquiry learning’, and ‘laboratory work’ which have similar connotations but which do not necessarily exclude simple inquiry tasks which include, simple observations, simple illustrations and simple experiments (Chinn & Malhotra, 2002). Furthermore, the term ‘hypothesis testing’ is not being used because not all investigations requires the generation of hypotheses (Anderson, 2007). A more detailed description of IPW in relation to simple inquiry tasks and authentic scientific inquiry will be presented later in Chapter Three.

Traditionally, practical work in science education involves learners following a highly structured, step-by-step approach, where teachers dominate and control the sequence of activities, while learners play a passive role (Zion & Sadeh, 2007; Bell, Smetana & Binns, 2005; Wellington, 1994). Passive role in this context implies the lack of higher-level engagement or reasoning, such as questioning procedures, generating own testable hypotheses or engaging in reasons for anomalous results. Practical tasks in this mode are strongly teacher directed, whereby learners follow a set of instructions for the execution of procedures handed down by the teacher either verbally or in worksheets. In this mode, learners perceive practical investigations as supporting theory. That is, it serves a verification purpose, without any other apparent benefits beyond the superficial observation and confirmation of established knowledge. If such investigations do not yield the expected established results, teachers then provide the 'correct' results or they refer learners to the text book for the results. Hence, the educational value of this traditional approach has been challenged (Viechnicki & Kuipers, 2006 p.115). Such tasks could also be in the form of teacher demonstrations. This mode however, promotes an imitative and observational form of learning whereby learners absorb information that is demonstrated by the teacher without being actively involved in constructing the knowledge which the teacher takes for granted. Hence, the learner is unable to identify his/her own learning needs. Following written instructions and observing an expert do something may be a valid way of learning in a science classroom. There is however, a need to move beyond this mode in higher grades like in the Grade 12 classes. In the South African context moving beyond teacher-directed practical activities is one of the imperatives for Grade 12 learners as per LO1 for Life Sciences as indicated in Table 3.2 in Chapter Three.

It must also be noted that while the old (pre-2006) South African *(A Resume of Instructional Programmes in Schools) (Report 550)* Biology curriculum also included practical investigations (refer to Table 2.3 in Chapter Two), it did not explicitly enunciate open-ended investigations. Table 2.3 in Chapter Two, illustrates the relationship between the LOs in Life Sciences and the Aims, Objectives and Approach to the old Biology syllabus. The Life Sciences Subject Assessment Guidelines (SAG) document (DoE, 2005), also prescribes investigations in the form of one 'hands-on' and one 'hypothesis testing' task for the purposes of formal assessment.

1.4 FOCUS OF THE STUDY

Over many years researchers in science education have devoted a great deal of effort in areas on promoting the enactment and propagation of reforms derived from their research (Fishman, Penuel, & Yamaguchi, 2006; Dede, 2006; Fishman, Marx, Blumenfield, Krajcik, & Soloway, 2004). The efforts of these researches are dedicated to enhance learner achievement through improved teacher practice. According to Borko (2004), it is the teachers who play a fundamental role in nearly all formal instructional systems. Hence, they are regarded as the "cornerstone" or "the most influential factor" in educational reforms and innovations (Van Driel, Beijaard, & Verloop, 2001; Fishman & Davis, 2006). Given the important role of the teachers in the implementation of the curriculum reforms the focus of this study was to understand any relationship between South African Grade 12 Life Sciences teachers' knowledge and their beliefs about science education and the teaching and learning of IPW. Teachers' knowledge within this context refers specifically to their understanding of Life Sciences content knowledge, knowledge for teaching and learning, including knowledge of the curriculum, general pedagogical knowledge, pedagogical content knowledge and pedagogical context knowledge. Teachers' knowledge could be regarded as the 'intellectual tools' for working as a Life Sciences teacher. Examples of these 'intellectual tools' include explaining terminology and concepts to learners, interpreting and understanding learners' statements, questions and explanations, being critical of and judging textbook/ magazine/newspaper representations of particular topics and correcting these, and using representations accurately in the classroom. In addition, it includes knowledge and understanding of the implementation of the processes and procedures of science and methods of inquiry as well as the requirements for the intended Life Sciences curriculum as represented in the *NCS*.

The study is limited to the implementation of LO1 for Life Sciences in the *NCS*, but its findings may have implications for Specific Aim 2 (SA2) of *CAPS* (DBE, 2010), which has been implemented in Grade 12 in 2014. A more detailed discussion in this regard will follow in Chapter Two.

Implementing IPW requires teachers who are well grounded in the content, process skills and procedures of their subject, confident in the classroom, and motivated to try something different from their traditional teacher-centred practices (Trumbell, Scarano & Bonney, 2006). Within the South African context however, there are several challenges or barriers with respect to the competence, confidence and motivation of teachers as well as external factors

such as the lack of physical resources. For example, only 17% of state schools have functional laboratories (Institute of Race Relations, 2012). Many teachers do not readily appreciate the implementation of inquiry teaching and learning because of these challenges or barriers that they encounter.

Another challenge is teachers' beliefs about classroom management that interfere with learning about 'doing' inquiry, beliefs that are unacknowledged and therefore unexamined (Trumbull, Scarano, & Bonney, 2006).

Classroom management refers to the multitude of techniques and skills that are used by teachers to ensure that learners are organised, orderly, focused, attentive, on task, and academically productive during a lesson (Hidden curriculum, 2014). When effective classroom-management strategies are implemented, teachers are able to prevent or minimize learner behaviours that hinder learning for both individual learners as well as groups of learners. In this way learner behaviour that facilitates or enriches learning is promoted. In general, effective teachers tend to display strong classroom-management skills, while the inexperienced or less effective teachers' classroom is disorderly where learners are not productive or are inattentive (Hidden curriculum, 2014). From a more traditional practice point of view, effective classroom management may focus largely on "compliance", that is, rules and strategies that teachers may utilise to ensure that learners are sitting quietly in their seats, following directions, listening attentively to the expert teacher providing them with all the information.

A more encompassing or reformed view of classroom management expands to everything that teachers may do to facilitate or improve the learning of their charges. This wider view may include aspects such as but not limited to, a positive attitude, encouraging statements, respect and fair treatment of all learners by the teacher, ensuring that the teaching–learning environment is intellectually stimulating and organised to support the teaching and learning process. Another critical aspect related to reformed science teaching includes the activities that are designed to engage learner interest, passion and intellectual curiosity (Hidden curriculum, 2014).

While poorly designed lessons or unclear expectations, for instance, could contribute to learner disinterest, unruly and disorganised classes, classroom management cannot be separated from all the other decisions that teachers make. Therefore, in this more encompassing view of classroom management, good teaching and good classroom management become, to some degree, inextricable and indistinguishable. However, managing

such an act becomes challenging to teachers who are 'inexperienced' with reformation in general and in implementing investigative practical work in particular. This may perhaps be the reason for the findings of two recent studies in South Africa. These studies (Seopa, Laugksch, Aldridge & Fraser, 2003; Rogan & Aldous, 2005) reported the lack of learner autonomy in practical work in science. Instead, practical work was still dominated by teacher demonstrations and the following of a very structured task with teacher direction. To successfully, and effortlessly integrate the classroom management techniques with lesson instruction requires a variety of sophisticated techniques and a significant amount of skill and experience. Such challenges may result in teachers who lack confidence and thereby continuing to teach in familiar ways.

The beliefs that teachers hold develop over years through the process of socialization as students and as teachers. Beliefs are important indicators of teacher action in the classroom (Woolfolk Hoy, Davis, & Pape, 2006; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Pajares, 1992; Bandura, 1986). However, these beliefs must be inferred from an understanding of teachers' intentions and response to a situation. In this respect Haney, Czerniak, and Lumpe, (1996) indicated that beliefs also represent teachers' intentions to implement reform-based strategies. Nespor and Barylske (1991) indicate that beliefs about subject matter are crucial to shaping a teachers' practice. For instance, if a teacher holds beliefs about knowledge being stable and unchangeable, is certain, and that such knowledge can only be transmitted by an authority figure then it is possible that the teachers' practice will promote such narrow views of knowledge through tasks and activities that have predetermined solutions. The teacher may also be reluctant to allow his/her learners to engage with one another, question facts and procedures and thereby prevent divergent thinking. In addition, Nespor and Barylske (1991) indicate that beliefs shape interpretations and expectations for future events, and that beliefs can be resistant to change. Furthermore, Verjovsky and Waldegg (2005) contend that there is an urgent need to understand teachers' beliefs in relation to their practices, especially to overcome any barriers and ultimately improve the quality of learning and understanding (Richardson, 2003).
Similarly, Keys and Bryan (2001), argue that research is limited and therefore needed in the following areas:

- Teachers' beliefs about inquiry
- Teachers' knowledge base for implementing inquiry
- Teachers' inquiry based practices

- How students learn in the science classroom from teacher designed inquiry instruction.

This study attempts at contributing to the first three areas of the suggested research.

The unequal distribution of resources by the previous apartheid government still haunts a democratic South Africa. The fragmented system of education and unequal funding resulted in poor school infrastructure, lacking laboratories, libraries and computer facilities. The few schools that have laboratories are mostly inadequately equipped or not equipped at all.

The researcher's experience as a senior curriculum specialist in the KwaZulu-Natal Department of Education also reveals that a significant number of Life Sciences teachers are either unqualified or under-qualified. Unqualified teachers are those who either do not have a tertiary qualification or those who are qualified in other specialist areas but are required to teach Life Sciences. The under-qualified teachers are the older teachers who possess a Primary Teachers Diploma (PTD) with some Science courses, as their tertiary qualification instead of a Secondary Teachers Diploma with Biology as a subject specialisation. This qualification has been phased out in South Africa since the closure of colleges of education. None of the teacher participants in this study possess a PTD qualification. Hence, there was a need to understand how teachers were coping with the introduction of investigations in the Life Sciences curriculum within a context of a lack of adequate infrastructure and low levels of qualification among teachers.

The researcher's observations in his different capacities, during the implementation of the Life Sciences curriculum revealed that there was a lack of inquiry-based activities taking place in Life Sciences teaching. In particular, there was a lack of IPW within the concept of 'hypothesis-testing' activities. In general teachers reverted to the old 'tried and tested method', which involved the use of teacher directed 'closed-ended' activities with highly structured instructions for the aim, procedure, and recording of results in text books or teacher prepared worksheets.

My interactions with South African teachers and colleagues also revealed reluctance towards the implementation and assessment of IPW that leaned towards greater open-endedness. Informal probing further into this situation led the author to suspect that this may be related to teacher's subject matter knowledge, knowledge with respect to Life Sciences education, their confidence or lack thereof, and their perceptions and attitudes about IPW. This study therefore focused on the interplay among teachers' knowledge and teachers' beliefs and its relation to the teachers' practice of IPW.

This state of affairs reflects similar trends in other parts of the world. Many international studies have shown that investigative work is sorely lacking in secondary schools. For example, according to Haigh (2007), whilst the curricula in New Zealand, UK and USA have always emphasised the importance of practical work during the 1980s and 1990s there had been a loss of much of these inquiry and process emphasis and by the end of the 20th century practical work in senior biology classrooms had largely become a recipe-following practical exercise.

According to Smith, Banilower, McMahon and Weiss (2002), in a survey conducted in the United States in 2000, only 12% of teachers asked learners to design or implement their own investigations. The study found that science investigations continue to be done in a 'cookbook' style to verify information in textbooks (Trumbull et al., 2006 p.1718).

Other studies have found that teachers' subject matter knowledge and their personal beliefs about the teaching and learning of investigations influence their teaching practice (for example, Saad & BouJaoude, 2012; Woolfolk Hoy, Davis, & Pape, 2006; Lin & Chen, 2002; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001; Nespor & Barylske, 1999; Richardson, 1996; McDonald, 1993; Carlsen, 1993; Pajares, 1992 and Nespor 1987). These studies highlighted the importance of beliefs as an indicator of teachers' actions during classroom practice. In addition, teachers' beliefs about students, learning, the nature of science and science education, epistemology, curriculum, expectations of students and parents and the role of the teacher affect the way that science teachers teach (Wallace & Kang, 2004; Wellington, 2000).

As stated earlier, to enhance scientific literacy the South African Life Sciences curriculum advocates the development of three learning outcomes (LOs). LO1 is concerned with scientific inquiry and problem-solving skills, LO2 is related to construction and application of Life Sciences knowledge, and LO3 is concerned with Life Sciences, Technology, Environment and Society. These three aspects of scientific literacy are similar to those referred to by Boujaoude (2002). Boujaoude however, included an additional aspect, namely, 'science as a way of thinking' and states that science is a way of thinking and the investigative nature of science are the aspects of scientific literacy that are related directly to inquiry-based science teaching and learning. Thus, it is argued that enhancing inquiry

teaching and learning including IPW in science classrooms will help promote scientific literacy (Wallace & Kang, 2004).

Based on the researcher's personal observation as a curriculum specialist, as well as his experience as an external moderator, it was found that teachers vary in their attempts to encourage learners to construct scientific knowledge. Some provide appropriate stimuli and/or guidance for an active and systematic search for knowledge and understanding, while others encourage less active or even passive learning. There was therefore a need to understand how the policy was being implemented and to understand the reasons for the lack of opportunities created and/or provided for IPW. Keke (2014) indicated that out of a total of thirty-four pedagogical needs identified by 147 Life Sciences teachers in a rural district of the KwaZulu-Natal Province, the following related to practical work and other subject matter knowledge.

Table 1.1: Teacher Identified Pedagogical Needs Related to Practical Work (Adapted from Keke, 2014, p.180)

Rank out of 34	Teachers identified Pedagogical Needs
1	Doing practical demonstrations to develop learners' practical and investigation skills
3	Design and plan investigations/experiments in Life Sciences
4	Develop active learning and higher order thinking skills
8	Demonstrate and develop learners' science process skills
9	Update subject matter knowledge in Life Sciences
10	Assess knowledge and understanding of investigations and practical work
11	Integrate content and practical skills when teaching

The identification of these pedagogical needs and their importance lies in the fact that it is ranked in the first one third of the total number of pedagogical needs identified. Furthermore, Motlhabane and Dichaba (2013) found that many teachers lack confidence in implementing practical work in their classrooms.

This therefore supports the significance of this study in order to obtain a deeper understanding of the situation with regard to the teaching and learning of IPW and more specifically its relationship with teachers' knowledge and beliefs about science education.

This study attempts to unravel the underlying reasons for the observations cited and to assist in considering appropriate intervention strategies to improve the practice of IPW. In addition, it is hoped that the findings of this study will lay the basis for further studies in this domain of science education.

The findings of the study would also provide Life Sciences subject specialists, curriculum developers and implementers with understandings into the intricate challenges that confront teachers with respect to the implementation of inquiry–based teaching and learning and more specifically IPW. Moreover, it would help to improve the classroom practice of Life Sciences teachers, which in turn would contribute to an enhancement in the general competency and scientific literacy of learners.

My proposition is that inquiry-based learning, facilitated through IPW can contribute to a society of creative and critical thinking beings who will form a productive workforce and an informed citizenry, capable of taking crucial decisions, such as those that concern the environment, economy and politics. However, this can only be achieved if teachers have the necessary knowledge, skills and determination to facilitate IPW. In addition, teachers' beliefs and cognition are important for the successful implementation of the transformed Life Sciences curriculum (Haney et al., 1996; and Bryan, 2003).

Fullan (2001) pointed out that implementation of a new approach which teachers are not trained for, can be affected by a number of characteristics of the teacher, for example, attitudes, knowledge and skills. Aspects such as the environment, support from professionals, administration and society can also affect the implementation of a new approach. Teachers' knowledge and beliefs are vital to the creation of classrooms in which learners construct thorough knowledge and understanding of how scientists develop and present explanations about phenomena in the natural world (Pomeroy, 1993; Roth, McGinn, & Bowen, 1998). Mansour (2009) and Crawford (2007), argue that the relationship among teachers' knowledge, beliefs and practice are intertwined, since what one believes about teaching inevitably depends to a large extent on one's knowledge of his or her discipline or subject, as well as on one's beliefs about how learning takes place. It is therefore logical to assume that what teachers know and believe have a bearing on their decisions in planning and preparation, before they enact or execute their plans when they enter the classroom.

1.5 BROAD PROBLEMS AND ISSUES TO BE INVESTIGATED

1.5.1 Problem Statement

One of the goals of the *NCS* for the science subjects was to address the issue of inquiry-based teaching and learning related to transformation in science education. While this was a forward thinking scheme, the problem that Life Sciences teachers were confronted with, was the challenge of implementation of the *NCS* in general and IPW in particular, given the fact that practical investigations were also part of the pre-2006 *Report 550* Biology curriculum as illustrated in Table 2.3 in Chapter Two. However, the pre-2006 Biology curriculum was not explicit about open-ended investigations, even though theoretical questions based on open-ended investigations appeared in the Biology examination papers. In addition, there were no imperatives or prescriptions with respect to open-ended investigations for the purposes of assessment as a complete investigative task. Teachers therefore had limited experience of IPW. Moreover, many lacked adequate Life Sciences knowledge for teaching the subject. Research in other countries (e.g. Lederman, 1992; Hogan, 2000; Thomas, Pederson, & Finson, 2000; van Driel, Beijaard, & Verloop, 2001) has shown that the implementation of inquiry-based teaching and learning approaches is influenced by teachers' knowledge of the subject and their beliefs about teaching and learning of investigations. Hence, the problem statement for the study is:

How do Life Sciences teachers' knowledge and their beliefs about science education relate to their implementation of investigative practical work (IPW)?

1.5.2 Aim of the study

The purpose of the study was to understand the relationship between Grade 12 Life Sciences teachers' knowledge and their beliefs about science education and the teaching and learning of investigative practical work (IPW).

1.5.3 Objectives of the study

The intentions of the study are to:

- Determine the nature of teachers' knowledge with respect to inquiry-based teaching and learning, subject matter, curriculum, general pedagogical knowledge, pedagogical content knowledge, and pedagogical context knowledge.
- Ascertain the kinds of beliefs that teachers hold about teaching and learning of investigative practical work (IPW)
- Determine the nature of practical investigations implemented by teachers

- Determine any relationship between Life Sciences teachers' knowledge and beliefs and the implementation of investigative practical work (IPW).

1.5.4 Key research questions

Bassey (1999) used a metaphor to describe a research question as follows: a research question is compared to the engine, which drives a train of inquiry, and should therefore be formulated in such a way that it sets the immediate agenda for the research. Even though, it is expected that the research questions could be modified and replaced as the research goes on, "without them the journey will be slow or chaotic" (p.67).

In order to explore 'The relationship between Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW) in the Life Sciences curriculum, the following critical questions were analysed:

1. What is the nature of Life Sciences teachers' knowledge?
2. What is the nature of Life Sciences teachers' beliefs about the teaching and learning of investigative practical work?
3. How do Life Sciences teachers implement investigative practical work in their classrooms?
4. Why do teachers implement investigative practical work in their classrooms in the way they do?

1.6 MOTIVATION AND RATIONALE FOR THE STUDY

The main motivation to pursue this study emanates from my interest in science education, the knowledge gained during my previous study on 'developing creative and critical thinking skills in secondary school biology', and my wide ranging experience as a teacher of Biology, teacher educator, a senior curriculum advisor, Provincial and National examiner for grade 12 Biology and Life Sciences and as an external moderator for the Biology and Life Sciences final Grade 12 examinations for the quality assurance body UMALUSI. However, my active involvement in the development of the Natural Sciences curriculum in the General Education and Training phase (GET) during the review and revision process of the transformed curriculum of South Africa and the subsequent implementation and adoption of its learning outcomes, particularly LO1 (with an emphasis on investigations) in the Life Sciences in the Further Education and Training phase (FET) provided me with the greatest enthusiasm, encouragement and motivation to embark on this study.

To be scientifically and technically literate requires one to think creatively and critically. As indicated by Earnest and Treagust (2001), science and technology education leads to a scientifically and technically literate labour force. In addition, Rogan and Grayson (2003), argues that, "improving science education is often regarded as a priority for developing countries in order to promote long-term economic development" (p.1171).
During the development of the *Revised National Curriculum Statement (RNCS)* for Natural Sciences (DoE, 2002a), as members of the Working Group we motivated strongly for the inclusion of investigations as an important component of the curriculum. One of the reasons to motivate for the inclusion of investigations in the Natural Sciences curriculum emanates from my previous study (Preethlall, 1996), which showed a link between creative and critical thinking skills and scientific investigative skills. In addition, the imperatives of *The Constitution of the Republic of South Africa* (1996) gave further motivation to this where, the *NCS* asserted to instil in learners, "core life skills such as communication, critical thinking, activity and information management, group and community work, and evaluation skills" (DoE, 2003a, p. 17).

It has been shown that the development of critical thinking skills can be integrated successfully with the study of the processes of science (Chapman, 2001). The processes of science includes the following: formulating a research question, planning experiments, controlling variables, drawing inferences, making and justifying arguments, identifying hidden assumptions, and identifying reliable sources of information. Zohar and Dori (2003) refer to these processes as examples of higher-order thinking in inquiry-oriented science education.

Critical thinking skills can be defined in several ways, but most often include the following: the ability to analyse arguments, make inferences, draw logical conclusions, and evaluate all relevant elements, as well as the possible consequences of each decision (King 1994). Critical reasoning is important in the development of scientific literacy, which emphasises scientific ways of knowing and the process of thinking critically and creatively about the natural world (Maienschein 1998).

The movement toward increased emphasis on creative and critical thinking skills across the curriculum arises from acknowledgement that learners learn best when actively constructing

their understanding, rather than absorbing it. Hence, learners need to be taught how to engage effectively in this knowledge construction process in a critical manner (King 1994). One of the ways in which this could be achieved is by prescribing critical thinking in the curriculum.
As indicated in the previous paragraphs, characteristics of inquiry learning and development of creative and critical thinking skills are similar to the requirements for investigative practical work, as well as to the imperatives of the South African *NCS* as espoused by the critical outcomes. The critical outcomes provided the motivation for the inclusion of investigations in the curriculum statements for both the Natural Sciences and the Life Sciences as LO1. Furthermore, I had motivated for the inclusion of 'hypothesis-testing' type of practical tasks as a prescribed piece, in the Subject Assessment Guideline (SAG) (DoE, 2005b) document for the Life Sciences. This prescription served to play a 'coercive' role in the hope that teachers will adjust their practice in implementing IPW in the manner in which it was intended, to facilitate the development of higher order thinking through engagement in greater learner autonomous open-ended tasks.

Studies on inquiry-based teaching and learning of school Life Sciences in South Africa seem to be neglected. While many international studies on the importance of inquiry-based activities in science education focused on improving learner performance, through the introduction of alternative learning strategies, few studies, investigated the teacher's role, knowledge, skills, understandings, levels of competency, environmental constraints and beliefs with respect to the implementation of a learner-centred approach such as IPW, to teaching science (Gunel, 2008).

1.7 CONTRIBUTION TO BODY OF KNOWLEDGE

The significance of the study lies in its potential to contribute to the literature and to educational practices related to teacher development, with special focus on inquiry–based teaching and learning, particularly IPW aimed at promoting higher cognitive processes in the classroom. This will contribute to the body of knowledge of how and why teachers implement or ignore curriculum reform initiatives, such as including IPW in their teaching of Life Sciences. This will have implications for designers and implementers of policy. More specifically, it will in turn have implications for curriculum development, teacher support and teacher development by curriculum advisors and the Department of Basic Education (DBE), and for teacher education.

The literature studied contains information with respect to the promotion of practical work, particularly inquiry-based teaching and learning strategies to improve learner performance. In most of these studies, there is limited or no indication of the relationship between teachers' levels of understanding and/or competence with respect to their knowledge, the nature and role of IPW, and their beliefs about the teaching and learning of investigations. In other words, although research evidence about students' learning and alternative conceptions in science is extensive, and almost unanimously agreed upon, there is limited knowledge about the way science teachers' knowledge and beliefs affect the way they teach science in general and IPW in particular. Saad and Boujaoude, (2012) argued that, "Studies about teachers' knowledge and beliefs about inquiry and their classroom practices are still few and scattered" (p. 114). Nespor (1987) and Pajaras (1992) state that teachers' beliefs are a neglected field in science education research. In addition, Fischler (1999) acknowledges that there is too little research evidence about science teachers' beliefs and knowledge with regard to their perceived roles, science-teaching objectives, and their influence on students' learning. The scarcity of research on the relationship between teachers' knowledge and their beliefs about scientific inquiry applies to South Africa as much as to other countries.

Given the South African context in which the researcher has experience and knowledge of the qualification or lack thereof of the teaching personnel, the findings of this study will further contribute to an understanding of the impact of teachers' knowledge and their beliefs on their practice. In addition, the results will inform priorities for teacher professional development and pre-service teacher education.

Further to this, the study offers a possible way of studying various relationships such as, between teachers' knowledge, their practices and learner attainment; between their beliefs, their practices and learner attainment; and between their knowledge and beliefs. Moreover, the findings of this study illustrate consistencies and inconsistencies between what teachers perceive, and say and what was actually observed in their practice. This therefore provides opportunities for further research in order to understand these relationships.

1.8 THE CONTEXT OF THE STUDY

South Africa was demarcated into nine provinces after attaining democracy in 1994. This study began in the year 2011, seventeen years after a democratic government was elected in South Africa. It was conducted in the Umlazi District, which is positioned in the southern part

of the province of KwaZulu-Natal (KZN). The KwaZulu-Natal Department of Education is the largest in terms of number of learners, educators and schools. The table below illustrates the statistics for the years 2010 to 2012.

Table 1.2: Statistics with respect to learners, educators and schools in the ordinary school sector (Public and Independent)

	Learners			Educators			Schools		
	2010	**2011**	**2012**	**2010**	**2011**	**2012**	**2010**	**2011**	**2012**
Number in KZN	2806988	2847378	2877969	91926	93266	94932	6147	6180	6176
Total Number in S. Africa	12260099	12287994	12428069	418109	420608	425167	25850	25851	25826
Percentage in KZN	23	23	23	22	22	22	24	24	24

Source: Extract of table from School Realities 2012 – Department of Basic Education (September 2012)

The original source also indicates that the highest percentage of learners, educators and schools occurred in KwaZulu-Natal. In 2012, KZN had 5955 public schools with more than 2.8 million learners, being taught by more than 90 000 teachers. For effective management and administration, the KZN Department of Education was divided into three clusters. Each cluster is made up of four districts. The Coastal cluster consists of four districts, namely, Umlazi, Pinetown, Illembe and Ugu (KZN Department of Education Summit, 2011). Districts are further divided into Circuits. A circuit consists of approximately 200 schools. These schools are further grouped into Wards, each consisting of about 35 Primary and Secondary schools.

The Umlazi District has the largest concentration of schools and learners in the Province of KwaZulu-Natal. Currently, the district has a total of 174 secondary schools of which 172 offer Life Sciences as a subject in the FET phase (Personal communication with EMIS unit Umlazi District, 2012)

The four circuits that constitute the Umlazi District are, Durban Central, Chatsworth, Phumelela and Umbumbulu. Furthermore, it must be noted that the researcher is employed as a Senior Curriculum Advisor in the Umlazi District, where the study was conducted.

The figure below illustrates the division or clustering of schools into circuits in the Umlazi District.

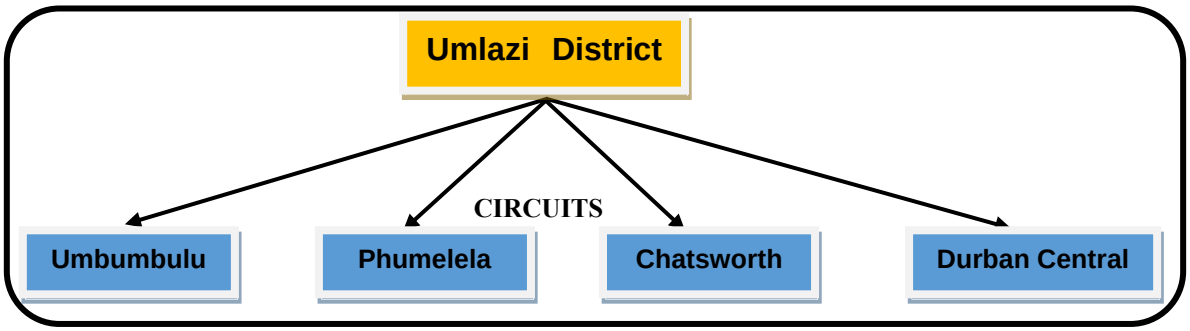

Figure 1.1: Clustering of schools in district into circuits

1.9 THE RESEARCH DESIGN AND METHODOLOGY

A brief outline for the choice of the research design and methodology is provided here. A more detailed account is presented in Chapter Five.

In order to ensure that the aims and objectives of the study would be achieved it was important to decide on and develop an appropriate research design and methodology to suit the study. I was mindful of this when the study was conducted. Hence, initial strategies involved the consultation of relevant literature such as, journals and books in order to critique the status of the subject to be studied (McMillan & Schumacher, 2001). In this case the strategy involved the collection of data with respect to teacher knowledge, teacher beliefs, and inquiry-based teaching practices.

The focus of the study was to ascertain the relationship between Life Sciences teachers' knowledge and their beliefs about science education and the teaching and learning of IPW. Hence, in addition to the literature review, qualitative interpretive approaches were also used as research designs. In this regard, a multiple case study approach (Creswell, 2002; Abrahams & Millar, 2008) was utilised. A qualitative approach was used to get an in-depth understanding of the key research questions. In this respect, a qualitative study thus provided the data needed to answer the key research questions about the selected participants, the Grade 12 Life Sciences teachers and their practice with regard to IPW.

This study used multiple data collection techniques in order to enhance the credibility or trustworthiness of the findings (Meriam, 2009). In this respect, a questionnaire, interviews, observation of lessons, and study of documents which included tasks completed by the teachers and the study of teacher and learner artefacts were used as sources of data.

Data was analysed in terms of pre-determined categories and themes for each case. The results of each case study was then pooled for the purposes of a cross case analysis.

1.10 LIMITATIONS OF THE STUDY

The following limitations were identified:

- The researcher is a Senior Curriculum Advisor in the Umlazi District. To reduce the negative impact of intimidation or 'power-play', there was a need for the researcher to engage in several trial visits to the selected classes with a view to developing a non-threatening environment. In addition, the participant teachers were informed that the purpose of the researchers' observations was not to evaluate their work, but to get insight into the implementation of practical investigations. Furthermore, while this may be a contrived situation, this was balanced by the analysis of data gathered from a variety of sources, which enhanced the credibility or trustworthiness of the findings through triangulation. However, because the researcher enjoys a cordial relationship with the teachers and this relationship spans more than sixteen years, the intimidation factor was not significant.
- The findings of this study cannot be generalised because the participant teachers may not be representative of the population of Life Sciences teachers

1.11 STRUCTURE OF THE THESIS

The study focused on the relationship between Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work. The design, development and findings of this study are presented in seven chapters.

Chapter One: Overview of the study

This Chapter provides a synopsis of the study. It introduces the requirements of the transformed South African curriculum. In addition, this Chapter provides an elaboration of practical work as a component of science education and affords a brief motivation for the location of IPW within the context of practical work. The focus of the study, broad problems to be investigated, purposes and intentions of the study as well as the key research questions are then elaborated upon. This is then followed by the motivation and rationale for the study. Furthermore, it highlights the context of the study and how the findings will contribute to the body of knowledge. It then presents a brief account of the research design and methodology, and limitations of the study. The Chapter then outlines the structure of the thesis.

Chapter Two: Education Transformation in a Democratic South Africa

This chapter provides an outline of the changing education scenario in South Africa, with a focus on Life Sciences education.

Chapter Three: Review of Related Literature

This chapter explores the literature that is pertinent to this study. Issues that are discussed include inquiry as an imperative in science education reform; locating investigative practical work (IPW) within practical work in school science; inquiry as a pedagogical approach to science education; the nature of inquiry activities; teachers' practices and learners' performance in inquiry activities; the value of inquiry-based teaching and learning; teachers' knowledge and beliefs and the relationship between knowledge and beliefs.

Chapter Four: Theoretical and Conceptual frameworks

This chapter discusses the learning theory of constructivism as the overarching theoretical framework with teacher change and conceptual change as supporting theoretical concepts.

Chapter Five: Research design and methodology

This chapter provides elaboration and motivation for the choice of the research paradigm, and the research design and methodology that underpins this study. It also contains discussion about multiple case studies, description in respect of the sampling of the participants, the location of the research, data collection and data analysis including data processing strategies and triangulation. Concerns regarding validity, trustworthiness, reliability and ethical considerations are also discussed in this chapter.

Chapter Six: Research Findings

The findings of the study are presented in this chapter. The study was guided by the four critical questions. Data obtained from the various instruments are processed, analysed and interpreted. The findings are also discussed.

Chapter Seven: Summary of findings, recommendations and conclusion

This chapter highlights the findings of the study and provides recommendations thereof. The final section presents a brief concluding comment.

1.12 CONCLUSION

Chapter One presented a synopsis of the study by guiding the reader through the presentations in each of the subsequent chapters. Chapter Two provides a brief account of the transformation of education in South Africa.

CHAPTER TWO

EDUCATION TRANSFORMATION IN A DEMOCRATIC SOUTH AFRICA

2.1 INTRODUCTION

This chapter provides a brief account of the changing education scenario within a developing democracy in South Africa. It focuses on educational transformation in general but on curriculum changes in particular. The chapter provides a brief elaboration on the state of education under apartheid; education in a democratic South Africa; key events of the curriculum transformation process such as, curriculum transformation in the GET Band, and review, revision, streamlining and strengthening of C2005. The section that follows is based on the transformation of the FET curriculum, the implementation of the *NCS*: FET and its subsequent revision into the *National Curriculum Statement* (*NCS*) *(CAPS)* Grades R-12 (DBE, 2011b).

This chapter also highlights the links and the thread that runs through the underlying principles and motives of each of the above mentioned initiatives with reference to inquiry-based teaching and learning.

2.2 CHANGES IN THE EDUCATION SYSTEM IN SOUTH AFRICA: FROM APARTHEID TO DEMOCRACY

A brief background of the state and evolution or transformation of education before 1994 follows.

2.2.1 The state of education under apartheid

The separatist system of education operating during the apartheid era was based on racial principles. The system was therefore fragmented and provided poor quality, unequal, and inferior education to its citizens. To enhance the separatist policies the government of the day established separate departments of education for each of the four recognised population groups namely, Blacks, Coloureds, Indians and Whites. The separatist system promoted the acquisition of rudimentary skills among the African learners to fulfil the needs of the labour market. Funding for education for each of the population group was also based on an inequitable model (Christie, 2002). The White learner was allocated the greatest amount while the African learner received the least with the Indian and Coloured child receiving proportionately more than an African child. This discrepancy in the funding model had an

impact on the different aspects of the education system of each of the different racial groups. For example, it influenced teacher education, school infrastructure, teacher-pupil ratios and teachers' salaries. This in turn affected classroom practice, which ultimately impacted negatively on learner performance, especially at the Grade 12 level (Asmal & James, 2002).

In the mid 1970s and 1980s the dissatisfaction with the poor quality of education that Black South Africans received led to heightened protest actions. The most prominent of these was the Soweto uprisings of 1976. These protest actions continued and increased in the 1980s. Simultaneously, various initiatives and committees developed in order to address and lead the struggles in education in communities around the country (Kraak, 1999). One such initiative was the National Education Policy Initiative (NEPI) which conducted its work under the auspices of 'People's Education' (NEPI, 1993).

'Peoples Education' advocated the following:

- The democratisation of education through the participation of a cross-section of the community in decision-making on the content, quality, and governance of education.
- The negation of apartheid in education by making education relevant to the democratic struggles of the people.
- The achievement of a high level of education for everyone.
- The development of a critical consciousness.
- The bridging of the gap between theoretical knowledge and practical life.
- The closing of the chasm between natural science and the humanities, and between mental and manual labour, with an emphasis on worker education.

Some of these ideas became firmly entrenched in South Africa's post-democratic education.

Other examples of initiatives, commissions and organisations included the following:

- The National Party government advocated the rationalisation of the number and variety of school syllabuses, the development of core learning areas, and an emphasis on vocational education (Jansen, 1999).
- The National Training Board (NTB), which produced an education policy document referred to as the *National Training Strategy Initiative (NTSI*) which proposed the formation of an integrated system of education focusing on the form that South Africa's curriculum and assessment policy should take. The *NTSI* stated that the South African system of education needed a paradigm shift "from thinking about education and

training as separate entities to thinking about learning as a lifelong process" (NTB, 1994).

One of the strategies proposed by the NTSI was a National Qualifications Framework (NQF), allowing for an array of qualifications drawn from a range of education and training pathways. The NQF became the crucial point of the proposed education and training policy. Young (1996) argued that it would have far-reaching consequences in the following respects:

* The traditional boundary after matriculation between academic and vocational will be thwarted. By doing this it was hoped that the social divide between the so called 'elite' academic institutions and the perceived 'inferior' vocational institutions would not exist. Hence, technikons are now referred to as Universities of technology.
* The result of such changes would allow more learners to study at tertiary institutions, which was previously not possible. Hence, educational resources could now be available and accessed by previously disadvantaged learners.

2.2.2 Education in a democratic South Africa

The new government of South Africa experienced several challenges in education after the first democratic elections in 1994 as a result of the legacy of apartheid education. Some of these challenges included:

- The existence of nineteen racially and ethnically fragmented departments of education operating in South Africa.
- Several certification bodies in the formal education sector and the lack of an umbrella quality assurance council.
- An inadequate teacher education system, especially in so-called 'Black' colleges of education.
- Unqualified and under-qualified teachers.

Despite these challenges, the State had to design appropriate policies and put in place systems that could deal with high levels of illiteracy, dysfunctional schools and universities and develop a credible curriculum that could promote 'unity and common citizenship and destiny for all South Africans irrespective of race, class, gender or ethnic background' (ANC, 1994, p. 68).

Two significant pieces of legislations played a crucial role in ensuring that this could be achieved. Firstly, the *Constitution of the Republic of South Africa* (1996) ensures that the rights of all citizens are protected and promoted. As far as education is concerned, the *Constitution* ensures that everyone has the right to:

- A basic education, including adult basic education; and
- Further education, which the State, through reasonable measures, must make progressively available and accessible.

Secondly, the promulgation of the National Education Policy Act (NEPA) *(No. 27 of 1996)* was important because it allowed for the formulation of a national curriculum in both the general and further education and training policies, for example in areas such as curriculum, assessment and quality assurance. The objectives of NEPA make provision for example:

- Developing skills, disciplines and abilities necessary for reconstruction and development.
- Recognising the aptitudes, abilities, interests, prior knowledge and experience of students.
- Encouraging independent and critical thought.
- Promoting inquiry, research and the advancement of knowledge.

It is important to note that all the above mentioned provisions are also reflective of reforms in science education and are therefore of particular significance to this study.

2.3 KEY EVENTS OF THE CURRICULUM TRANSFORMATION PROCESS

The information in the Table 2.1 serves as a window into the curriculum developmental processes and implementation that took place and continues to occur in a post-apartheid South Africa.

Table 2.1: Summary of key events with respect to curriculum changes in a democratic South Africa

Year	Key events	Grade 10	Grade 11	Grade 12
Prior to 1994	19 separate departments of education	Separate syllabus for each province and each department		
1994-1997	Development of C2005 Development of Interim Core syllabus and Provincials guides	**Interim core syllabus and provincialised guides for Biology implemented**		
1996	Common Provincialised Grade 12 exit examinations	**Interim core syllabus and provincialised guides for Biology implemented**		
1999	Review and modernization of Grades 10-12 curricula begins.	**Interim core syllabus and provincialised guides for Biology implemented**		
2001	Implementation of first National examination for Grade 12 Biology	**Interim core syllabus and provincialised guides for Biology implemented**		
2006		**NCS 1: Life Sciences**	**Interim core syllabus….**	**Interim core syllabus….**
2007	Revised content for *NCS* = *NCS 2*	**NCS 1: Life Sciences**	**NCS 1 NCS 1: Life Sciences**	**Interim core syllabus….**
2008		**NCS 1: Life Sciences**	**NCS 1: Life Sciences**	**NCS 1: Life Sciences**
2009		**NCS 2: Life Sciences**	**NCS 1: Life Sciences**	**NCS 1: Life Sciences**
2010	Review of NCS to develop *CAPS*	**NCS 2: Life Sciences**	**NCS 2: Life Sciences**	**NCS 1: Life Sciences**
2011		**NCS 2: Life Sciences**	**NCS 2: Life Sciences**	**NCS 2: Life Science**
2012		**CAPS**	**NCS 2**	**NCS 2**
2013		**CAPS**	**CAPS**	**NCS 2**
2014		**CAPS**	**CAPS**	**CAPS**

One important aspect illustrated in the above table is the rapid changes to the Life Sciences curriculum. While the change from *NCS* 1 to *NCS* 2 involved mainly the Life Sciences content, it nonetheless created uncertainty and frustration amongst teachers. This was exasperated further when the *NCS* 2 changed to *CAPS*. Notwithstanding the above changes the requirements for the practical work did not drastically change. That is, for *NCS* 1 and *NCS* 2 LO1 was retained. In *CAPS* however, LO1 was replaced with Specific Aim 2 (SA2). A comparison of LO1 and SA2 in Table 2.3 will reveal that the requirements are virtually the same.

2.3.1 Curriculum Transformation in the General Education and Training (GET) Band

The transformed curriculum in the South African context was referred to as Curriculum 2005 (C2005). The principles of C2005 are different from the principles that drove apartheid education (Fataar, 2001). C2005 was introduced for the GET band, which covered Grade R to Grade 9 in January 1998 (Taylor & Vinjevold, 1999).The goals of C2005 was to achieve the Critical Outcomes (COs) and the Developmental Outcomes (DOs) which were derived from the Constitution, through an outcomes-based philosophy which underpinned the curriculum. C2005 is not the same as outcomes based education (OBE).

(a) Critical Outcomes (COs) and Developmental Outcomes (DOs)

The preamble of C2005 focused on the critical and developmental outcomes, which were derived from the principles of the *Constitution of the Republic of South Africa* (1996). These critical and developmental outcomes could be regarded as the goals of education in South Africa.

The *critical outcomes* anticipate that learners will be able to:

- Identify and solve problems and make decisions using critical and creative thinking.
- Work effectively with others as members of a team, group, organisation and community.
- Organise and manage themselves and their activities responsibly and effectively.
- Collect, analyse, organise and critically evaluate information.
- Communicate effectively using visual, symbolic and/or language skills in various modes.
- Use science and technology effectively and critically to show responsibility towards the environment and the health of others.
- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.

(DoE, 2003a).

The above-mentioned critical outcomes that underpinned C2005 required that learners are able to develop and use higher order thinking by being able to criticise, evaluate, analyse, synthesise, construct and apply their knowledge rather than recall and regurgitate information like the pre-democracy curricula were perceived to do.

The *developmental outcomes* expect learners who are able to:

- Reflect on and explore a variety of strategies to learn more effectively.
- Participate as responsible citizens in the life of local, national, and global communities.
- Be culturally and aesthetically sensitive across a range of social contexts.
- Explore education and career opportunities.
- Develop entrepreneurial opportunities.

(DoE, 2003a).

The Department of Education envisaged that the above-mentioned developmental outcomes would help learners to develop personally and also lead to the social and economic development of the country at large (DoE, 1997b). The above-mentioned critical and developmental outcomes provided the impetus for the development of specific outcomes for each phase and learning area in C2005.

(b) Relationship between C2005 and OBE

Several policy documents on the new curriculum refer interchangeably to C2005 and OBE (Chisholm, Volmink, Ndhlovu, Potenza, Mohammed, Muller, Lubisi, Vinjevold, Ngozi, Malan, & Mphahlele, 2000, p.5). This has caused a great deal of confusion among the various stakeholders in education.

C2005 is a common name given to the *National Curriculum Statement (NCS).* The *NCS* is similar to the 'National Curriculum' of the United Kingdom for example. The *NCS* was implemented gradually grade-by-grade from 1997. It has been commonly referred to as C2005 because the South African government envisaged this new curriculum to be implemented in all grades by the year 2005.

The *NCS* grounds itself on an outcomes-based educational philosophy. In addition, the *NCS* is underpinned by principles such as redress, access and equity. In order to achieve these, 'different' methodologies which promote active learners, learner-centeredness, skills-based, teachers as facilitators, relevance, contextualised knowledge and co-operative learning has to be employed. C2005 also emphasised 'learning by doing', problem-solving, skills development, and continuous assessment (Christie, 2002, p. 174). These 'methodologies' also underpin inquiry-based teaching and learning in science.

Hence, C2005 outlines the content that has to be dealt with in each subject/learning area in each grade, while OBE is an education approach, in other words the methodology

that is used to teach. In fact it is one of the many methods that may be used during teaching and learning (DoE, 2002).

Within the context of the current study investigative practical work (IPW) is seen as an example of an OBE approach to teaching and learning in order to meet the requirements for the Life Sciences in the *NCS.*

(c) Introduction to changes in classroom practices

As indicated in the preceding section, C2005 places a great deal of emphasis on the learners, by virtue of its principles of learner-centeredness, activity-based and teacher as facilitator. This therefore advocates a significant shift from the traditional transmission mode of teaching and learning. Table 2.2 compares the old transmission model of teaching and learning to the new outcomes-based model, which was proposed by the Ministry of Education (DoE, 1997a).

Table 2.2: Comparison between the old and new models of teaching and learning.

ASPECTS	OLD TRANSMISSION MODEL OF TEACHING AND LEARNING	NEW C2005 OUTCOMES-BASED MODEL OF TEACHING AND LEARNING
THE LEARNER	* Passive learners	* Active learners
ASSESSMENT	* Graded * Exam-driven * Exclusionary	* Continuous assessment
ROLE OF THE TEACHER	* Teacher-centred * Textbook bound	* Learner-centred; * teacher as facilitator; * teacher constantly using group work and team work
CURRICULUM FRAMEWORK	* Syllabus seen as rigid and non-negotiable * Emphasis on what teacher hopes to achieve	* Learning programmes seen as guides that allow teachers to be innovative and creative in designing programmes * Emphasis on outcomes-what the learner becomes and understands
TIME FRAMES AND LEARNER PACING	* Content placed into rigid time frames	* Flexible time frames allow learners to work at their own pace

Source: Department of Education (1997a).

In theory the proposed C2005 outcomes-based model of teaching and learning seemed plausible to implement as opposed to the old transmission model of teaching and learning. However, the implementation of C2005 in the classroom posed a great deal of challenges for educators, which was supposed to be addressed through the review, revision, streamlining and strengthening process.

2.4 REVIEW, REVISION, STREAMLINING AND STRENGTHENING OF C2005

A number of challenges were experienced during the implementation of C2005. The intention of C2005 did not match what was being implemented in most schools. Various reasons were forwarded for this state of affairs. For example, primary schools were under-resourced, and teachers were inadequately trained. Teachers as well as other role-players in education were often critical of C2005 for various reasons. In lieu of such shortcomings, a committee was appointed by the Education Ministry to review C2005 early in the year 2000.

It must be noted that C2005 was only implemented in 2006 for the first time in grade 10 (the FET phase). The FET phase of the schooling system continued to use the *Report 550* syllabus up until 2005 for grade 10, 2006 for grade 11 and 2007 for grade 12 (Refer to table 2.1).

The Review Committee had to focus on the structure and design of the curriculum, teacher development, learner support materials, provincial support to teachers in schools and implementation time-frames (DoE, 2002a). In the main the Review Committee found that there was still a great deal of support for the over-arching principles of C2005 and the OBE approach to it, but what was needed was a,

> *"Revised and streamlined outcomes-based curriculum framework which promoted integration and conceptual coherence within a human rights approach which paid special attention to anti-discriminatory, anti-racist, anti-sexist and special needs issues"* (Chisholm et al., 2000, p.2).

2.4.1 Development of the Revised National Curriculum Statement *(RNCS)*

A Ministerial Project Committee (MPC) was appointed in October 2000 by the Minister of Education, Professor Asmal to revise the curriculum for the GET phase. According to Chisholm (2003), in developing the curriculum due cognisance was given to issues about implementation, human rights and inclusivity as well the inclusion of indigenous knowledge systems and the environment across learning areas in the curriculum. In addition, the

importance of subject content knowledge and skills development was emphasised by describing the curriculum as promoting 'high knowledge' and 'high skills'.

2.4.2 Natural Sciences in the Revised National Curriculum Statement *(RNCS)*

Natural Sciences is a learning area in the GET phase. Information about it is included here because its development in the *RNCS* has bearing and implication for the Life Sciences in the FET phase.

In order to develop curriculum statements for the various subjects or learning areas the expertise and knowledge of subject specialists were required. In this regard, 'Working Groups' were created and filled by individuals who were selected on the basis of their response to the advertisement (by the MPC) or had been nominated by the relevant Provincial Education Departments. The Natural Sciences Working Group consisted of six members. The researcher was one of these members.

In brief, the *RNCS* was now being developed on the basis of fewer design features compared to C2005. In fact the *RNCS* was now made up of only three design features compared to the original eleven features. These were: the *critical and developmental outcomes*, *learning outcomes* and *assessment standards*.

An *outcome* is what is required of learners to achieve by the end of a learning process. Learners should be able to show what they know and can do with their learning. Outcomes include understanding, knowledge, skills, values and attitudes. The *NCS* builds its *Learning Outcome*s (LOs) on the Critical and Developmental outcomes.

A *learning outcome* (LO) is a statement of intended result of teaching and learning. It describes the knowledge, skills and values that learners need to acquire by the end of a course of study such as in the GET band. In the South African context, the LOs are designed to lead to the achievement of the Critical and Developmental Outcomes. These LOs are defined in broad terms and are flexible, making allowances for the inclusion of local inputs. In the Natural Sciences, three LOs were formulated taking into account the aims, objectives and skills involved in the teaching and learning of Science. The members of the Working Group also motivated for 'the doing' or investigations in science to receive priority. Hence, LO1 deals with scientific inquiry and problem – solving skills. LO2 deals with the construction and

application of Natural Science knowledge and LO3 focuses on science, technology and the environment including indigenous knowledge systems.

Assessment Standards (ASs) are criteria that collectively describe what a learner should know and be able to demonstrate at a specific grade. They embody the knowledge, skills and values required to achieve the LOs within each grade. The Subject Statements set out the ASs in detail and form the basis for designing learning programmes for the year. They are very concrete, and they refer to the ways in which learners show that they can do what is required by the learning programme.
The subject content in the Natural Sciences for the GET *RNCS* consisted of a combination of the old subjects such as, Biology, Physical Science and Geography. Based on this combination, the content for the Natural Sciences was grouped as four knowledge areas, namely, *Life and Living; Energy and Change; Planet Earth and Beyond and Matter and Materials.*

At the end of June 2001, the Draft Revised National Curriculum Statement was released for public comment. Several comments were received from the general public as well as from teachers, teacher unions, academics, and officials of provincial education departments. All the relevant comments were taken into account by the writers of the curriculum which eventually enhanced the '*Draft Revised National Curriculum Statement* for the GET phase. The *RNCS* ultimately became policy in April 2002 (DoE, 2002a).

2.5 CURRICULUM TRANSFORMATION IN THE FET BAND

2.5.1 Birth of the Interim Core Syllabus and Provincialised Guideline

Curriculum change in post-apartheid South Africa began immediately after the election in 1994 through a process of syllabus revision and subject rationalisation. The purpose of this process was mainly to lay the foundations for a single national core syllabus (DoE, 2002a). In addition, this process was responsible for eradicating the school syllabuses and textbooks of sexist and racist content so that it could be ready for implementation in the following school year (Tikly & Motala, 2003). For the first time curriculum decisions were made in a participatory and representative manner. However, "this process was not nor was it intended to be, a curriculum development process" (DoE, 2002a, p.4). According to Jansen (1999) the process involved a cursory review and cleansing of the apartheid syllabuses with the explicit task of:

- Removing any sexist and racist content,
- Eliminating inaccuracies in subject content, and
- Establishing a common National core curriculum (Jansen, 1999).

After the 'cleansing' of the old apartheid syllabuses was complete the 'new' curriculum (syllabuses) was referred to as the 'Interim Core Syllabus', which was to be used in the Grade 10, 11 and 12 classrooms from 1995.

This 'Interim Core Syllabus' then underwent a process of provincialising and became known as the 'Interim Core Syllabus and Provincialised Guideline'. The provincialising of the 'Interim Core Syllabus' was to ensure that no Grade 12 Biology learner within a province would be disadvantaged when s/he wrote the common provincialised examinations, which began in 1996. All schools within each of the nine provinces of South Africa wrote common examinations. The examinations were set, moderated and marked independently by each province.

The exit examination at the end of Grade 12 allowed learners to attain a qualification known as the Senior Certificate. Learners were required to register for a minimum of six subjects with two compulsory languages as subjects. These six subjects could be offered either on the 'higher grade' (HG) or on the 'standard grade' (SG). Subjects like Biology on the HG offering differed from the SG offering in that the content in some topics required a greater depth of attention. In addition, the SG examination consisted of a lower percentage of higher order (application, analysis, synthesis and evaluation) questions in the examinations. The minimum pass requirement on the HG was 40% while SG pass was $33^{1}/_{3}$ %.

Of importance to this current study is the preamble or 'general remarks' to the Biology 'Interim Core Syllabus' for both HG and SG. It consisted of two sections:

(1) **Aims and objectives of the syllabus** which is to provide a course, which develops in pupils important attributes such as, "An understanding of fundamental biological principles based upon a study of living organisms"

(2) **Approach to the syllabus** which indicates that the approach to the course should as far as possible, embody the important principles such as "Pupils should make their own observations of specimens and experiments" (DoE, 2002b).

A study of the different curricula reveals commonalities in the requirements for teaching and learning of the post-2006 Life Sciences curriculum in the *NCS* and *CAPS* and its predecessor pre-2006 *Report 550* Biology syllabus with respect to IPW. This is illustrated in Table 2.3 by highlighting the relationship among LOs, SAs and the aims, objectives and approach to teaching of Biology.

Table 2.3: Relationship between the Learning Outcomes and Specific Aims in the Life Sciences post-2006 and the Aims, Objectives and Approach to teaching of Biology pre-2006

LO (*NCS1, NCS2* and Examination Guidelines)	**Aims, Objectives and Approach (*Report 550* Biology syllabus)**	**Specific Aims (*CAPS*)**
LO1: Scientific inquiry and problem-solving skills The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem solving, critical thinking and other skills (DoE, 2003b)	1.3 An ability to make critical, accurate observations of biological material, and to make meaningful records of such observation. 1.4 An ability to analyse and evaluate biological information, to formulate hypotheses and to suggest procedures to test them. 1.5 An ability to communicate clearly when reporting information and expressing ideas. 2.1 Pupils should make their own observations of specimens and experiments. 2.2 Pupils should learn to handle and set up apparatus correctly. 2.3 Organisms should be observed in their natural environment. (DoE, 2002)	**SA 2:** Investigating phenomena in Life Sciences Learners must be able to plan and carry out investigations as well as solve problems that require some practical ability. Learners must be able to: ➢ Follow instructions ➢ Handle equipment and apparatus ➢ Make observations ➢ Record information or data ➢ Measure ➢ Interpret ➢ Design/Plan investigations or experiments (DBE, 2011b, p. 15-16)

LO2: Construction and application of Life Sciences knowledge The learner is able to access, interpret and use concepts to explain natural phenomena relevant to Life Sciences. (DoE, 2003b)	1.1 An understanding of fundamental biological principles based upon a study of living organisms 1.2 An awareness of biological relationships 2.4 Constant emphasis should be placed upon facts being understood, interpreted and applied rather than being merely memorized. (DoE, 2002b)	**SA 1**: Knowing Life Sciences Involves knowing, understanding and making meaning of sciences, thereby enabling learners to make many connections between the ideas and concepts. Making such connections makes it possible for learners to apply their knowledge in new and unfamiliar contexts. Learners must be able to: ➢ Acquire knowledge. ➢ Understand and make connections between ideas and concepts to make meaning of Life Sciences. ➢ Apply knowledge on Life Sciences in new and unfamiliar contexts. ➢ Analyse, evaluate and synthesise scientific knowledge, concepts and ideas. (DBE, 2011b, p. 13-14)
LO3: Life Sciences, Technology, Environment and Society The learner is able to demonstrate an understanding of the nature of science, ethics and biases in Life Sciences and the inter-relationship of Science, Technology, Indigenous knowledge, the environment and society. (DoE, 2003b)	1.6 A respect for all living things created by God and an urgent awareness of man's responsibilities in the preservation of life, particularly in the South African context. 1.7 A love and appreciation for South African flora and fauna and recognition of the urgent need for nature conservation. (DoE, 2002)	SA 3: Appreciating and understanding the history, importance and application of Life Sciences in Society To enable learners to understand that school science can be relevant to their lives outside of the school and that it enriches their lives. Learners must be able to understand: ➢ The history and relevance of some scientific discoveries. ➢ The relationship between indigenous knowledge and Life Sciences. ➢ The application of Life Sciences knowledge in industry in respect of career opportunities and in everyday life. (DBE, 2011b, p. 17)

A comparison of the information in Table 2.3 indicates that six out of the ten (60 %) of the pre-2006 aims, objectives and approaches of the Biology curriculum found a home in LO1 of the post-2006 *NCS* Life Sciences curriculum and SA2 of *CAPS* Life Sciences curriculum. LO1 and SA2 are about investigations and problem solving and its correspondence with six of

the aims and objectives identified in Table 2.3 indicates that practical investigations or inquiry-based teaching and learning is not entirely new in the post-2006 South African context. Aim 1.4 of the pre-2006 particularly aligns the teaching approach with inquiry-based learning.

Approach 2.4 of the pre-2006 Biology syllabus aligns with LO2 of the post-2006 Life Sciences. LO2 refers to the construction and application of Life Sciences knowledge, implying that memorisation and regurgitation of information is not promoted. Approach 2.4, while not being explicit about the construction of knowledge, is nevertheless quite explicit about the emphasis being placed on facts being understood, interpreted and applied rather than it being merely memorised. This is further evidence that the pre-2006 curriculum, especially Biology, did not advocate the memorisation and regurgitation of information, as perceived by the critics of the old system. However, the practice or the enactment of this Biology curriculum may have been different.

The aim/objective 1.6 was grouped with LO3 because it deals with 'societal' issues. This particular aim/objective is related to 'anti-evolution' because the pre-2006 curriculum was developed during the apartheid era as part of Christian National Education which did not promote open discussion in areas that are controversial. However, by placing it in LO3 in the post-2006 curriculum, there is the opportunity for debate and discussion about such issues.

For teachers who taught Biology before 2006, the expectations of the LOs are not entirely new. Also, as indicated in Table 5.3, which illustrates the biographical details of the teacher participants, the youngest participant has teaching experience of eleven years and has taught Biology for at least one year. These teachers would have studied Biology at school level and would therefore have been exposed to the aims, objectives and the approach to Biology education, either explicitly or through the teaching and learning process, provided that the aims and objectives of the pre-2006 syllabus were implemented by all teachers. Hence, one could argue that in theory the introduction of learning outcomes should not have required a radical change in pedagogy.

In the year 2000 a common National examination was introduced in the five 'gateway' subjects, namely, Biology, Physical Science, Mathematics, Accounting and English Second Language, in response to setting and maintaining national standards in a democratic South

Africa. In order to facilitate such a change and in preparation for the National Biology Examination in Grade 12, the 'Interim Core Syllabus' was Nationalised to clarify the depth and breadth of the content for each topic. This document also listed six categories of skills to be assessed in Biology. These categories of skills included, measurement, observation, handling apparatus and materials, recording data and data transformation, interpretation of data and experimental design (DoE, 2002b).

According to Kuhn and Dean (2004) inquiry skills have been broadly incorporated as a significant aim of science education. Hence, these skills now appear in a number of national curricula, for example, the United States NSES (NRC, 1996, 2000) as well as in the science curricula of other countries (Abd-El-Khalick, BouJaoude, Duschl, Lederman, Mamiok-Naaman, & Hofstein, 2004), as well as in South Africa (DoE, 2002a, 2003b; and DBE, 2011b). Despite this widespread inclusion of the development and practice of inquiry skills into the science curriculum, there is little consensus about the exact nature of these skills (Abd-El-Khalick et al., 2004; Duschl & Grandy, 2005; Kuhn, 2005).

However, for the purposes of this study the policies and supporting documents of the different South African curricula resulted in the identification of several core skills that are associated with inquiry. These source documents included the following: in the case of Biology, a section in the examination guideline document titled "Categories of skills to be assessed in Biology" (DoE, 2002b); in the case of the *NCS* it was the elaboration of LO1 in the policy and guideline documents (DoE, 2003b; KZN DoE, 2005a), from the Content Framework document (DoE, 2007) and from circular E16 of 2010 (DBE, 2010) which contained the examination guideline; for *CAPS* the information was sought from the policy document (DBE, 2011b, p.15-16). In addition, the research literature reviewed in Chapter Three also assisted in identifying, synthesising and grouping these skills (NRC, 1996; 2000; Marques et al., 2000). Table 2.4 is an attempt to compare these skills as it pertains to the requirements for inquiry-based teaching and learning amongst the different South African curricula.

Table 2.4: Comparison of the requirements of inquiry skills among the pre-2006 Biology Interim Core Syllabus and Life Sciences in *NCS* and in *CAPS*

CORE SKILLS INVOLVING INQUIRY	DIFFERENT SOUTH AFRICAN CURRICULA		
	Interim Core syllabus for Biology	***NCS* for Life Sciences**	***CAPS* for Life Sciences**
	Aims and objectives, approach and categories of skills	**Assessment Standards of LO1**	**Sub-aims of SA2**
1. Measuring	*Reading scales, measuring out quantities, systemic counting	*systematically and accurately collect data using selected instruments and/or techniques and following instructions *Display and summarise the data collected *Identify irregular observations and measurements *Allow for irregular observations and measurements when displaying data	*What to measure and how to measure
2. Observation and recording of observation	*An ability to make critical, accurate observations of biological material		*Make observations
3. Following instructions		*Plans an investigation using instructions *Conducts investigations in Gr 10 & 11 by following instructions	*Follow instructions
4. Planning / Designing investigations or experiments			
4.1 Generating questions and identifying problems	*Identifying problems	*The learner identifies and questions phenomena	*Identifying a problem
4.2 Formulating hypothesis	*To formulate hypotheses	*Generates hypotheses	*Hypothesising
4.3 Making predictions	*Generating logical predictions	Make predictions regarding phenomena in order to solve bigger problems	
4.4 Identifying relevant variables	*Suggest procedures to test them *Identifying variables *Recognise that only one independent factor in an experiment is variable *Suggest appropriate control/s	* Designs tests or surveys to investigate observed phenomenon (Gr 12)	*Design / plan investigations or experiments *Identifying variables *suggesting ways of controlling variables *Understanding the need for replication or verification
4.5 Conducting investigations and handling apparatus and materials	*Pupils should learn to handle and set up apparatus correctly *Specifying the apparatus *Planning the sequence *Precautions to be taken	*The learner conducts investigations	*Handle equipment and apparatus *Selecting apparatus and equipment and/or materials
4.6 Collecting and recording data / observations	*Make meaningful records of such observation *Recording and	*by collecting and manipulating data	*Record information or data *Suggesting ways of

	transformation of data		recording results of experiments
4.7 Analysing, interpreting and evaluating data	*An ability to analyse and evaluate biological information *Analysing information from tables/graphs/ charts/ diagrams *Make accurate calculations *Identify anomalous results and explain variation in results *See elements in common to several items of data *Recognise patterns/trends in data and make inferences from these	*The learner analyses, synthesises, evaluates data	*Translation of information from table, and graphs *Recognise patterns and trends
4.8 Evaluating the design of the investigation	*Recognise experimental and technical problems inherent in experimental designs *Criticising faulty experiments	*Evaluate the experimental design	
4.9 Making justifiable conclusions	*Evaluate the relevance of data and draw valid conclusions *Evaluate the relevance of data and draw valid conclusions *Transfer and apply conclusions to new situations	*Provide conclusions that show awareness of uncertainty in data	*Make deductions based on evidence
5. Communicating findings	*An ability to communicate clearly when reporting information and expressing ideas	*communicate findings	

Sources: (DoE, 2002b, 2003b; 2005b; DBE, 2011b)

The data in the table shows that the inquiry skills required for the pre-2006 Biology and post-2006 Life Sciences curricula are common. Ten out of thirteen core skills (77 %) are common to all three curricula. In fact, the skill of 'communicating findings' seem to be an omission rather than a shortcoming in the *CAPS* policy document. This assertion is based on the observation that the *CAPS* policy also promotes activities that deal with the preparation and presentation of posters and reports as elaborated within the content in the column labelled 'investigations' (DBE, 2011b). Hence, if this is an omission, then eleven out of thirteen core skills (85 %) are common to the three curricula.

In addition, the table also reveals that the *NCS* complies with all the core skills identified as important for inquiry based teaching and learning. The pre-2006 Biology curriculum differs from the *NCS* in that it did not explicate the skill of 'following instructions' while *CAPS*

differ from the *NCS* in one skill (if we exclude 'communicate findings'), namely the skill of 'making predictions'. Furthermore, an examination of the table illustrates that process skills as well as aspects of IPW as an example of inquiry-based teaching and learning was also an imperative of the pre-2006 Biology curriculum as indicated by the sub-skills 4.1 to 4.9 and skill 5. Given Table 2.4, it is therefore reasonable to assert that the teacher participants in this study should have knowledge, understanding and experience of the implementation of IPW and therefore would not have had to change their practice drastically. However, this will also be dependent on their experiences and practices during the teaching of Biology.

2.5.2 The National Curriculum Statement *(NCS)* for FET

In 1999 a process of reviewing and modernising (RAM) the Grades 10-12 school curriculum had commenced. The aim of the RAM process was to re-work and re-write the *Interim Core Syllabuses* for Grades 10-12 in an integrated manner so that it responded to the Learning Programmes, which endeavoured to broaden access to a range of career opportunities for learners. However, this process was not fully implemented, but only served as a preface to the development of the *NCS* for Grades 10-12.

According to DoE (2003a) the purpose of the Further Education and Training curriculum was to:

- Deepen the foundation laid by General Education and Training,
- Lay a foundation for specialist learning,
- Prepare learners for further learning,
- Prepare learners for employment,
- Develop citizens with a commitment to democracy,
- Promote the holistic development of learners and
- Contribute to economic and social development (DoE, 2003a).

In addition, the Committee also recommended the transformation of the Further Education and Training system, by aligning to the National Qualifications Framework (NQF). It was envisioned that this transformation would streamline the selection of subjects that were being offered as well as the standard setting process. In response, the NQF organised careers and curriculum offerings into twelve organising fields.

Table 2.5 contains information on the Learning Fields and the related subjects that make up the *NCS* Grades 10-12.

Table 2.5: Learning Fields and Related Subjects

LEARNING FIELDS	SUBJECTS
Languages (Fundamental)	Eleven Official Languages First Additional and Second Additional levels
Arts and Culture	Dance Studies Design Dramatic Arts Music Visual Arts
Human and Social Studies	Geography History Life Orientation Religion Studies
Physical, Mathematical, Computer, Life Sciences	Computer Applications Technology Information Technology **Life Sciences** Mathematical Literacy Mathematics Physical Sciences
Business, Commerce, Management Studies	Accounting Business Studies Economics
Engineering and Technology	Civil Technology Electrical Technology Engineering Graphics and Design Mechanical Technology
Services	Consumer Studies Hospitality Studies Tourism
Agricultural Science	Agricultural Sciences Agricultural Management Practices Agricultural Technology

Source: DoE (2005a).

Table 2.5 illustrates the learning fields and the subjects within each field that learners may choose in the FET phase. Life Sciences as a subject falls into the learning field 'Physical, Mathematical, Computer and Life Sciences'. Subjects other than Life Sciences in this field include Physical Sciences, Mathematics, Mathematical Literacy, Computer Applications Technology and Information Technology.

2.5.3 Implementation of C2005 after 2002

The Education Ministry in South Africa decided to revise the FET Curriculum (Grades 10-12) in April 2002. The FET curriculum was developed along the same lines as the *RNCS* in the GET. In developing the FET curriculum the following recommendations were made by the National Committee on Further Education:

- The new policy reduced the total number of subjects to 28, from 124 subjects including the 11 official languages (DoE, 2003a).

- The learning of either Mathematics or Mathematical Literacy be made compulsory for all learners in the FET phase.
- The curriculum be implemented in 2004.
- The subject Biology in the old curriculum be adapted with new foci and be known as Life Sciences.

Due to a public outcry about the compressed time-frames for the implementation of the FET curriculum it was decided to fix the implementation date for the *NCS* in Grades 10 to 12 to the beginning of 2006 (DoE, 2003a), and as indicated in Table 2.1.

2.5.4 Principles underlying the *NCS*

According to the DoE, the *NCS* Grades 10-12 was based on the following nine key principles which have been derived from the Constitution of RSA:

- Social transformation,
- Outcomes-based education (OBE),
- High knowledge and high skills,
- Integration and applied competence,
- Progression,
- Articulation and portability,
- Human rights, inclusivity, environmental and social justice,
- Valuing indigenous knowledge systems; and
- Credibility, quality and efficiency (DoE, 2003a, p. 10).

2.5.5 The design features of the *NCS*

The *NCS* Grades 10-12 mirrors the design features of the *RNCS* in the GET. The design features consists of the critical and developmental outcomes, learning outcomes and assessment standards. The policy documents consisted of the following: an Overview document, the Qualifications and Assessment Policy Framework and the Subject Statement. Each of the designated subjects had a Subject Statement. Each subject statement consisted of four chapters, which included: introduction; key features of the subject; content and context, and assessment. The first chapter is generic, which introduces the *National Curriculum Statement* and is the same for all subject statements, while the other chapters are specific to the subject concerned (DoE, 2003a). The section on Assessment was subsequently removed and replaced with the 'Subject Assessment Guideline' (SAG) document for each subject

(DoE, 2005b). This document elaborates in the first section the general issues with respect to assessment in the *NCS*. The subsequent sections are devoted to subject specific requirements.

2.5.6 Life Sciences as a subject in the *NCS*

As indicated in Chapter One, LOs written specifically for each subject was used as a vehicle to achieve the COs and DOs (DoE, 2003b).

In the Life Sciences, the Learning Outcomes were:

LO1: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem-solving, critical thinking and other skills.

(DoE, 2003b)

LO2: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences.

(DoE, 2003b)

LO3: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the inter-relationship of science, technology, indigenous knowledge, the environment and society.

(DoE, 2003b)

IPW as a method of inquiry learning in the Life Sciences provides a suitable vehicle for creating an appropriate active, learner-centred and learner-directed environment, as required to achieve LO1 and therefore the relevant Critical and Developmental Outcomes.

The seven COs and five DOs are related to the three LOs as indicated in Table 2.6 below.

Table 2.6: Relationship between Life Sciences LOs and COs and DOs

LIFE SCIENCES LEARNING OUTCOMES (LOs)	CRITICAL OUTCOMES (COs) (DoE, 2002a, p11)	DEVELOPMENTAL OUTCOMES (DOs) (DoE, 2002a, p11)
LO 1: Scientific inquiry & problem solving skills (DoE, 2003b)	**CO 1**: Solve problems, decision-making and thinking **CO 4**: Collect, analyse, organise and critically evaluate information **CO 5**: Communicate effectively using visual, language, symbolic and other modes (DoE, 2002a, p11)	**DO 1**: Reflect and explore a variety of learning strategies (DoE, 2002a, p11)
LO 2: Construction & application of Life Sciences knowledge (DoE, 2003b)	**CO 6**: Use science and technology effectively and responsibly towards environment and people **CO 3:** Organise and manage themselves and their activities responsibly and effectively **CO 7**: Demonstrate understanding of the world as a set of related systems by recognising that problem solving contexts do not exist in isolation (DoE, 2002a, p11)	**DO 2:** Participate as responsible citizens in the life of local, national and global communities **DO 4:** Explore education and career opportunities **(**DoE, 2002a, p11)
LO 3: Life Sciences, technology, environment and society (DoE, 2003b)	**CO 2**: Work with others as members of a team, group, organisation and community **CO 6**: Use science and technology effectively and responsibly towards environment and people (DoE, 2002a, p11)	**DO 2**: Participate as responsible citizens in the life of local, national and global communities **DO 3**: Be culturally sensitive across a range of social contexts **DO 5**: Develop entrepreneurial opportunities (DoE, 2002a, p11)

The information in Table 2.6 reveals that:

* LO1 is reflective of three of the COs and one of the DOs.
* LO2 relates directly to three of the COs and two of the DOs.
* LO3 relates directly to two of the COs and three of the DOs.
* LO2 and LO3 relates to DO2

2.6 IMPLEMENTATION OF THE NATIONAL CURRICULUM STATEMENT *(NCS)* IN THE FET PHASE

The *NCS* in the FET was confirmed as a policy in the year 2003. The first year of implementation was 2006 in Grade 10, with Grade 11 being implemented in 2007 and Grade 12 in 2008. Thus the first exit-level examinations leading to the awarding of the National Senior Certificate, were written in 2008.

Prior to the implementation of the transformed FET curriculum in the South African classrooms, the Department of Education embarked on a strategy to prepare the various role-players for this mammoth task. This preparation involved the training of the relevant stakeholders at different levels. The training made use of the 'cascade model'. This cascade model involved the training of a core group of educators at the National level. This group of 'experts' were called the 'National Core Training Team' (NCTT). This National team then trained curriculum advisors from throughout the country at a central venue which was in Durban in the case of Life Sciences. The curriculum advisors were now tasked to train the relevant stakeholders within each province. This involved training a core team of educators including union representatives. The KZN provincial curriculum specialists who attended the National training trained these teams. This group of trained educators made up what was referred to as the Provincial Core Training Teams (PCTT). The PCTT was deployed to each of the districts to train classroom practitioners. Each team consisted of a curriculum advisor, a union representative and a lead teacher.

2.6.1 Training by the National Department of Education

All Life Sciences Curriculum Specialists from the nine Provinces in the Republic of South Africa were trained by the NCTT. This training took place in Durban in April 2005, some eight months before the implementation of the new curriculum in the Grade 10 classrooms. The responsibility for this training lay with the National Department of Education. The training consisted of a four-day programme. The four-day training, which the researcher also attended, consisted of a programme as indicated below.

- Day 1: Background to transformation, legislation and policies.
- Day 2: Working with Learning Outcomes and Assessment Standards; Choosing Learning, Teaching and Study Materials (LTSMs).
- Day 3: Planning and classroom practice.
- Day 4: Assessment; Designing and developing Lesson plans; feedback and way forward.

As is evident from this programme the training did not involve practical investigations, although the SAG (2005b; 2008) highlighted the fact that 'hypothesis-testing' type of investigations is 'new' to the Life Sciences fraternity.

Information obtained at the National training had to be cascaded and shared with the Life Sciences classroom practitioners. In order to do so, training sessions had to be held within each Province following the cascade model.

2.6.2 Training by the Province of KZN

Training within the Province mirrored the National training in that it occurred over a four day period. Similar training sessions were conducted for the Provincial curriculum specialists by the NCTT in 2006 and 2007 for Grades 11 and 12 respectively. The various provincial Curriculum Specialists attended these sessions. Training within the province followed the same protocol as the previous year for the previous grade. In addition, several curriculum support workshops were held for Life Sciences teachers in the different districts. This was done in an effort to strengthen teacher's subject matter knowledge, including assessment practices with respect to the *NCS*.

2.7 NEW CONTENT FRAMEWORK (NCF) FOR THE LIFE SCIENCES

Dissatisfaction with the extreme under-specification of the content material of the *NCS* led to its re-writing only three years into its implementation **(**Doidge, Dempster, Crowe, & Naidoo, 2008; DoE, 2007). This re-written version was referred to as the New Content Framework (NCF) (DoE, 2007). It is commonly referred to as 'version 2 of *NCS*' (*NCS* 2). According to the introduction to this document it indicates that this knowledge framework describes the content and the contexts for the teaching of Life Sciences in the Further Education Phase (FET) (Grades 10 to 12) (DoE, 2007). "It is written from the view that science is a process – a way of knowing; and a way of interpreting natural phenomena involving living organisms. It encourages asking "what", "how" and "why" questions when observing living organisms and moving from intuitive understandings to counter-intuitive" (DoE, 2007, p. 1). This version of the curriculum retained the four Knowledge Areas and Learning Outcomes but the structure and focus of the content was greatly altered and provided more detail. Current theory and practice in both education and in the Life Sciences as well as the ten outcomes as listed in the document (DoE, 2007) have informed its structure (p.1). The following four of the ten outcomes are of relevance to this study:

At the end of Grade 12 learners should have:

- Devised and evaluated investigations in biological processes and systems by following the principles of scientific investigations.
- Demonstrated knowledge of the nature of science, its benefits and its limitations.
- Demonstrated an ability to critically evaluate and debate investigations, practices, issues and popular articles in terms of their scientific validity and credibility.

- Developed a level of academic and scientific literacy that enables learners to read, talk about, write about, and construct diagrams that illustrate biological processes, concepts and investigations.

(DoE, 2007, p. 1)

With the introduction of this NCF Life Sciences teachers would have to be trained again in the implementation of this version of the curriculum. Training in this respect was conducted only at the District level. The training involved re-orientating teachers with respect to the content and developing them further where the content was new. This change brought about a great deal of frustration amongst Life Sciences teachers. They were just about getting to grips with the transformed curriculum and then suddenly they had to make more changes to their teaching approach.

2.8 CHALLENGES IN IMPLEMENTING THE *NCS* IN THE FET AND THE BIRTH OF *CAPS*

While the *NCS* was implemented in all FET schools in the country many education stakeholders were not satisfied with the new curriculum. According to the *Sunday Times* (11 July 2011) the Minister of Education, identified the following shortcomings:

- It was a weak and superficial curriculum that was unrealistic and lacking in specific objectives;
- The assumption that learners had access to research facilities such as telephones, the internet, libraries and newspapers was indeed ambitious; and
- OBE was opened to a variety of interpretations and teachers had no clarity about what was required of them.

It was also found that teachers did not fully understand the content knowledge in the subject. The implementation of the *NCS* was subsequently reviewed in 2010. The outcome of the review resulted in the development of the *National Curriculum Statement* (*NCS*) Grades R-12 (DBE, 2011a). *NCS* Grades (R-12), commonly referred to as *CAPS* was intended to amend the *NCS*, with the amendments coming into effect in selected grades in January 2012. This represents the third curriculum change since 2006 for Life Sciences teachers. The *NCS* Grades R-12 *(CAPS)* represents a policy statement for learning and teaching in South African schools and comprises of the following:

- Curriculum and Assessment Policy Statements (*CAPS*) for all approved subjects, such as the Life Sciences (DBE, 2011b);
- National policy pertaining to the programme and promotion of the *NCS (CAPS)* Grades R-12 (DBE, 2011c); and
- National Protocol for Assessment Grades R-12 (DBE, 2011d).

The *CAPS* (DBE, 2011b) document is a single comprehensive document for each subject, and it replaces the previous separate Subject Statements, Learning Programme Guidelines (LPG) and Subject Assessment Guidelines (SAG) in Grades R – 12 (DBE, 2011b).
While Specific Aims (SAs) and sub-aims in the *CAPS* replaces the LOs and ASs for Life Sciences, and the addition, deletion and re-organisation of content between the grades, the broad principles for studying Life Sciences remain unchanged.

- Specific Aim 1 (SA1) –relates to LO2, that is, knowing Life Sciences (concepts, processes, phenomena, mechanisms, principles, theories, laws, and models) (DBE, 2011b).
- Specific Aim 2 (SA2) – relates to LO1, that is, to doing science or practical work and investigations (DBE, 2011b).
- Specific Aim 3 (SA3) – relates to LO3, that is, to the understanding of the applications of Life Sciences knowledge in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and science (DBE, 2011b).

The focus of this study is on LO1 and SA2 and the relation between LO1 and SA2 was elaborated on earlier in this chapter in Table 2.3.

SA2 is concerned with the development and assessment of the following skills and sub-skills:

- Following instructions
- Handling equipment and apparatus – (using these appropriately and safely)
- Making observations – (counting, drawings, comparing)
- Recording information or data – (as drawings, graphs, tables)
- Measuring – (what and how)
- Interpreting– (translating information from one form to another, calculating, recognising trends and patterns)

- Designing/Planning investigations or experiments–(identifying a problem, hypothesising, selecting apparatus or equipment and /or materials, identifying variables, selecting ways of controlling variables, planning an experiment, planning ways of recording results, understanding the need for replication or verification).

(DoE, 2011b, p.16).

The importance of IPW is expressed, as indicated in chapter one of this study, by the imperatives of the *NCS,* namely, two formal activities, that is, a 'hands-on' activity and a 'hypothesis testing' activity as part of the continuous assessment (CASS) or school based assessment (SBA). The significance and value of practical work is further reinforced in *CAPS*. It has become so important that it justified the inclusion of a practical examination for grades 10 and 11. In addition, learners will have to be formally assessed on one practical task in each of the first three terms. That is, a total of three practical tasks will count towards the CASS/SBA mark, in grades 10, 11 and 12. A shortcoming of *CAPS* is that it does not prescribe or indicate the complexity of the practical task. It also does not indicate the level of learner autonomy of these tasks for each of the grades. It is therefore possible that without such prescriptions IPW with a high degree of learner autonomy in open-ended tasks will become non-existent. A situation that will be worse than currently observed.

Table 2.4 in this chapter earlier illustrated the similarities in the requirements for inquiry-based teaching and learning, in the pre-2006 Biology Interim Core syllabus and post-2006 Life Sciences in the *NCS* (original version) and *NCS* (*CAPS* version).

2.9 CONCLUSION

While a great deal of criticism has been levelled at different aspects of the post democratic curricula in South Africa, very little has been commented on about teachers' knowledge and about their perceptions, attitudes, confidence and values about teaching and learning and the impact that these have on their practice.

One needs to also be mindful that, the learning outcomes and specific aims especially LO1 and SA2 of the post-2006 Life Sciences resemble the aims and objectives and the approach to the syllabus of the pre-2006 curriculum. The assumption therefore is that most teachers should have encountered the requirement for IPW as an example of inquiry-based teaching and learning even before the introduction of the *NCS*.

Chapter THREE reviews the literature that is relevant to this study.

CHAPTER THREE

REVIEW OF RELATED LITERATURE

3.1 INTRODUCTION

This chapter reviewed literature in order to understand the implementation of investigative practical work (IPW) within the broader scope of inquiry-based teaching and learning. Literature on teachers' knowledge and teachers' beliefs was also consulted in order to facilitate understanding of its relationship on the teaching practice of IPW as an example of inquiry-based teaching and learning.

The chapter is separated into four broad sections. The 'introduction' provides an outline of the chapter. The next section under the heading 'inquiry-based science education' discusses inquiry as an imperative in science education reform, locating IPW within practical work in school science, the role of the teacher and pedagogical support strategies to implement IPW, the nature of inquiry activities, teachers' practice and learners' performance in inquiry activities, and the benefits of inquiry-based teaching and learning approaches. It then elaborates on teachers' knowledge and teachers' beliefs. The final section provides a brief summary to this chapter.

The constructivist theory of learning, conceptual change theory, epistemological beliefs and teacher change model are discussed in Chapter Four, which focuses on the theoretical and conceptual frameworks.

3.2 INQUIRY–BASED SCIENCE EDUCATION

The concept of inquiry is very diverse and as such inquiry in science teaching and learning has been a regular topic of discussion in science education (Bybee, 2000; Chiappetta & Adams 2000; DeBoer, 1991; Schwab, 1962; Trowbridge & Bybee 1990). According to Barrow (2006) over the last century inquiry had multiple meanings. The complexity of defining inquiry in science education has been summed-up by Wheeler (2000, p.14) in the following response to the variety of its meaning,

"An elastic word stretched and twisted to fit people's differing worldviews"

The multiplicity meanings of inquiry has come about due to the various challenges experienced in the practice of school science. However, its past has been problematic due to various understandings and therefore different means of practice (Bybee, 2000). One significant difference is the role of content and process (Chiappetta & Adams, 2000).

The debate about science as content versus process has been going on for almost a century (Bybee, 2000; Dewey, 1910; Schwab, 1962). There are changes in the emphasis of science teaching and learning as learners' progress from primary school to high school. Primary school science tends to focus on the processes of science, with little emphasis on content (Chiappetta & Adams, 2000). This approach emphasises the skills of science such as observing and experimenting, but does not support the critical thinking and reasoning associated with scientific inquiry (NRC, 1996). In contrast, secondary school science tends to emphasise established science knowledge or content without attention to the methods by which that knowledge has been generated (Chiappetta & Adams 2000). This approach presents science as a body of knowledge that explains our understanding of the world around us.

Furthermore, due to contextual factors schools organise teaching and learning in ways that fit-in with the resource availability and prescripts of the Education Departments. For instance, if a school has only one laboratory for Life Sciences then teachers of Life Sciences need to share this facility at different times. This results in the time table being constructed in a way that promotes the teaching of theory and practicals separately.

In order to develop scientific understanding there has to be meaningful activities, which integrates content knowledge, the processes of science and the nature of science for learners to actively engage with. This will therefore provide learners with the necessary opportunities to develop inquiry skills, critical thinking skills, and expand their understanding of science content and processes. However, such integration of content and process in a school context is rarely accomplished. In most cases it generally manifests as the teaching and learning of content only (Haefner & Zembal-Saul, 2004). This practice is further motivated by high stakes examinations, which focuses on established science knowledge. Hence, teacher's classroom performance is geared towards content coverage and thus 'teaching to the test'.

Dewey (1964, p.183), cited in Latta, Buck, Leslie-Pelecky, and Carpenter (2007) stated that science has been taught too much as an accumulation of facts with which learners are to familiarise themselves. Learners are not provided with enough opportunities to enable them to think, or to help them develop an attitude of mind. Latta et al., (2007) maintains that the terms of inquiry are too often betrayed not only within the study of science, but in all teaching and learning. Why does such a state of affairs exist? Perhaps it is due to the lack of knowledge about pedagogical support on the part of science teachers.

Dewey refers to knowledge that cannot be learned on its own and which does not involve the accumulation of information but rather a way of making meaning (Latta et al., 2007). Dewey's argument is that, only by being actively involved in the construction of knowledge will one be able to acquire knowledge and understanding of how one knows. This is also an important principle of the theory of constructivism.

Inquiry is regarded both as teaching science and also as doing science (Colburn, 2000). Hence, inquiry-based teaching and learning (IBTL) is viewed from different perspectives. On the one hand, it is seen as how scientists conduct science, referring to the use of science process skills, and on the other hand as a teaching approach, referring to its implementation in a science classroom, including how students learn science and about how science works (NRC, 2000).

In order to develop learners' epistemological views of science, the means to achieve this may be found in re-emphasising the definition of inquiry from the perspective of it being a pedagogical approach to teaching and learning science, while encompassing the notion of science as inquiry (Hodson, 2008).

Despite this variety of views, there is one common aspect that covers both perspectives. This aspect can be drawn from Audet's (2005) interpretation which point out that,

> *"The legion of data, beliefs, definitions, and description of inquiry all boils down to: Inquiry is any activity aimed at extracting meaning from experience"* (p.6).

Hence, in this respect the current study adopts Bybee's (2000) description of "science as inquiry". According to this description "science as inquiry" comprises three main elements, namely:

* Skills of scientific inquiry (what learners should be able to do),
* Knowledge about scientific inquiry (what learners should understand about the nature of scientific inquiry), and
* A pedagogical approach for teaching science content.

(Bybee, 2000).

3.2.1 Inquiry as an imperative in science education reform

Reform in school science has argued for a decrease in the memorisation of inert or decontexualised scientific facts and a greater emphasis on learners' investigation of the everyday world. Transformations in recent times have therefore set impressive goals for science education in order to address the issues of science as inquiry and science teaching and learning (Chiappetta & Adams, 2000; NRC, 1996; DoE, 2003b; DBE, 2011b). For citizens to cope in a modern world, it is necessary for them to become scientifically and technologically literate (UNESCO, 1994; Saad & Boujaoude, 2012). Furthermore, the limitations of the traditional methods of teaching science have been recognised for many years (Feyzioglu, 2012). Therefore, in order to improve scientific thinking and knowledge, transformed science curricula advocates the use of inquiry approaches to teaching science (e.g. Chinn & Malhotra, 2002). Scientists use similar approaches to create science knowledge. Science educators have indicated that working on authentic science research projects facilitates the development of scientific literacy by enhancing learners' understanding of the nature of scientific inquiry (Chinn & Malhotra, 2002; Gallagher, 1991; Lemke, 1990; NRC, 1996; Solomon, 1999). Hence, many reform efforts and subsequent studies have focused on the development of inquiry–based, constructivist pedagogy as the most successful way of teaching science, (e.g. Valk & de Jong, 2009; Plevyak, 2007; Bianchini & Colburn, 2000; AAAS, 1990, 1993). This has therefore resulted in the emphasis on reformation of the science curricula in many parts of the world (Saad & Boujaoude, 2012; Cheung, 2007; van Driel, Beijaard & Verloop, 2001). Inquiry has featured prominently in the reform literature in defining the nature of science, which is an important learning outcome for learners (Newman, Abell, Hubbard, McDonald, Otaala & Martini, 2004). Transformation of science education across the globe highlights the importance of presenting images of science that espouses the present constructivist teaching and learning perspectives (Feyzioglu, 2012; Millar & Osborne, 1998; National Research Council (NRC), 1996; American Association for the Advancement of Sciences (AAAS), 1993; Driver et al., 1996; Hodson, 1998; Matthews, 1994; Ryan & Aikenhead, 1992).

Constructivist approaches to science teaching and learning argue that learning results from observing the natural world, scaffolding that information with prior conceptions and interacting with more knowledgeable and capable peers to construct new understandings (Barba 1998; Llewellyn 2002; Stewart & Kluwin 2001). Constructivists support an inquiry-based approach to learning.

The practice of science by scientists is not normally represented in the classroom (Chinn & Malhotra, 2002; Ryder, Leach, & Driver, 1999; Driver et al., 1996; Roth, 1995). While both the real world as well as the classroom contexts do provide opportunities for social construction of meaning the teaching and learning situation in the classroom seldom promote complex reasoning and negotiation of meaning as it is articulated within the scientific community (e.g. Chinn & Malhotra, 2002). It is argued that without understanding the values, assumptions and the procedures by which science knowledge is constructed, learners view science merely as a body of inert information, which is independent of a context (Lederman, 1998; Schwab, 1962).

Scientific inquiry at the school level takes the form of activities or tasks and may be described as the focus of the classroom in terms of what science concepts are taught and learned and the ways in which the nature of scientific knowledge is represented, the manner in which a lesson is conducted, the nature of the classroom interactions and the practice of inquiry skills (Haefner & Zembal-Saul, 2004). In other words, teaching and learning by inquiry advocates investigative activities or tasks in which learners are actively engaged in answering science oriented questions thus emphasising learning science content and the processes involved in its construction (Chiappetta & Adams, 2000). The authors however, do not indicate what is meant by learner engagement. It could be engagement by following a set of highly-structured step-by-step instructions or procedures provided by the teacher or the text book or it could involve the active involvement of the learners in directing the activity with appropriate guidance and support from the teacher. Wilke and Straits (2005) on the other hand indicates that the focus of this approach is on the active involvement of the learner in order to make meaning of the scientific ideas and it encourages higher-level learning. Also, science learners should come to understand what inquiry is, as well as to develop the requisite abilities to do inquiry (Haefner & Zembal-Saul, 2004; NRC, 1996, 2000). Inquiry therefore, is more than just about science as a process where learners are taught specific skills such as, observation or recording of results. It is an approach to learning that involves a process of exploring the natural world that leads to asking questions and making discoveries in the search for new understandings (Ash and Klein, 2000). This process allows learners to be actively involved in for example, answering a research question by engaging in data analysis. (Bell, Smetana, & Binns, 2005). In fact, inquiry is fundamental to science learning (Haefner & Zembal-Saul, 2004).

From a constructivists perspective engaging learners in inquiry activities and stages of scientific investigation foster learners' curiosity, and promote scientific activity as an intellectual worth. Furthermore, opportunities to experience science-in-the-making together with the ability to engage in discussion may lead to a better understanding of the nature of scientific research (Bell, Blair, Crawford, & Lederman, 2003).

When learners are engaged in inquiry involving designing and conducting valid scientific investigations, they incorporate complex processes of asking questions, describing objects and events, they formulate explanations from evidence, test those explanations against current scientific knowledge, and communicate and justify their proposed ideas or explanations to others (NRC, 1996, 2000). This definition of inquiry has been widely used by researchers and educators (for example, Anderson 2002; Caton, Brewer, & Brown 2000; Crawford 2000; Lederman & Niess 2000).

The *National Science Education Standards (NSES)* (NRC, 1996) for example, have placed significant emphasis on inquiry in both its teaching and content standards. Two important features of inquiry teaching and learning are alluded to by the *NSES*. One aspect is the ways in which scientists study the natural world and propose explanations based on evidence from their study. The second aspect of inquiry refers to the activities which learners engage in when they develop knowledge and understanding of scientific ideas, as well as knowledge and understanding of how scientists study the natural world (NRC, 1996).

Latta, Buck, Leslie-Pelecky and Carpenter (2007), maintains that:

> *"By placing inquiry at the core of the thinking and experiences of school science teachers as a philosophical / theoretical / practical educative process to be worked with, could result in cultivating, sustaining, and nurturing inquiry in teachers' practices"* (p.21).

The *NSES* suggests that practice with engagement in science inquiry enable learners to both learn important science concepts and become familiar with the scientific processes such as, ways of generating and formulating questions, rules of evidence and ways of proposing explanations in order to understand how science knowledge is generated and accepted (NRC, 1996).

Stoddart, Abrams, Gasper, and Canaday (2000) describe inquiry as allowing learners to experience the development of research questions and testable hypotheses. Edelson, Gordin,

and Pea (1999) define inquiry in a very similar way to the *NSES,* in that, they purport inquiry to involve the study of open-ended questions which are generated by the learners. However, while some researchers agree with the *NSES* description of inquiry, they also argue that multiple modes and patterns of inquiry-based instruction are not only expected but also advantageous because it creates a strong picture of meaningful learning in diverse situations (Keys & Bryan 2001, and Keys & Kennedy 1999). Examples of diverse situations could be characteristics of the learners, the school culture, class sizes, and the lesson topic.

According to the British House of Commons Science and Technology Committee (2006), learners should be given opportunities to do stimulating and diverse experimental and investigative tasks in order to progress in science. By providing opportunities to do practical investigations in the school set-up it is expected to help learners develop their knowledge and understanding of science, appreciate that science is based on evidence and acquire hands-on skills.

In South Africa, the curriculum for Life Sciences *(NCS)* prescribed two practical pieces / tasks for each of Grades 10, 11 and 12 for the purposes of the Programme Of Assessment (POA) for School Based Assessment (SBA)/Continuous Assessment (CASS) in order to generate a year mark. In addition, it prescribed the type of practical task, namely, 'hands-on' and/or 'hypothesis-testing' (DoE, 2005b). The revised curriculum (*CAPS*) for Life Sciences prescribes three practical tasks per year (one per term) and a practical examination for Grades 10 and 11. For Grade 12 it prescribes three practical tasks for the year (DBE, 2011b). However, it does not prescribe the type of practical task for any of the grades. Instead it indicates that all the stipulated skills must be assessed in the year. These skills for example, following instructions, handling equipment and apparatus, making observations, recording observations, measuring, interpreting and designing and planning investigations have been alluded to in Chapter Two, section 2.8 as well as in Table 2.4 (DBE, 2011b, p.15). However, in both the older version of the curriculum *(NCS),* as well as the newer version *(CAPS)* many more practical activities may be done in addition to those prescribed for assessment. While the House of Commons Science and Technology Committee (2006) may not prescribe the type and number of practical activities, its rationale for practical work namely, to develop learners' understanding that science is based on evidence, and to acquire hands-on skills, is also implicit in the South African Life Sciences curricula.

3.2.2 Locating IPW within practical work in school science

The purpose of this study was to determine any relationship between Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW). IPW is an example of inquiry-based approach to teaching and learning science. Since IPW is central to this study the elements of the practice of IPW will be used to analyse data. These elements are located within the prescripts of the South African Life Sciences curriculum and include for example, generating questions and identifying problems; formulating hypotheses; making predictions; identifying relevant variables; collecting and recording data; analysing and interpreting and evaluating data; evaluating the design of the investigation and making justifiable conclusions.

Table 3.1 illustrates the similarities between IBTL and the South African Life Sciences curriculum.

Table 3.1: Similarities between Inquiry-based teaching & learning and the South African Life Sciences Curriculum

Inquiry-based teaching and learning	South African Life Sciences curriculum
➢ Learner centred and learner directed	➢ Learner centred (Comparison between old and new model of teaching and learning -DoE, 1997a)
➢ Active involvement	➢ Active learners (Comparison between old and new model of teaching and learning -DoE, 1997a)
➢ Connects new evidence to prior knowledge / ➢ understandings ➢ Involves searching the task environment, evaluating ➢ data, linking to prior understanding	➢ Identify and solve problems using critical & creative thinking. (CO – D0E, 2003a)
➢ Encourages meaningful learning. ➢ Use critical and logical thinking, reasoning and thinking skills. ➢ Encourages higher level learning. ➢ Reflection of scientific knowledge and scientific process	➢ Use cognitive and social strategies such as ➢ reasoning, researching, collaborating, expressing ➢ opinions and debating (CO – DoE, 2003a) ➢ Reflect on and explore a variety of strategies to ➢ learn more effectively (DO – DoE, 2003a)
➢ Nature of learning is both individual and social activity ➢ Promotes collaboration.	➢ Work effectively with others as members of a ➢ team, group, organisation or community. (CO – DoE, 2003a) ➢ Be culturally and aesthetically sensitive across a range of social contexts (DO – DoE, 2003a)
➢ Answers the research question	➢ Promotes inquiry-based learning and teaching (LO1 – DoE, 2003b)
➢ Active construction of knowledge	➢ Construction of knowledge is advanced (LO1, LO2 & LO3 – DoE, 2003b)

➢ Approach to learning involves process of exploring the natural world in search of new understandings ➢ Consider alternative explanations	➢ Demonstrate an understanding of the world as a set of related systems, by recognising that problem–solving contexts do not exist in isolation (CO – DoE, 2003a)
➢ Process skills involved involves the use of process skills: observing, inferring, predicting, measuring, classifying	➢ Promotes the development of skills (LO1 – DoE, 2003b)
➢ Involves a sequences of steps: stating a problem, generating / stating asking questions/ hypotheses, identifies assumptions	➢ Identifies and questions phenomena and plans ➢ investigation ➢ Identifying a problem ➢ Hypothesising (LO1 – DoE, 2003b)
➢ Planning the investigation, and conducting ➢ investigations, controlling and manipulating ➢ variables	➢ Conducts investigation ➢ Handling equipment and apparatus ➢ Selecting apparatus and/or materials ➢ Identifying variables ➢ Selecting ways of controlling variables ➢ Planning an experiment ➢ Planning ways of recording results ➢ Understanding the need for replication or verification
➢ Using tools to collect, analyse, interpret data and state conclusion	➢ Collect, analyse, organise and critically evaluate information ➢ Analyses, synthesises and evaluates data ➢ Accesses knowledge ➢ Collects data ➢ Manipulates data ➢ Making observations ➢ Recording information ➢ Interpreting data (LO1 – DoE, 2003b)
➢ Formulating explanations and using evidence to respond to questions ➢ Encourages the development of more appropriate understandings of science	➢ Interprets and makes meaning of knowledge (LO1 – DoE, 2003b)
➢ Communicating explanations and justifications	➢ Communicates findings effectively using visual, ➢ symbolic and/or language skills in various modes (LO1 – DoE, 2003b)

The information on IBTL was extracted from the literature that was surveyed for discussion in this chapter. The relevant *NCS* Life Sciences policy documents were analysed in order to align the imperatives of the *NCS* with the characteristics of inquiry-based teaching and learning. As is evident from the information in the Table 3.1, there is a distinct alignment across the two constructs, namely, inquiry-based teaching and learning and the Life Sciences curriculum for all the identified characteristics.

Inquiry-based teaching and learning (IBTL) is constructivist in nature. The relationship between IBTL and constructivism and their alignment to the South African Life Sciences curriculum is elaborated in Table 4.1 in Chapter Four.

Furthermore, this study compared the categorisation of inquiry by Chinn and Malhotra (2002) with the imperatives of the South African Life Sciences curriculum and then located IPW within these. Chinn and Malhotra (2002), make a distinction between simple inquiry tasks and authentic scientific inquiry. Simple inquiry tasks include simple observations, simple illustrations and simple experiments (Chinn & Malhotra, 2002).

Simple observations requires learners to carefully observe and describe objects (Chinn & Malhotra, 2002).

Simple illustrations requires learners to follow a specified procedure, usually without a control condition (Chinn & Malhotra, 2002). The learners are to employ the variables that are provided to them. These are inquiry tasks only in the narrowest sense, where learners may encounter new empirical phenomena when they carry out the procedure, but they have no freedom / opportunities to explore further (Chinn & Malhotra, 2002).

Simple experiments involve activities where the research question is given to learners. In addition, the learners are provided with the necessary directions on how to implement a procedure. The learners are informed as to what variables to control or how to set-up a control, what to measure and how to record data. Identifying faulty experimental design is seldom relevant (Chinn & Malhotra, 2002). The 'hands-on' type of activity of the South African curriculum, which is teacher or text book directed and highly structured, resembles the simple inquiry tasks of Chinn and Malhotra (2002). Examples of such simple inquiry tasks may include, 'the starch test' or 'extraction of DNA from spinach'.

Authentic scientific inquiry refers to the research that scientists actually carry out (Chinn & Malhotra, 2002). This type of inquiry involves the scientists generating the research question and sometimes employing complex design features including the use of expensive and sophisticated equipment, elaborate procedures and theories and advanced techniques for data analysis and modelling (Chinn & Malhotra, 2002). However, authentic scientific investigations can also be executed within the school environment, depending on the

complexity of the problem as well as on the specialised equipment that is required. The 'hypothesis-testing' type of tasks resembles the authentic scientific inquiry of Chinn and Malhotra (2002). An example of such a task may be on the topic 'Solid waste disposal'. With background information on decomposition of materials provided, learners must 'Design an investigation to determine which type of material will be most suitable for the packaging of household items'. The teacher provides minimal guidance.

The imperatives of investigations in the South African Life Sciences curriculum is espoused by Learning Outcome 1 (LO1) (Scientific inquiry and problem solving skills) and its related Assessment Standards (ASs) and its elaboration for each grade in the FET phase. While the post-2006 *NCS* Life Sciences curriculum implicitly advocates the principles of constructivism, such as activity-based, learner-centeredness', and teacher as facilitator, it also promotes guided inquiry and which acts as scaffolding for learners to master the more complex cognitive processes in the implementation of open-ended IPW in Grade 12.

Table 3.2, which follows, indicates the increasing complexity of the cognitive processes for LO1.

Table 3.2: Increasing complexity in the Assessment Standards (ASs) of Learning Outcome 1 (LO1) from Grades 10 to 12

Assessment Standards (ASs)	Grade 10	Grade 11	Grade 12
AS1: The learner identifies and questions phenomena and plans an investigation	➢ Identify and questions phenomena ➢ Plans an investigation using instructions ➢ Considers implications of investigative procedures in a safe environment	➢ Identify phenomena involving one variable to be tested ➢ Design simple tests to measure the effects of this variable ➢ Identify advantages and limitations of experimental design	➢ Generate questions and hypotheses based on identified phenomena for situations involving more than one variable ➢ Design tests and/or surveys to investigate these variables ➢ Evaluate the experimental design
AS2: The learner conducts investigations by collecting and manipulating data	➢ Systematically and accurately collect data using selected instruments and/or techniques and following instructions ➢ Display and summarise the data collected	➢ Systematically and accurately collect data using selected instruments and /or techniques ➢ Select a type of display that communicates the data effectively	➢ Compare instruments and techniques to improve the accuracy and reliability of data collection ➢ Manipulate data in the investigation to reveal patterns ➢ Identify irregular observations and measurements ➢ Allow for irregular observations and measurements when displaying data
AS3: The learner analyses, synthesises, evaluates data communicate findings	➢ Analyse, synthesise, evaluate and communicate findings	➢ Compare data and construct meaning to explain findings ➢ Draw conclusions and recognise consistencies in the data ➢ Assess the value of the experimental process and communicate findings	➢ Critically analyse, reflect on and evaluate the findings ➢ Explain patterns in the data in terms of knowledge ➢ Provide conclusions that show awareness of uncertainty in data ➢ Suggest specific changes that would improve the techniques used.

Source: National Curriculum Statement Grades 10-12: Life Sciences Manual for Educators: OBE in FET (KZN DoE, 2005)

The information in Table 3.2 reveals the following:

- That LO1 is about investigations and that the *NCS* conceptualises investigations in Life Sciences as predominantly involving experiments. The non-acknowledgement of other ways of carrying out investigations in Biology, for example, that the study of cells,

tissues and diversity of organisms is based on observations and comparisons, is a shortcoming of the *NCS* curriculum.

- That these investigations are reflective of aspects of both the 'simple experiments and simple illustrations' as well as the 'authentic scientific inquiry' of Chinn and Malhotra, (2002).
- There is a gradual development and assessment of these inquiry skills over the years from Grade 10 to Grade 12. For each succeeding year from Grade 10, there is an increasing complexity in the demonstration and assessment of these skills. In this regard Table 3.2 has been constructed to illustrate this increasing complexity. For example, AS2 of LO1 is stated as follows:

  "The learner conducts investigations by collecting and manipulating data".

  The skill of 'measuring', for example, is not explicitly stated in the AS. However, if one considers how this skill is to be demonstrated by the learner, then one needs to unpack and understand the requisite skill/s involved in the AS. One of the ways in which this can be demonstrated by the Grade 10 learner is stated as follows:

  "Systematically and accurately collects data using selected instruments and/or techniques and following instructions".

  One way in which a Grade 12 learner may demonstrate this is to,

  "Identify irregular observations and measurements".

  (KZN DoE, 2005, p. 28)

  This therefore demonstrates the increasing complexity in the development and assessment of this particular skill.
- The activities for Grade 12 learners require a degree of open-endedness.

Hence, the concept of 'investigative practical work' (IPW) relates to degrees of open-endedness within the context of this study. In addition, IPW may be located closer to authentic scientific inquiry on a continuum from simple inquiry to authentic scientific inquiry as per the categorisation of Chinn and Malhotra (2002).

Studies on domain-general inquiry skills has shown that it is possible to develop such skills, even in pre-adolescents and that the evidence for this development lies in the learners' ability to use these strategies or skills in different contexts (Kuhn & Dean, 2008). However, in order to be able to do so, there has to be multiple exposure and engagement with these skills or

strategies as well as appropriate assistance by a more experienced knower, like a teacher. Continued studies in this regard, resulted in a dichotomy of thought about how this could be achieved by different researchers. For example, studies by Klahr and Nigam (2004) and Chen and Klahr (1999) resulted in them advocating explicit instruction or directed teaching on the one hand, and Kuhn and Dean (2005) and Dean and Kuhn (2007) who have preferred a more self-directed approach focusing on activities and multiple opportunities or exercises, on the other hand. In both cases however, the focus of attention has continued to be on the transferability of newly acquired inquiry skills across content and contexts. These studies lend support to the stance that the *NCS* has adopted with respect to the increasing complexity of the development of inquiry skills since the *NCS* does not prescribe the content or context for the development and assessment of these skills. This is an indication that the skills need to be developed and assessed in different content areas. In addition, the manner in which the *NCS* prescribes the demonstration or the development of these inquiry skills alludes to the notion of a gradual build-up through relevant and appropriate scaffolding exercises. Kuhn and Dean (2005) showed that scaffolding learners' skill at the early stages of inquiry for example, during the question identification stage greatly enhanced achievement at subsequent stages.

While the *CAPS* policy makes provision for investigating phenomena in Life Sciences, it does not make explicit the implementation of open-ended investigative tasks or IPW. The assessment of practical work in *CAPS* does not prescribe such investigations. The impression created is that IPW has been de-emphasised.

The following cognitive processes make authentic inquiry of Chinn and Malhotra (2002) different from IPW at the school level.

- Scientists select and even invent variables to investigate.
- Complex procedures for example, the use of analogue models utilising complex theories, may be used.
- Elaborate techniques may be used to guard against observer bias
- Observed variables may not be identical to the theoretical variables of interest.
- Scientists may utilise multiple forms of arguments.
- Theories may be constructed.
- Results from multiple studies are co-ordinated
- Other scientist's research reports are used for various purposes.

(Chinn & Malhotra, 2002)

This study therefore does not include the above cognitive processes as part of IPW.

3.2.3 The role of the teacher and pedagogical support strategies to implement IPW

There is a variety of modes of inquiry in the sciences. Examples of such modes include: following a set of instructions to dissect a sheep heart, collecting and classifying different types of leaves, and following a set procedure to conduct a starch test or prepare a microscope slide. In addition, there is a diversity of contextual factors within the teaching and learning environment. Due to this diversity this study was therefore limited to one example of inquiry-based activity and that is investigative practical work (IPW). IPW encompasses the aspects of inquiry such as open-endedness and learner autonomy as espoused by various researchers (e.g. Edelson, Gordin, & Pea, 1999).

Open-ended activities are designed in ways that offer learners opportunities to solve problems in diverse ways. The degree of open-endedness of an activity depends on the extent or amount of guidance that is provided by the teacher or text book to the learners. The greater the extent of guidance provided the less open and more closed the activity is. With a decrease in the extent of guidance by the teacher or text book there is an increase in the level of learner autonomy or learner independence. In such situations the activities will be led and directed by the learners, with no constraints from the teacher (Wellington, 1994).

Reformed science curricula require learners to participate differently from traditional practices. For example, the role of the learner need to change from one of a passive receiver of information engaging with teacher-prescribed or teacher-directed activities to one which requires the learner to be actively involved in learner-directed activities (Anderson, 2007). By being actively involved the learner is expected to process information, interpret, explain, hypothesise, design their own activities and share authority for answers. By directing their own, activities, learners will be directing their own learning, designing and directing their own tasks which will be varied among the group of learners and the following aspects will be emphasised: reasoning, reading and writing for understanding, solving problems, building from existing knowledge and understanding, and explaining complex problems (Anderson, 2007).

For learners to successfully act out their roles as described above, they will need the support and guidance of the teacher who understands this changing demand towards reformation pedagogy. Such a teachers' role changes from a dispenser of knowledge to one who acts as a

coach and facilitator (Anderson, 2007). The coach and facilitator will need to help learners to process information instead of providing the information; communicate with groups of learners instead of individuals only; guide and coach learners' actions instead of directing their actions; facilitate learners' thinking instead of explaining conceptual relationships; and guide learners in the flexible use of resource materials instead of directing the use of textbooks (Anderson, 2007).

(a) Understanding the 5Es or learning processes

According to the NRC (1996; 2000) there are five essential features or learner activities or phases that are at the core of inquiry-based approaches to science teaching and learning. These stages are referred to as the 5 Es, or learning processes (Bossé, Lee, Swinson & Faulconer, 2013) through which science lessons should progress. The 5 Es represents: e*ngagement*, e*xploration*, e*xplanation*, e*laboration* or e*xtension*, and e*valuation*. Each of these phases entail the following:

Phase 1: **[Engagement]**

Learners **engage** with a scientific question, event, or phenomenon. This relates with their prior knowledge or preconceptions, creating dissonance or disequilibrium with their own ideas, and/or encourages them to learn more.

Within the classroom, a question that is forceful and fruitful enough to drive an inquiry generates a "need to know" in learners, thereby stimulating additional questions of "how" and "why" a phenomenon occurs (Bossé et al., 2013).

Phase 2: **[Exploration]**

Learners **explore** ideas through hands-on experiences, generate, formulate and test hypotheses, arrive at solutions to problems and create explanations for what they observe (NRC, 2000).

Phase 3: **[Explanation]**

Learners analyse and interpret information, create their ideas, construct models, and simplify concepts and **explanations** with teachers' and other sources of scientific knowledge. "Explanations are ways to learn about what is unfamiliar by relating what is observed to what is already known" (NRC, 2000, p.35).

Phase 4: [**Elaboration**]

Learners expand their new knowledge, understanding and abilities and apply what they have learned to new situations. Alternative explanations may be reviewed as they participate in discussions, compare results, or check their results with those proposed by the teacher or text book. A critical aspect of this characteristic is ensuring that learners make the appropriate relationship between their results and scientific knowledge (NRC, 2000).

Phase 5: [**Evaluation**]

Learners together with their teachers critique and assess what they have learned and how they have learned it (NRC, 2000). Engaging in discussions and conversations may result in adjusting or re-visiting explanations or it could support and strengthen the connections learners make with respect to the evidence, established scientific knowledge, and their proposed explanations. In this way they could "resolve inconsistencies and ambiguities and strengthen an argument" (NRC, 2007).

Such learner-centred, activity-based inquiry lessons allows learners to explore science as a process, also align with inquiry skills related to IPW as well as the scientific and engineering practices identified in the *Next Generation Science Standards (NGSS)* (Achieve Inc., 2013). The *NGSS* was developed in response to the advancing scientific and technological world in order to educate learners to be scientifically literate and ready to pose questions, define problems, investigate, analyse data, construct explanations and design solutions. It emphasises not only the need for knowledge about inquiry but also the practice of inquiry. It was developed through an open collaborative process amongst experts and stakeholders in science and engineering in the USA. The *NGSS* not only provides an opportunity to improve science education, but also to improve learner achievement by creating contexts for learning and comprehending core knowledge and engaging in scientific and engineering practices. It also prepares learners for broader understanding and deeper levels of scientific and engineering investigations later on even after high school and college and beyond. (Achieve Inc., 2013). This therefore, alludes to the application of *NGSS* for life-long learning as well.

In considering the imperatives of IPW a very close alignment appears among the 5Es or learning processes, inquiry skills related to IPW, and the *Next Generation Science Standards (NGSS)* as illustrated in Table 3.3.

Table 3.3: Relationship among the 5Es, Inquiry Skills and the *Next Generation Science Standards (NGSS)*

	Essential features or learner activities / 5Es (NRC, 2000)	**Inquiry Skills related to IPW**	**Next Generation Science Standards (Achieve Inc., 2013)**
1.	**Engagement**: ➢ Learners engage with scientific question, event or phenomenon. ➢ Helps to connect with what they already know and generates a 'need to know' in learners.	➢ Generate questions and identify problems	1. Asking questions (science) and defining problems (engineering)
2.	**Exploration:** ➢ Learners investigate ideas through direct experiences. ➢ Give importance to evidence, which allows them to develop and evaluate explanations that answer scientifically oriented questions to support ideas	➢ Formulate hypotheses ➢ Make predictions ➢ Design investigations ➢ Conducting the ➢ investigations ➢ Collect, record and transform ➢ data	2. Developing and using models 3. Planning and carrying out investigations 5. Using mathematics, information and computer technology, and computational thinking
3.	**Explanation:** ➢ Learners' analyse and interpret data, construct their ideas and build models. ➢ Give importance to evidence, which allows them to develop and evaluate explanations by clarifying concepts and explanations with teacher or other sources of scientific information	➢ Analyse and interpret data ➢ Discuss the data ➢ Evaluate data ➢ Generate justifiable conclusions	4. Analysing and interpreting data 6. Constructing explanations (science) and designing solutions (engineering) 7. Engaging in argument from evidence
4.	**Elaboration:** ➢ Evaluate their explanations by extending understandings and abilities and apply it to new situations	➢ Application of concepts and processes in a different situations	8. Obtaining, evaluating, and communicating information
5.	**Evaluation:** ➢ Learners together with teacher reviews and assess their learning and how they have learned it. This process helps to identify preconceptions and/or misconceptions or contradictions and these could then be resolved.	➢ Communicate findings	

The information in the Table 3.3 shows how the inquiry skills with respect to IPW as well as the scientific and engineering practices of the *NGSS* can be accomplished in a science lesson by following the 5Es or learning processes. The 5Es has the potential to assist learners in becoming life-long science learners capable of devising solutions to scientific questions and problems based on evidence and communicating the ideas in a public forum. This therefore, warrants teachers to constantly question and monitor their own strategies and practices so as to ensure that they are providing learners with meaningful scientific investigations rather than 'cookbook' type activities (Llewellyn, 2002). While step-by-step instructions are necessary for certain tasks such as doing a verification starch test or preparing a microscope slide, or dissecting a sheep's kidney, it however, reduces the cognitive challenge if procedural instructions to 'open investigations' such as IPW are given without providing learners opportunities to question these.

The Life Sciences curriculum of South Africa as contained in the *NCS* (DoE, 2003) and *CAPS* (DBE, 2011b) also espouses the essential features of inquiry-based teaching and learning, as illustrated in Table 3.3, by virtue of the assessment standards of LO1 and the skills of SA2 (represented as inquiry skills).

Although the educational potential for inquiry learning is significant, this learning cannot be achieved by merely placing learners in the midst of a complex scientific field for free-reign investigation (Germann, Aram & Burke, 1996). Learners may still not have the necessary prerequisite knowledge for such activities and therefore will need to be guided and supported by teachers. The South African Life Sciences curriculum ensures that there ought to be a gradual surrendering of much of the control by the teacher in the lessons involving practical investigations from Grades 10 to 12.

If IPW as an example of inquiry is to be successfully implemented with the promotion of learner autonomy and learner independence, then the role of the teacher and the nature of the pedagogical support that is provided to learners need to be thoroughly understood so as not to confuse it with the traditional teacher control. Teacher control refers to the degree to which the teacher determines what is done and how it is done.

In order to achieve the outcomes of IPW, teachers will therefore need to possess the necessary pedagogical knowledge, skills and resources to guide and facilitate inquiry-based teaching and learning (Onwu & Stoffels, 2005). The implementation of activities such as, IPW require minimum teacher guidance and a reduction or surrendering of control by the teacher (Minstrell & van Zee, 2000; NRC, 1996; Krajcik et al., 1994; Roth & Roychoudhury, 1993). This therefore entails teachers designing and providing activities or tasks with appropriate instructions for learners to implement their knowledge and skills about scientific inquiry when solving problems in the classroom. Hence, some degree of learner autonomy or learner independence is called for in the practice of IPW. This will therefore, warrant the learners to be able to think critically, creatively and logically and to be able to consider alternatives when engaging in such lessons (Newman, Abell, Hubbard, McDonald, Otaala, & Martini, 2004).

The role of the teacher will now warrant a change to that of a facilitator to provide the necessary and appropriate pedagogical support for learners to engage with IPW. Toth, Morrow and Ludvico (2009) were able to determine two different perspectives on teaching investigations based on three phases of problem-solving during scientific inquiry. One perspective suggests that the best way to teach scientific inquiry is by providing learners with authentic experiences that resemble the real-world environment of scientific laboratories (Roth, 1995). Another perspective focuses on the practical constraints of classroom environments and suggests the incremental assistance of learners' inquiry learning experience (Bell et al., 2005; Rezba, Auldridge, & Rhea, 1999). The three phases referred to by Toth et al., (2009) involves searching the task environment, evaluating data and reasoning by mapping new knowledge to prior understanding as espoused by Fay and Klahr (1996). This focus is no different from the imperatives of the transformed South African Life Sciences curriculum (DoE, 2003b & 2005b). This active search for knowledge and understanding implies a constructivist approach to learning.

According to Fradd and Lee (1999) current knowledge on strategies to promote a learner-centred environment for scientific investigations is limited. Research conducted in this respect has identified questioning, role modelling, and teacher feedback as teacher support strategies for learners (Ramnarain, 2011; Villanueva-Hay

& Webb, 2007; Wu & Hsieh, 2006). Such strategies describe the guidance the teacher gives learners in order to facilitate their progress when conducting investigations.

(b) Questioning

Questioning by both teacher and learners as a pedagogical support strategy, which usually leads to observations/experiments is a significant aspect of this initiative and forms an essential part of classroom discussion (Chinn, 2007). In a traditional, structured practical activity where the teacher dominates, the type of questions posed by the teacher are usually closed-ended, which are information seeking and learners are inevitably prevented or discouraged from articulating their thoughts (Chinn, 2007). In addition, such questions also have the function of controlling the teaching-learning situation (Lemke, 1990). In open-ended, learner-centred investigations the teachers' role is that of providing pedagogical support. In such instances the teacher is encouraged to pose "productive type of questions which calls for reflection and analysis that promote a view of science as a dynamic search for answers" (Ramnarain, 2011, p. 93).

Many studies have highlighted the importance and value of questioning skills (E.g. Hofstein, Navon, Kipnis, Mamlok-Naaman, 2005; Hofstein, Shore, & Kipnis, 2004; Yip, (2004); Cuccio-Schirripa & Steiner, 2000; Dori & Herscovitz, 1999; Shodell, 1995; Shepardson & Pizini, 1993; Zoller 1987). Asking questions is regarded as a constituent of thinking skills for learning tasks and as a crucial step in the problem-solving process (Zoller, 1987; Shepardson & Pizini, 1993). Similarly, as pointed out by Cuccio-Schirripa et al., (2000) questioning as a thinking processing skill is structurally rooted in the thinking procedure of critical thinking, creative thinking, and problem solving. According to Shodell (1995) when learners are provided with opportunities to ask questions it has the potential to improve their creative thinking and other higher order thinking skills. Studies by Hofstein, et al., (2004) and Hofstein, et al., (2005) found that when learners are provided with opportunities to engage in inquiry in the laboratory enhanced their ability to ask more and better higher cognitive level questions, to hypothesise and to suggest questions for further experimental investigations.

(c) Role Modelling

Role-modelling as a support strategy allows learning without doing things through trial and error (Bandura, 1977). It is a form of learning that uses humanist and social learning theories (Rogers, 2003). A key feature of this type of learning is the experience that learners bring to the classroom. According to Bandura (1977) social learning involves a continual learning interaction between a person and the environment. Learning occurs when an individual observes another. The negative aspect of such a strategy is that learning may be passive whereby learners merely imitate the teacher. This strategy is similar to teacher demonstrations.

(c) Teacher Feedback

Research has shown that meaningful teacher feedback to learners either, verbally or in writing enhances learning and improves learner achievement. Stenger (2014) contends:

"*When people are trying to learn new skills, they must get some information that tells them whether or not they are doing the right thing. Learning in the classroom is no exception. Both, the mastery of content and, more importantly, the mastery of how to think require trial-and-error learning"* (p. 2).

Teacher feedback could also be linked with the strategy of questioning. In this way feedback is immediate. However, not all feedback is equally effective. It could even be counterproductive, especially when provided predominantly in a negative or corrective way.

Whilst there are no direct answers to the question: *What exactly are the most effective ways to use feedback in educational settings?* Research has provided some tips for providing learners with the kind of feedback that will increase motivation, build on existing knowledge, and help them reflect on what they have learned.

These tips include

- Being specific as possible with information about what learners are doing correctly or incorrectly, that is, being explicit about what needs to be done in order to achieve the desired outcome (Stenger, 2014).

- Providing feedback immediately rather than later. Studies have shown that participants who were given immediate feedback showed a significantly larger increase in achievement than those who had received delayed feedback (Stenger, 2014).

- Addressing learner's progression toward a goal. Hattie and Timperley (2007) reported that effective feedback is most often oriented around a specific achievement that learners should be working toward. When giving feedback, it should be clear to students how the information they are receiving will help them progress toward their final goal (Stenger, 2014).

- Feedback ought to be presented carefully. The manner in which feedback is given can have an impact on how it is received. This implies that at times even the most well-meaning feedback can come across the wrong way and reduce a learner's motivation. Examples of such instances are, when learners feel that they are being too closely monitored, they might become nervous or self-conscious and as a result, disengaged from learning; learners may sometimes interpret feedback as an attempt to control them or tell them how they *should* be doing something rather than guidance on how to improve (Stenger, 2014).

- Learners should be involved in the process by being provided with information about their own performance. It is important for them to know whether they have mastered the knowledge or skill. By providing them with such information it helps them recognise their shortcomings and eventually develop strategies for addressing such shortcomings (Stenger, 2014).

For the successful implementation of IPW the pedagogical approach to teaching science should therefore promote the development of inquiry lessons with relevant guidance and support wherever possible. In addition, planning and preparation for such lessons by the teacher will determine the nature of classroom interactions and the application of inquiry skills (Haefner & Zembal-Saul, 2004). One of the characteristics of effective teachers is their confidence in the classroom. This confidence is due to their high degree of lesson preparation (Erdamar & Alpan, 2013).

Teachers may have different ideas about the meaning of inquiry-based instruction. At one extreme there are teachers who believe they are practicing inquiry by posing questions to their learners and guiding them toward answers. At the other extreme there are teachers who feel they are not practicing inquiry unless they allow their learners to engage in lengthy open-ended tasks that directly mimics scientific research (NRC, 1996). It is therefore imperative for teachers to understand the variety of pedagogical strategies and how these may be utilised to achieve their lesson outcomes.

3.2.4 Science process skills and the 'scientific method'

When scientists conduct research, they engage in scientific inquiry whereby they use a number of skills, known as science process skills such as, observing, inferring, posing questions, planning and conducting experiments, predicting, measuring, classifying, identifying assumptions, and communicating findings (NRC, 1996) and use many methods referred to as the 'scientific method' to develop scientific knowledge. It must be emphasised that there is no single 'scientific method' used by all scientists (Storey & Carter, 1992). Instead, scientists use a variety of approaches to develop and test ideas and to answer research questions. Some of these methods may include observations, descriptive studies, experimentation, correlation, and epidemiological studies (SCORE, 2009). What is referred to as 'the scientific method' is the very basic description of how experiments are done. It shows for example, a general sequence of steps, which underlies the principles of investigation to be followed (Storey & Carter, 1992). These principles or steps may include, stating the problem, generating and stating a hypothesis, planning the investigation through controlling and manipulating variables, conducting the experiment, collecting and recording data, analysing data and stating conclusion. While it is important for school-based learners to understand this basic sequence that is involved in an investigation it must also be emphasised to the learners that it is not the only way in which scientific investigations are conducted (Storey & Carter, 1992). The 'scientific method' is highlighted in the Life Sciences curriculum so that the learners who are novices at carrying out authentic scientific activities will be provided with opportunities and guidance to engage with it in order to understand some aspects of the scientific enterprise. In order to understand the scientific enterprise learners should be provided with authentic investigations to engage with the processes and not just be told about it for the purposes of memorising the steps.

Figure 3.1 below illustrates the basic steps of the scientific method that is followed when conducting an experiment.

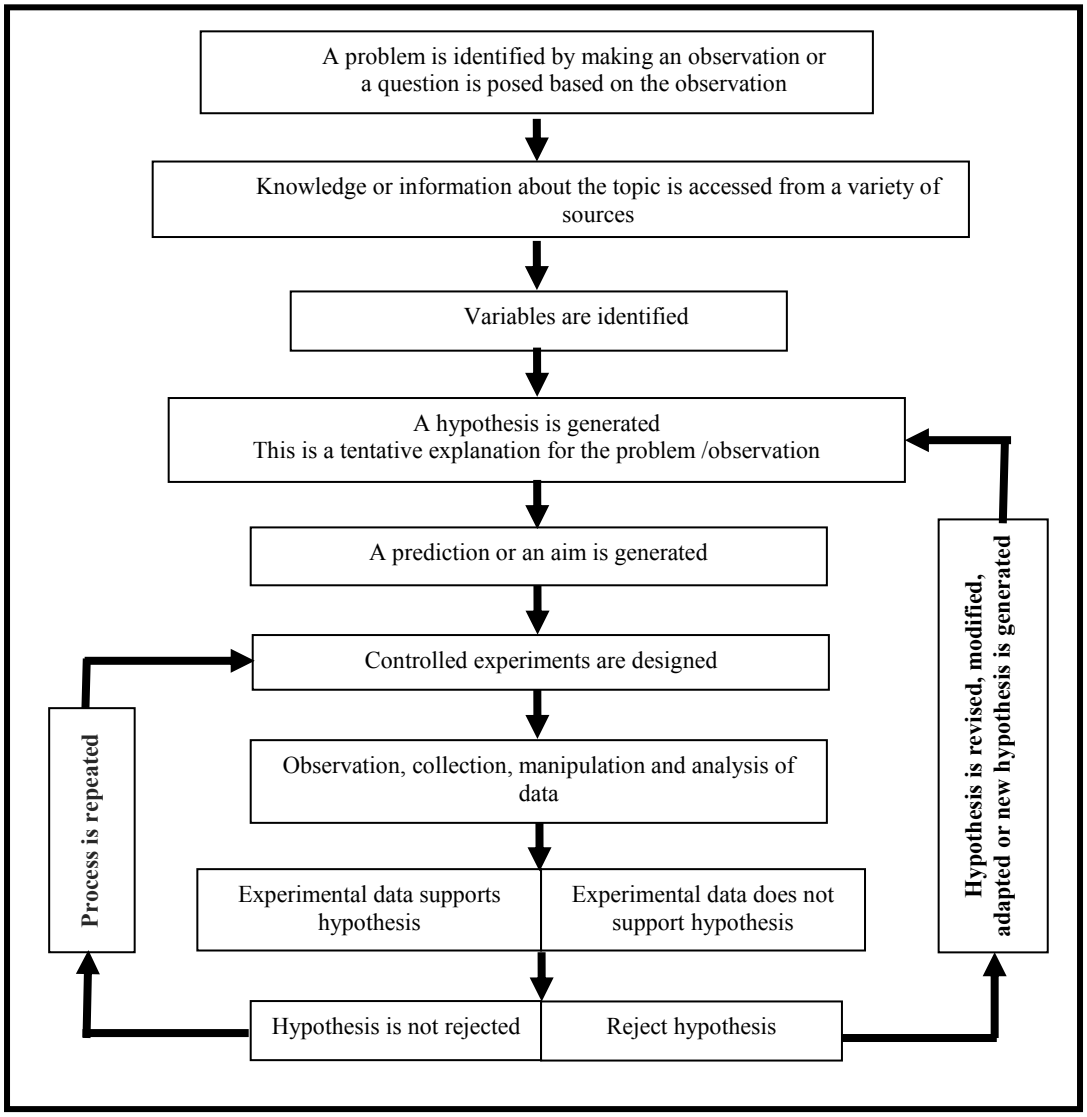

Figure 3.1: The sequence of steps in the scientific method (DoE, 2005b)

While many useful points are embodied in this procedural scheme, it can easily be misinterpreted as linear and 'cookbook'. This linear, stepwise representation of the process of science may be simplified, but it does however, capture the core logic of science that is, testing hypotheses that attempt to explain observed phenomena by collecting data that is valid and reliable.

3.2.5 Common aims of authentic research and science classrooms

Teachers and learners have to recognise that their science laboratory/classroom is different from the context of a scientists' research laboratory (Jenkins, 1998). However, despite these differences, there are many common aims between the research laboratories and the science classrooms. Table 3.4 lists some of these common aims.

Table 3.4: Common aims of research laboratories and science classrooms

No.	Common aims of research laboratories and science classrooms
1	Identify problems
2	Generate hypotheses
3	Design investigations
4	Predict, speculate or make assumptions
5	Collect and record data
6	Analyse data
7	Transform data
8	Discuss data
9	Generate conclusions
10	Provide suggestions for transferring information emanating from one investigation to the solving of other problems

Source: Adapted from Marques et al., (2000)

The similarities referred to in Table 3.4 above, are however, not in sync with the aims or strategies related to traditional routine practical work, which are concerned with detailed step-by-step, structured instructions to which the learners must adhere without being allowed to challenge or question the procedures and the design of the investigations. However, these aims are in alignment with inquiry-based teaching and learning and hence, investigative practical work (IPW). They are also imperatives for investigative practical work (IPW) as espoused by the South African National Curriculum Statement (*NCS*) for Life Sciences as indicated in Chapter One of this study. The degree of open-endedness of IPW is dependent on the extent of guidance that is provided by the teacher or textbook.

Investigative practical work (IPW) as an example of IBTL is a method of teaching and learning by inquiry. It enables learners to integrate and internalise the spirit and processes of scientific inquiry by providing them with opportunities to investigate and find out things for themselves. It entails giving learner's opportunities to develop research questions and testable hypotheses (Stoddart, Abrams, Gasper, & Canaday, 2000) in pursuit of open–ended tasks, which are directed by the learners (Edelson, Gordin, & Pea, 1999). It could also be seen as an opportunity for developing thinking skills (Friedlander, Nachmias, & Linn, 1990).

Furthermore, it could be seen as a way of enhancing learners' knowledge of science as a process and their conceptions of science knowledge.

3.2.6 The nature of inquiry activities: Full Inquiry and Partial Inquiry activities

Many researchers, such as Klahr (2000) and the *NSES* (NRC, 1996), characterise an inquiry process as consisting of several steps as indicated in the general 'scientific method' and as represented in Figure 3.1.

According to Bell, Smetana, and Binns, (2005) two important conditions must be satisfied in order to determine whether an activity involves scientific inquiry. Firstly, the activity/task must involve a research question which has the potential to be answered through a scientific investigation. The second condition is that the activity or task must involve analysis of data in order to answer the research question. While it is important that learners must be involved in data analysis themselves, the learners do not necessarily need to collect their own data in order to satisfy this condition (Bell et al*.,* (2005). Instead, data could be presented to learners for analysis. What is important to be evaluated here is, whether learners are doing their own data analysis and interpretations in order to draw conclusions and answer the research question (Bell et al., 2005). While this might be acceptable in cases where the data gathering process is an elaborate one and difficult in a school setting, it is important that the data collection process and / or the experimental design be provided to learners together with the data so that they can engage with it in a critical manner.

The notion of an inquiry activity being satisfied if it involves only two aspects of investigations namely, the inclusion of a research question and an analysis of data, is problematic because this will be in sync with the definition of a partial inquiry and not that of IPW as indicated for this study.

The *NSES* acknowledges that not all inquiry is truly deserving of this title and therefore distinguishes between "full-inquiry" and "partial inquiry" (NRC, 2000, p. 143). In spite of the general consensus and approval of this definition of inquiry, there is a significant amount of dispute and deliberation in this regard (e.g., Lehrer & Schauble, 2006; Fortus, Hug, Krajcik, 2006; Duschl & Grandy, 2005; Ford, 2005; Kuhn, 2005; Sandoval, 2005; Krajcik, Blumenfeld, Marx, Bass, Fredricks & Soloway, 1998). At one extreme, the inquiry process is regarded as a simple control-of-variables strategy that can be taught to learners in a single

short session (Klahr & Nigam, 2004) and at the other it is a complex and evolving activity which defies simple characterisation (Lehrer & Schauble, 2006), with many other conceptions intermediate between these two (NRC, 2007; Zimmerman, 2007).

The nature of the inquiry activities will determine the complexity of the investigations. The complexity of the investigation given to learners is dependent on the extent of guidance and information provided by the teacher to the learners. The greater the extent of guidance provided for the activity the more closed the investigation and vice versa.

Wellington (1994) refers to different types of investigations across a continuum from closed – ended activities which involve a single pathway and a single answer, teacher–led and teacher-directed with structured guidance at all stages to open–ended activities with many possible routes and solutions, led by learners and with no direction, no structure, no guidance and no constraints from the teacher. Wellington (1994) illustrates his framework diagrammatically and refers to it as 'dimensions of investigational work'. This framework is represented in Figure 3.2.

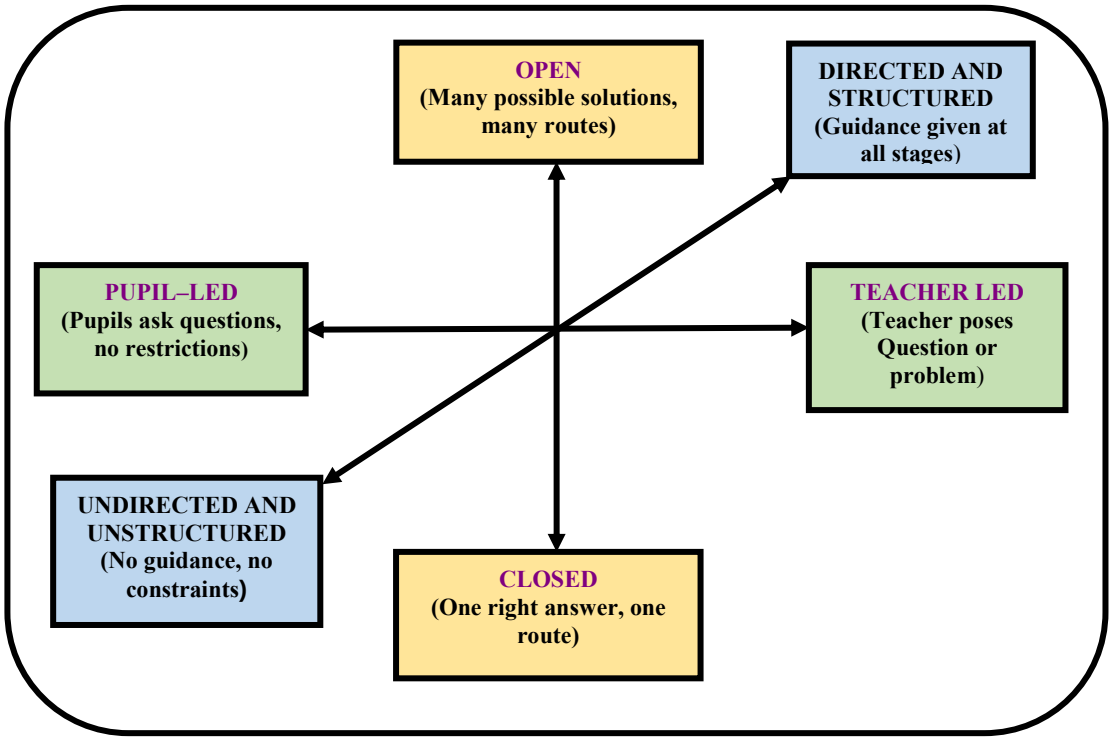

Figure 3.2: Dimensions of investigational work (Wellington, 1994)

As can be determined from the above, not all inquiry activities are equivalent. Inquiry lessons can be described as either full or partial with respect to the five essential elements of inquiry

identified in *NSES* (NRC, 1996) and as illustrated in Table 3.3, namely, engagement, exploration, explanation, elaboration and evaluation.

Full-inquiry lessons make use of each of the five elements described in Table 3.3, namely, where learners engage with scientifically oriented questions; give priority to evidence by exploring; formulate explanations from evidence; elaborate on such findings and evaluate and justify their explanations by communicating these to others. However, any individual element can vary with respect to how much direction comes from the learner and how much comes from the teacher. For example, inquiry begins with a scientifically oriented question. This question may come from the learner, or the learner may choose the question from a list. Alternatively, the teacher may simply provide the question (Bell et al., 2005).

Inquiry lessons or activities are described as partial when one or more of the five essential elements of inquiry are missing. For example, if the teacher provides an explanation for the expected results then that lesson is regarded as being partial inquiry. Lessons that vary in their level of direction and the extent of guidance and support provided by the teachers are needed to develop learners' inquiry abilities. When young learners are first introduced to inquiry lessons, they are not developmentally or academically ready to benefit from full inquiry activities. Hence, partial or guided inquiry lessons usually work for such learners (Bell et al., 2005). The information in Table 3.2 earlier in this chapter illustrates this increasing complexity or openness from Grades 10 to 12 for the South African Life Sciences curriculum. Guided inquiry may also work well when the goal is to have learners study particular science concepts. In contrast, a full or open inquiry is preferred when the goal is to have learners sharpen their skills of scientific reasoning. Hence, the participants who were chosen for this study were Grade 12 teachers and their learners, since these teachers and learners should have had at least three years of experience engaging in IPW in the FET phase.

Zion and Sadeh (2007) proponents of inquiry as methods of teaching science identified three levels of inquiry, which are mainly distinguished by the degree of learner involvement / autonomy at the planning stage of the inquiry process. These include:

* Structured inquiry at level 1, in which the teacher sets up the problems and processes;
* Guided inquiry at level 2, in which the teacher poses the problem and the learners determine both processes and solutions;
* Open inquiry at the third and most demanding level in which, the teacher merely

provides the context for solving problems that learners then identify and solve.

Herron (1971) identified four levels of openness for inquiry in science activities. Based partly on Herron's work, Rezba, Auldridge, and Rhea (1999) developed a four-level model of inquiry instruction, which was subsequently modified by Bell et al., (2005). This model of inquiry instruction illustrates how inquiry-based activities can range from highly teacher-directed to highly learner-directed, based on the extent of guidance provided to the learner. This model is illustrated in Figure 3.3.

	Level of Inquiry	How much information or guidance is given to the learner?		
		Question	Methods	Solution
Teacher-Directed	1- Verification	✓	✓	✓
↕	2- Structured	✓	✓	
	3- Guided	✓		
Learner--Directed	4- Open-ended			

Figure 3.3: Four-Level Model of Inquiry (adapted from Bell et al., 2005)
Note: the ticks (✓) indicate the information given to learners.

Level-1 and Level-2 inquiry activities are characterised as low level activities (Bell et al., 2005). They are often referred to as 'cookbook' approaches in that the procedure is typically laid out for learners in a step-by-step sequence. Level-1 inquiry activities provide learners with the research question and the method by which the research question can be answered (Bell et al., 2005). In addition, the expected answer to the research question is known in advance. In these activities, learners confirm or verify what is already known.

Level-2 inquiry activities, referred to as structured inquiry, are those in which learners are given a research question and the prescribed procedure, but the answer to the research question is not known in advance. Changing the instructions can easily change a Level-1 inquiry activity to a Level-2 inquiry activity (Bell et al., 2005). For example, if learners were taught a concept that provides them with the expected results of an inquiry activity before they perform it, the activity would be considered Level-1. However, if the inquiry activity were completed prior to learning the concept such that learners do not know the expected outcome, it would be considered a Level-2 activity (Bell et al., 2005).

Level-3 and Level-4 inquiry activities are characterised as high level inquiry activities, as they require significant cognitive demand on the part of the learner (Bell et al., 2005). In Level-3 inquiry activities, learners are presented with a teacher-posed research question, but the learners devise their own methods and solutions to answer the question. In this "guided inquiry," learners practice investigation design. Level-1 or Level-2 inquiry activities can be transformed into a Level-3 activity by having the learners develop their own, teacher-approved method to answer the investigation question (Bell et al., 2005).

Level-4 inquiry activities are those in which the learners are responsible for choosing the investigation question, designing their own procedure for answering the question, and developing their own solutions to the problem (Bell et al., 2005). Only after learners have completed activities at the first three levels are they prepared to tackle the open inquiry of Level-4. This second perspective is supported by numerous studies illustrating learners' difficulties during inquiry learning. For example, in science settings learners have difficulties with scientifically controlling experiments; they may use biased interpretation of empirical data, and often formulate inappropriate inferences to explain the results obtained (Toth et al., 2002; Chen & Klahr, 1999; Kozlowski, 1996.)

In the South African context, 'hands-on' type of activities may be classified as Level-1 and Level-2 type of inquiry activities, while 'hypothesis-testing' may involve grades from Level-3 to Level-4 kinds of inquiry activities in the *NCS* (DoE, 2005b). However, in the CAPS version of the curriculum, the only prescription is that all seven skills must be assessed by the end of an academic year (DBE, 2011b). According to the *CAPS* policy (DBE, 2011b) in Grades 10 and 11 three practical pieces are prescribed together with a practical examination while in Grade 12 only three pieces of practical work are prescribed for formal assessment. Furthermore, the *CAPS* policy does not indicate how the seven skills ought to be assessed. Hence, the focus becomes one of process skills. The danger of such a situation is the independent or out of context address of these skills. Therefore there is the potential of minimising learner practice and understanding of the role and use of the process skills threaded together in a complete investigation. This state of affairs is no different from somebody learning the steps of a dance, but not having the opportunity of practising these steps in a dance.

3.2.7 Teachers' practices and learners' performance in inquiry activities

The traditional approaches to teaching science, 'chalk and talk' and routine 'recipe' or 'cookbook' practical work, are only slowly giving way to more modern investigative

approaches managed in part by learners (Praia & Marques, 1997, cited in Marques, et al., 2000). As far as present types of 'routine' or 'traditional' practical work matters, it is of concern that many learners are unable to give a clear account of what they have been doing during these activities and the reason for doing it (Hodson, 1990). In addition, Yip (2007), illustrates the poor understanding of the concept of hypothesis by learners. It is therefore apparent that deep-seated beliefs including attitudes have to be changed in order to encourage and enable a thorough and conscious, active participation of the learners. In other words, classroom experiences are tools enabling learners to improve their explanations about natural phenomena rather than the end of a process itself (Marques, Praia, & Futuro, (1996), cited in Marques et al., 2000).

According to epistemological thinkers such as Bachelard, Kuhn, Lakatos or Popper, truly investigative practical work should be seen both in the context of problem solving and as an attempt to look for solutions to questions not already answered, rather than being a verification activity. In other words, they have called for practical work, which is investigative or inquiry in nature (Marques et al., 2000). Some science educators may disagree with these epistemological thinkers, if a great deal of emphasis is placed on the contextual, and practical aspects of the learning environment, including the demands of written examinations, the competence and commitment of teachers and the availability of resources. However, when one examines the imperatives of the South African Life Sciences curriculum particularly LO1 for Grade 12 (refer to Table 3.3) one would notice that it calls for more open-ended and less structured tasks.

The lack of knowledge and understanding creates severe restrictions on a teachers' ability to plan, prepare and implement lessons that will help learners develop an image of science that goes beyond the familiar 'body of knowledge' (Gallagher, 1991). Very often, teachers incorrectly equate inquiry activities with highly structured activities. Researchers have referred to such activities as traditional because it seems to be involved in transmitting information from the teacher or the textbook to the learners (Prawat, 1992; Howard, McGee, Schwartz & Purcell, 2000; Kang & Keys, 2000). The highly structured tasks which require learners to follow it step-by-step as a 'cookbook' (Hofstein & Lunetta, 2004) serves to verify or confirm established knowledge (Tsai, 2002). In addition, Tsai (2003) also points out that before carrying out the 'inquiry' activity the teacher explains the procedure to be followed and that such procedure merely serves the purpose of memorising the scientific truths.

From a constructivist viewpoint, following such rigid and structured procedures does not take into account the importance of learners' prior knowledge and such knowledge is therefore of no consequence in such a learning environment (Windschitl, 2002; Roehrig & Luft, 2004). Furthermore, such structured and closed activities do not allow for debates and discussions. Also, such lessons usually lack deep probing questions to guide learners' thinking (Feyzioglu, 2012). Instead, the types of questions posed are of the lower cognitive type which leads the learners towards the teachers' expected answers and is therefore information seeking (Chinn, 2007). In open-ended activities, which are learner-centred and which encourages learner autonomy, the type of questions posed by the teacher to support such independent learning should be of the constructive type, which calls for analysis, reflection and metacognition. Such questions should provoke thought and encourage learners to justify their actions (King, 1994).

The structured activities involve the use of worksheets prepared by the teachers or from a textbook. Learners follow the instructions in these worksheets and continue to perform the task at hand. At the end of the lesson the teacher provides the learners with the expected results usually without considering learners' results and understanding (Peers, Diezman & Watters, 2003).

Teachers may lack confidence in managing a class of learners who may seem to be disorderly if they engage actively and co-operatively with their peers and the teacher and therefore opt to design lessons in which they can have a greater degree of control (Bryan, 2003; Roehrig & Luft, 2004; Tsai, 2003).

While inquiry instruction involves active learner engagement and is therefore learner-centred, not all hands-on activities advocate inquiry. Similarly, not all inquiry activities need to be hands-on. It is possible for learners to engage in inquiry through analysing existing data (Bell et al., 2005) as indicated earlier, without the need for hands-on data collection. All inquiry–based activities do not have to engage learners in activities where they must design investigations and therefore physically carry them out on their own.

Learners often have an objectivist orientation towards science, viewing the process of science as looking for facts rather than as the creation of knowledge (Tobin, Tippins, & Hook, 1995). Penner and Klahr (1996) found that learners failed to recognise the spirit of inquiry as a

process that combines a physical or experimental and a cognitive or intellectual aspect. That is, a process which attempts to understand natural phenomena. Learners often see practical investigative tasks as activities aimed at obtaining pre-determined results. Hence, they plan their experiments accordingly or their teachers prepare the plans for them.

Learners' scientific inquiry skills are dynamic and it is therefore dependent on internal cognitive factors as well as external contextual or environmental factors. These factors include interest and motivation in science, epistemological understanding of the scientific process and its value (Smith, Maclin, Houghton, & Hennessey, 2000), familiarity with the area of investigation, and the context of the activity (Germann, Aram, & Burke, 1996; Kuhn, Garcia-Mila, Zohar, & Andersen, 1995), environmental support of inquiry activities (Greeno, 2001), and communication abilities (Germann, Aram, & Burke, 1996).

For learners to be able to design and carry out valid investigations on their own they will need a great deal of support and plodding in the lower grades. Therefore, there is a need for teachers to provide the necessary guidance and scaffolding for inquiry instruction to enable learners to develop their abilities and understandings of inquiry to the point where they can confidently design and conduct their own investigations from start to finish (Peters, 2009).
In this regard the *NCS* intended to groom Grades 10 and 11 learners to be able to engage with open-ended tasks in Grade 12 (DoE, 2005b), as illustrated in Table 3.2. This study also determined whether teachers do provide such scaffolding and the extent to which the teachers' knowledge and beliefs determined this. In addition, while learners need not have to physically carry out the investigation it is important for them to have an idea about the design of the investigation, so that they could develop their skills of speculation and predicting and sharpen their ability to think critically and creatively.

According to Bell, Blair, Crawford, and Lederman (2003) allowing learners to engage in 'hands-on' activities alone will not necessarily help to develop the appropriate understandings of the concepts or content and processes. Instead, learners need to actively engage in purposeful conversation and thinking about scientific knowledge and science processes. In this respect Bell (2008) contends that understanding the nature of science requires debate, discussion and reflection on the distinctiveness of scientific knowledge and the scientific processes. Moreover, learners need to be guided through the process of learning *about* science as they *do* science (Schwartz, Lederman, & Crawford, 2004). Effectiveness of learning

'about' science by 'doing' science has been shown to be successful when there is a linking of science concepts to process skills instruction (Binns, Schnittka, Toti, & Bell, 2007). The implementation of this approach allows learners to learn about the nature of science and science knowledge and processes as they develop the skills necessary to do science. The teacher explicitly links science concepts to activity-based lessons incorporating science process skills such as, observing, measuring and classifying (Schwartz et al., 2004).

In order to benefit fully from inquiry activities, both epistemic demand and regulation of cognition appear to be crucial components in all stages of learners' investigative efforts (Bell et al., 2003). Epistemic demand can direct the learner on the task and can improve the outcome of the inquiry learning activities. In order to facilitate the activity of epistemic demand, the learner may be guided in small steps to the execution of a certain inquiry stage. For example, guidance in the hypothesis generating stage may provide the learner with an example of a statement for a hypothesis. These instructions provide learners with general and cognitive strategies that may be used to perform their learning tasks (Hong, McGee, & Howard, 2001). However, epistemic demand alone may not be enough to change learners' view of inquiry (Bell et al., 2003). They will need to use regulation of cognition to monitor the solution (Hong, McGee, & Howard, 2001; Kluwe & Freidricksen, 1985). In addition, the nature of guidance and support provided by the teacher is also an important factor. Dewey's comment was apt when he argued that,

> *"We learn by doing and by thinking about what we are doing"*
>
> (Rowe, 1978 p. 216).

According to Hong et al., (2001) the regulation of cognition and not the knowledge of cognition is a predictor in open-ended tasks.

3.2.8 The benefits of inquiry-based teaching and learning (IBTL) approaches

Studies have shown that the effect of inquiry approaches to science education is favoured over traditional methods (Furtak, Seidel, Iverson, & Briggs, 2012). Inquiry-based lessons have the following characteristics or advantages in that they are learner-centred and/or learner directed; activity-based; skills based and they encourage the development of higher-order thinking; and it involves an active search for knowledge (Makitalo-Siegl, Kohnle, & Fischer, 2011; Wilke & Straits, 2005; Dewey, 1964; Novak, 1964).

A recent study in South Africa on the benefits of autonomous science investigations in the Natural Sciences (Ramnarain, 2010) found that the majority of teachers and learners surveyed perceive the following benefits when learners are actively involved in doing investigations:

- Their interest in the subject is stimulated.
- Their conceptual understanding is improved.
- They develop scientific skills.

(Ramnarain, 2010).

In addition, it develops independent learning through learner autonomy. In other words it promotes a highly self-directed, constructivist approach to teaching and learning science (de Jong & van Joolingen, 1998). They also encourage an understanding of unusual elements in the environment (Haury, 1993) by focusing on learning through experimenting and scientific reasoning (Kolloffel, Eysink, & de Jong, 2011) and participatory thinking (Dewey, 1964).

Furthermore, investigations in the science classroom involve complex cognitive processes that require learners to have an understanding of a range of science concepts and science processes or investigation procedures (Lubben & Millar, 1996). However, Quintana, Zhang, and Krajcik (2005), established that inquiry may be too complex for learners due to the range of metacognitive and cognitive activities. But with appropriate guidance and support it is possible to overcome such difficulties. Ramnarain (2011) for example, found that teachers' use of appropriate questioning strategies during investigative practical work (IPW) enabled learners to understand more clearly the hypothesis they were to investigate. According to *NSES* (NRC, 2000) learners enjoy engaging in scientific inquiry when provided with the necessary guidance and support.

Moreover, they have the potential to participate enthusiastically in learning about the nature of science. Besides, meaningful and active engagement with science concepts and investigation procedures of science are necessary ingredients for learning and understanding science (NRC, 1996; 2000). Inquiry-based approaches to teaching and learning encourage learners to develop scientific habits of mind (Schwartz et al., 2004) that will enable them to be effective decision-makers beyond the classroom (NRC, 2000).

Other studies have illustrated that learners find practical work relatively useful, effective and enjoyable as compared with other science teaching and learning activities (Maeots & Pedaste,

2014). In a survey conducted by Cerini, Murray and Reiss (2003), of the 1400 learner-respondents, 71% chose 'doing an experiment in class' as one of the three methods of teaching and learning science they found 'most enjoyable'. The study, however, does not elaborate on what constitutes 'enjoyable'. It is therefore possible for activities to be enjoyable but with no or limited enhancement on the understanding of concepts. A smaller proportion (38%) selected it as one of the three methods of teaching and learning science they found 'most useful and effective' (Cerini, Murray, & Reiss, 2003).

A study by Newton, Driver and Osborne (1999) reported that learners' interest in, and curiosity for science are high when they are young (6 years–12 years) and decrease, as they grow older (13 years–16 years). This is ascribed to the changes in science teaching and learning activities performed by secondary school learners. In the lower grades school science teaching and learning generally focuses on the processes of science rather than on the content (NRC, 1996) while in the secondary school science the focus is on established science knowledge or content (Chiappeta & Adams, 2000).

Studies also show that involvement in inquiry learning can lead to improved attainments in understanding science content as well as higher order thinking skills such as, critical thinking and problem solving (Bransford, Brown, & Cocking, 2000). It also supports the development of more appropriate understandings of science and scientific inquiry, and that prospective teachers became more accepting of approaches to teaching science that encourage children's questions about science phenomena (Haefner & Zambaul-Saul, 2004). Hence, in order to apply both the approaches at the primary school and at the secondary school there is a need to integrate the processes and products of science during science lessons. Science educators have suggested that when properly developed, inquiry-based activities have the potential to enhance learners' meaningful learning by promoting constructivist learning, conceptual understanding, and their understanding of the nature of science (Wilke & Straits, 2005; Hofstein & Lunetta, 2004; Hodson, 1990; Lazarowitz & Tamir, 1994; Lunetta, 1998).

Engaging in IBTL has the potential to develop higher-order thinking skills. Zohar and Dori (2003) include the following as examples of higher-order thinking in inquiry-oriented science education: formulating a research question, planning experiments, controlling variables, drawing inferences, making and justifying arguments, identifying hidden assumptions, and identifying reliable sources of information. These higher-order thinking skills are very much

in alignment with those that are developed during investigative practical work (IPW). Hypothetical thinking requires higher-order cognitive skills and an awareness of the thinking process itself that is, meta-cognition (Zohar & Dori, 2003).

The movement toward increased emphasis on creative and critical thinking skills across the curriculum arises from acknowledgement that learners learn best when actively constructing their knowledge and understanding, rather than by absorbing it. In this regard, King (1994) contends that learners need to be taught how to engage effectively in the knowledge construction process. In other words, learners ought to be taught to think critically.

The South African curriculum in this regard, also emphasises the development of critical and creative thinking skills as is evident by one of its 'critical outcomes' as indicated in section 2.3.1 (a) in Chapter Two, namely, *"Identify and solve problems and make decisions using critical and creative thinking"*.

Critical thinking skills are examples of higher-order thinking skills. Critical thinking skills can be defined in several ways, but most often it includes the following: the ability to analyse arguments, make inferences, draw logical conclusions, and evaluate all relevant elements, as well as the possible consequences of each decision (King, 1994). Critical reasoning is important in the development of scientific literacy, which emphasises scientific understanding and the process of critically and creatively thinking about the natural world (Maienschein, 1998). Hence, engaging learners in scientific inquiry helps develop scientific literacy and affords them the opportunity to practice science process skills (Schwartz et al., 2004). The results of a study by Chapman (2001), emphasising concepts and reasoning skills showed that development of critical thinking skills could be integrated successfully with the study of the process of science and that this approach was consistent with content learning. Hence, learners ought to be given opportunities to engage with stimulating and wide-ranging experimental and investigative tasks.

The researcher's previous study also showed the existence of a relationship between aims and objectives of biology education, scientific creative and critical thinking skills and general creative and critical thinking skills (Preethlall, 1996). These overlapping skills are predominantly those that are developed during IPW. This relationship is illustrated in Figure 3.4.

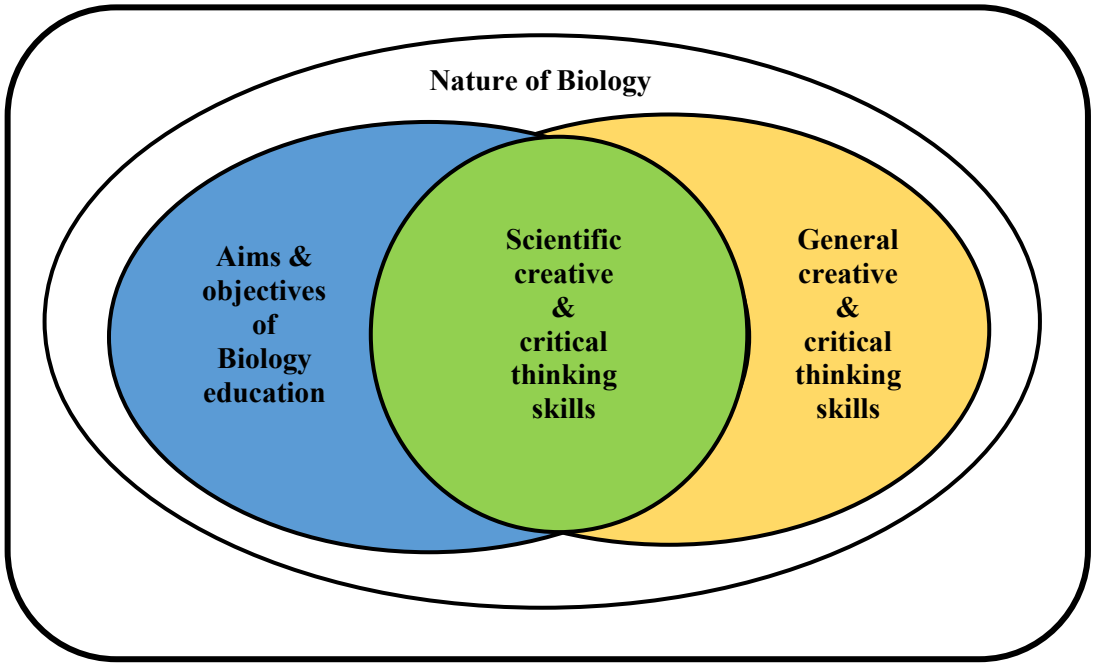

Figure 3.4: Relationship between nature of biology, aims and objectives of biology education, scientific creative & critical thinking skills and general creative and critical thinking skills

Hence, providing opportunities for learners to engage actively and autonomously, with limited appropriate guidance and support in IPW has the potential to achieve the development of higher-order thinking skills. Constructing knowledge and learning to think scientifically need not be adversarial processes. Various studies have shown that they can be synergistic (e.g. Edmondson & Novak, 1993; Zohar, Weinberger & Tamir, 1994).

In order for learners to obtain such benefits it is imperative for teachers to design their lessons in ways that would promote such achievements.

3.3 TEACHERS' KNOWLEDGE AND TEACHERS' BELIEFS

Teachers' knowledge and beliefs are vital for classroom interactions in which learners are provided with opportunities to develop thorough knowledge and understandings of how scientists develop justifications for phenomena in the world (Crawford, 2007). Knowledge and beliefs about teaching and learning are intertwined, since what one believes about teaching inevitably depends to a large extent, on one's knowledge as well as on one's beliefs about how learning takes place (Crawford, 2007; Mansour, 2009). It is therefore logical to assume that what teachers know and what they believe has a bearing on their decisions in

planning and preparation, before they enact or execute their decisions in the classroom (Crawford, 2007).

3.3.1 Teachers' Knowledge

The successful implementation of the transformed science curriculum depends on teachers' variety of knowledge such as, conceptual, procedural and pedagogical knowledge and beliefs about teaching and learning (Aguirre & Speer, 2000; Richardson, 1996; 2003; Zohar, 2006). In order to get learners to engage with and develop higher-order thinking, teachers must possess a high degree of subject matter knowledge, for example, in the field of Life Sciences, as well as good pedagogical knowledge on how to develop higher-order thinking through investigative practicals in a learner-centred environment. In order to support students' learning in transformed science curricula which emphasises inquiry and thinking, teachers will require "sophisticated knowledge" (Zohar, 2006 p. 332). This special brand of knowledge does not occur in curriculum materials nor is it "scripted into instructional routines" (Zohar, 2006 p. 332).

According to Barak and Shakhman (2008) teachers do not merely conform to knowledge about teaching but rather construct new knowledge on the basis of their initial conceptions or ideas and adapt accordingly. Bransford et al., (2000, chap. 8) in their book 'How People Learn', contend that teachers learn from the continual monitoring and adjustment of good practice, from understanding their environmental milieu, including the learners, schools, curriculum, and instructional methods.

According to Gess-Newsome (1999), knowledge is empirically based, non-emotional, sensible, slowly developed, and well organised. Shulman (1886; 1987) was responsible for highlighting the importance and distinction among 'subject matter knowledge' (SMK); 'general pedagogical knowledge' (GPK); and 'pedagogical content knowledge' (PCK). These categories of knowledge he regarded as separate but interacting. Shulman (1987) identified other categories of knowledge such as, Content knowledge (CK); Curriculum knowledge; Knowledge of learners and Knowledge of educational contexts. To provide a framework for teacher knowledge, SMK, GPK and PCK remained at the forefront of what is essential to effective science teaching.

This study uses the following broad knowledge domains in order to gather and interpret data:

(a) Subject Matter Knowledge (SMK)

According to Grossman (1989) knowledge of subject matter is the basis of a discipline which includes factual information, organizing principles, and central concepts. As indicted in section 1.3, teachers' knowledge constitutes the 'intellectual tools' of the Life Sciences teacher. Part of the 'intellectual tools' is subject matter knowledge. Teachers need to have subject matter knowledge that may be different in some respects to other Life Sciences specialists, for example horticulturists, medical biologists and other academics. In order to teach effectively teachers need to be in possession of good subject knowledge (Goldschmidt & Phelps, 2010). Rogan (2004) indicates that the majority of Grade 11 and 12 teachers do not have adequate post-school qualifications in the subject that they teach. At the most they have between 1 to 2 years of post-school studies. Rogan (2004) therefore contends that this limited content knowledge of teachers has led to teachers' over-reliance of a transmission mode of teaching and superficial use of content. Hence, there is a need for the attention of SMK for the development of PCK (Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008).

People who are specialists in a discipline may be distinguished from others in at least three ways. Firstly, they know a great deal of specific content, that is, facts and ideas. Secondly, they would have formed a variety of complex relationships among these pieces of content. Thirdly, they understand how to solve new problems and how to produce new ideas within the subject. In other words such persons would have acquired habits, perspectives, and a host of other intellectual and personal dispositions that could be regarded as part of their SMK (Kennedy, 1998). SMK within the context of this study constitutes the content, the organisation and structure of the content and the methods of inquiry.

The content refers to the facts, principles or laws that have been generated over many years of inquiry into the subject.

The organisation and structure of the content refers to the numerous relationships among facts and ideas which students of the discipline have developed. While a subject may contain numerous specific facts or ideas, these are not meaningful in their disconnected, inert forms. Instead, they are judged to be important through the patterns

of relationships that are created among them. It is the patterns, and the networks, among these facts and ideas that form a body of knowledge. Understanding of fundamental concepts and how the concepts are related and organised that enables teachers to use their subject matter knowledge for teaching (Bertram, 2011).
The methods of inquiry include a set of assumptions, rules of evidence, or forms of argument that are or can be used by those who contribute to the development of the discipline (Kennedy, 1998). Within the context of this study the methods of inquiry relate to 'the scientific method' or methods of investigation or procedure.

This construct of subject matter knowledge (SMK) refers to Life Sciences content, concepts and the various laws and principles as well as the methods of inquiry. Life Sciences teachers acquire a foundation of subject-specific knowledge in different ways, for example, through formal academic studies, work-related experiences, and informal, everyday experiences (Crawford, 2007). In addition, it must be noted that science knowledge is not static but is tentative in nature. It is therefore imperative for teachers of science to keep abreast of the latest developments with respect to their discipline knowledge especially those aspects which are relatively new in the Life Sciences curriculum. This however, becomes fairly difficult for teachers of Life Sciences in the South African context who are still trying to cope with the many curricula changes. This therefore becomes an added workload on their part.

For the purposes of this study, the first two sub-categories of SMK have been combined and referred to as 'content or conceptual knowledge' while the remaining sub-category will be referred to as 'procedural knowledge or knowledge of inquiry'.

(i) Content or Conceptual knowledge

When knowledge is based on concepts that drive factual pieces of information from the world around us, it is called conceptual knowledge and focuses on regrouping big understandings and corresponding relationships among them. Conceptual knowledge highlights connections between the concepts themselves. This type of knowledge can only be acquired through purposeful and reflective learning (Deng, 2007).

Possessing in-depth content or conceptual knowledge is imperative not only for teaching itself but also for the critiquing, evaluation and selection of learning and

teaching study materials, such as, text books, laboratory equipment, teaching aids and computer software. Having in-depth knowledge of content and concepts provides teachers with the necessary confidence to plan prepare and teach in a variety of ways to facilitate understanding by learners. Such knowledge and understanding helps to clarify alternative conceptions and misconceptions confidently. Palmer (2006) and Posnanski (2002) maintain that science teachers' content knowledge plays an important role in their beliefs about science teaching and learning. Accordingly, in-depth science content knowledge coupled with teaching methods creates a foundation for effective science teaching. Possession of such a high knowledge base helps to increase the level of teacher effectiveness by reducing the level of anxiety about science and science teaching (Bryan, 2012; Palmer, 2006; Posnanski, 2002).

In addition, McNamara (1991) states that teachers with a high level of conceptual knowledge may teach in more creative and unusual ways whilst those with little or low level conceptual knowledge may be cautious to venture into unusual approaches and may stick to what they are comfortable with. To be dynamic in the classroom, it is therefore imperative for teachers to constantly upgrade their subject matter knowledge to keep abreast with changes in a subject area (Nicholson & Duckett, 1997). Keeping abreast of conceptual knowledge may be achieved in various ways. For example, there are different views on how teaching experience affects conceptual knowledge. While Leach and Moon (1999) argue that conceptual knowledge changes or enhances through teaching practice and more particularly, by the resources that may be used during classroom practice, Prestage and Perks (2000), on the other hand maintain that conceptual knowledge is only advanced if teachers reflect on their teaching practice beyond a consideration of simple classroom events. Hence, teachers need to consider their own understanding of the subject matter if practice is to affect conceptual knowledge. A study by Rollnick et al., (2008) of one of their subjects lends support to this assertion. Thus the important aspect in changing conceptual knowledge appears to be how a teacher internally reflects on a teaching experience rather than just the experience itself. There is a lack of research into whether teachers who are confident in their conceptual knowledge bring particular attributes to their classroom practice (Leach & Moon, 1999; McNamara, 1991) Medwell, Wray, Poulson, & Fox (1998) found that effective teachers of literacy had extensive knowledge about the subject. Askew, Brown, Rhodes, Wiliam and Johnson (1997) in their study of effective teachers of

Mathematics found that the teachers did not necessarily have high qualifications in Mathematics but they were more likely involved in mathematics-specific professional development over a prolonged period. The results of these two studies may not be necessarily contradictory. It is perhaps the in-depth and appropriate understanding of the relevant content or conceptual knowledge that makes the teachers effective practitioners (Askew et al., 1997). There is agreement amongst researchers that teachers' conceptual knowledge is important for the development of PCK and for effective teaching and learning (e.g. Rollnick et al., 2008; Alexander 2003; Hay McBer, 2000 & McNamara (1991). Shulman (1987) contends that conceptual knowledge is an integral part of teaching since it affects all aspects of the act of teaching and learning such as, planning and preparation. As indicated earlier, one of the hallmarks of an effective teacher is being well prepared for the classroom enactment (Erdamar & Alpan, 2013).

(ii) Procedural knowledge or Knowledge of inquiry

Knowledge that shows how a task may be accomplished by following certain rules and by being performed through a process of following step-by-step instructions is referred to as procedural knowledge (Star, 2002). Various researchers have demonstrated that both procedural and conceptual knowledge are interrelated and that one can be derived from the other (e.g. Sahdra & Thagard, 2003; Thagard, 2005; Hao, Li & Wenyin, 2007; Rittle-Johnson, Siegler & Alibali, 2001). According to Sahdra and Thagard (2003) procedural knowledge is about how to think. Furthermore, it has been shown to be linked to changes in knowledge, skills and tasks (LeFevre, Smith-Chant, Fast, Skwarchuk, Sargla, Arnup, Penner-Wilger, Binsanz, & Kamawar, 2006). Both procedural knowledge as well as conceptual knowledge forms can be developed through different methods and techniques; or they contribute to the development of different methods and techniques (Howe, Tolmie, Tanner, & Rattray, 2000; Johnson & Star, 2007; Kırkhart, 2001). Understanding procedural knowledge is accomplished when connections are established between the sequence of stages in 'the scientific method' such as, proposing the question, generating hypotheses, and the collection and interpretation of data (Harlen, 2000; Traianou, 2006). This also entails knowing how to control the relevant factors for examining some phenomenon, performing a certain task or completing an activity (Traianou, 2006).

Dealing with questions and queries from learners require an excellent grasp of SMK. For teachers to recognise good questions, for example, about a biological process like photosynthesis, how to generate a hypothesis, relevant variables, issues about reliability and validity, or to help their learners gain the background knowledge necessary to develop good inquiries they need to possess a good understanding of SMK (Carlsen, 1993). Lin and Chen (2002) found that teachers who regard science as an accumulation of a body of facts tended to teach by following the textbook and emphasised getting 'right answers' that is, answers from the text book. Hence, teachers' views and understanding of subject matter can influence their conceptions of inquiry, and the subsequent use of inquiry in the classroom.

(b) General Pedagogical Knowledge (GPK)

The definition and what constitutes pedagogy is somewhat obscure, not easily defined and is complex. Watkins and Mortimer (1999) define it as 'any conscious activity by one person designed to enhance the learning of another' (p3).

Alexander (2003) believes that pedagogy involves classroom interactions as well as its associated deliberations and considerations. It involves the knowledge, skills and values, which teachers must possess in order to justify the variety of decisions that are taken in this dynamic process.

Leach and Moon (1999) define pedagogy by describing a pedagogical setting. According to them a pedagogical setting is created by the practice, interaction and experiences of a teacher and a specific group of learners.

Shulman (1987) considers general pedagogical knowledge as the styles of classroom management and organisation that go beyond subject matter. This therefore, implies that pedagogy is a dual activity in which the learner is an active participant and therefore creates a social interaction between teachers and learners.

According to Everston and Weinstein (2006) classroom management seeks to ensure that the learning environment is orderly and conducive for meaningful engagement by the learners. Marzano and Marzano (2003) also argue that learner achievement and learning is dependent on the teachers' management strategies in the classroom.

Classroom management strategies are based on two theories namely, constructivist or behaviourist theories (Brannon, 2010). Behaviourist strategies allows for the teacher to have greater control and display of authority in the classroom. Hence, in order to maintain and sustain an orderly environment, teachers would engage in lessons that are structured in ways to ensure that they have control of what goes on in the classroom. The constructivist approaches on the other hand allow for the surrendering of control by the teachers (Yasar, 2008) and thereby allowing for a greater and more productive engagement in the science classroom. The teaching and learning of 'higher order thinking skills' is regarded as GPK since GPK addresses aspects such as, knowledge about how to ask questions about 'higher order thinking skills' or about how to assess inquiry learning. Metacognitive knowledge of specific thinking skills, including generalisations about them is normally part of what constitutes GPK (Brant, 2006; Turner-Bisset, 2001). Since GPK deals with classroom organisation and management, instructional models and strategies, and classroom communication and discourse, understanding the processes involved in IPW as being examples of higher order thinking skills would help teachers prepare and act appropriately for the efficient implementation of IPW.

Rollnick et al., 2008 describes GPK as:

> *"Understanding what counts as good teaching, the best teaching approaches in a given context, informed by knowledge of applicable learning theories"* (p19).

According to Richards and Farrell (2005) GPK empowers prospective teachers with self-awareness of the educational system as a whole together with an understanding of learners supported by studies in psychology and pedagogy. Furthermore, this type of knowledge paves the way to build pedagogical expertise as well as an understanding of curriculum and materials which do not necessarily derive from Life Sciences. It also allows teachers to have a better understanding of their educational context which transcends the Life Sciences classroom. Researchers such as Loveless (2002) have acknowledged that teaching is a complex activity and that there are many factors which affect classroom practice. Teachers of Life Sciences may have only specialised in the Sciences and it is therefore imperative for them to be aware of the dynamics of the educational system as a whole. Teachers therefore have to have a greater knowledge and

thinking than what they would have gathered from their teacher education courses on teaching practice. Understanding learners and how learning occurs, understanding of curriculum, curriculum change and instruction, teacher's position in the school, previous teaching experience, teacher training and a teacher's own experience of learning are some of the factors that affect teaching practice.

Brant (2006) along with Turner-Bisset (2001) and Schon (1983) maintain that GPK is often learned from practice and with interaction with others (Johnson 2006; Borg, 2009). However, classroom practices may lead to adaptations and modification and improvement to GPK, which the teacher may come to bear as a student teacher, if s/he engages in the process of monitoring and adjustment. Nonetheless, if it is plausible that GPK is often learned from practice it is feasible to therefore assume that the teacher participants in this study would have developed a great sense of GPK which should allow them to practice or implement investigative practical work (IPW) fairly successfully in their respective classrooms.

(c) Pedagogical Content Knowledge (PCK)

Shulman (1987) referred to pedagogical content knowledge (PCK) as knowledge of how to teach a particular topic in a subject area so that it makes learning easier for learners. This Shulman (1987) argued may be achieved through the use of various strategies such as, clear explanations, concept maps, appropriate analogies and presenting learning in interesting, motivating and even entertaining and unusual ways. The use of such strategies during teaching helps learners understand concepts better, helping to identify possible misunderstandings and difficulties (Loughran, Berry, & Mulhall, 2012). In this way the teacher will be able to provide the necessary support and scaffolding to bring about conceptual change.

Shulman's (1987) notion of PCK therefore distinguishes between the different domains of knowledge for teaching. PCK does not only represent the blending of content and pedagogy in order to present a topic. Instead its utility is based on the teachers' knowledge and understanding of how the various aspects of specific topics is organised, represented, and adapted to the diverse interests and abilities of learners, and then presented to learners.

The implication therefore is that teachers' require a good understanding of SMK, knowledge of the curriculum, general pedagogical knowledge, and pedagogical context knowledge in order to develop PCK as teachers' …

"Own special form of professional understanding" (Shulman, 1987, p.8).

The notion of PCK as espoused by Shulman (1986; 1987) above, shows that it goes beyond just knowledge of subject matter, but rather into the realm of subject matter knowledge for teaching. That is, as a form of teachers' (professional) practical knowledge (Van Driel, Verloop & De Vos, 1998).

Adler and Reed (2002) also concurs that content knowledge alone is not sufficient for teaching. Instead the further acquisition of knowledge for teaching a particular subject or topic, that is, PCK is necessary to make the learning process more accessible for the learner. Furthermore, it is not just the possession of good content knowledge that will develop a teachers' PCK, but teachers need to possess good conceptual understanding of the subject matter. That is, understanding the facts, ideas and the interconnectedness of these. GPK the teaching knowledge is fundamentally related to content knowledge (Alexander, 2003; McNamara, 1991; Brown & McIntyre, 1993). Loughran et al., (2006) argue that PCK does not merely involve the application of a teaching strategy because it works but it is about integrating knowledge of pedagogy and content so that the content is better understood by learners. In developing PCK teachers also need to understand such aspects as the learners' preconceptions or naive knowledge that they bring to the classroom and what makes the teaching of a particular topic easy and/ or challenging (Shulman, 1987).

There is however, much debate as to what these links are and how PCK is formed. It also requires an understanding of what happens at their junction before this is manifested in practice for example, curriculum saliency, and representations of concepts (Rollnick, et al., 2008). McNamara (1991) similarly suggests that it is not the case that content knowledge is simply added to GPK but that a teacher reflecting on classroom practice may create his or her own PCK. In this regard for example, Rollnick et al., (2008) found that one of the teachers was able to address some difficulties inherent in the teaching of a Chemistry concept in his classroom practice, despite his not having read such issues in academic papers. The authors were able to put this down to experience the teacher gained over the years. However, the potential of teachers

themselves to create their own PCK raises further debate on the relationship between the experiential knowledge and the theoretical knowledge of teachers. Goodson and Hargreaves (1996) suggest that teachers develop their skills from the interaction between experience and theory.

If this is the case then it implies that beginning or novice teachers can hardly learn PCK from a textbook, or a short course only. To develop PCK teachers need to explore instructional strategies with respect to teaching specific topics in practice. Also, they need to gain an understanding of learners' conceptions and learning difficulties concerning these topics (Lederman, Gess-Newsome, & Latz, 1994).

Literature conceptualised PCK as consisting of five components, namely, orientations towards science teaching; knowledge of the curriculum; knowledge of science assessment; knowledge of science learners; and knowledge of instructional strategies (Abell, 2008; Magnusson, Krajcik, & Borko, 1999). While teachers may possess these kinds of knowledge for teaching and knowledge of various teaching strategies, it is assumed that the introduction of the *NCS* and *CAPS* should therefore stimulate them into adjusting, adapting or changing their repertoire of strategies in order to make it relevant for the implementation of the new curriculum.

While knowledge of the curriculum is a constituent of PCK, within the context of this study it has been elevated to a category on its own in order to understand teachers' knowledge of the new curriculum and its impact on their practice. PCK also incorporates knowledge of learners' understanding of subject matter and knowledge of instructional strategies as conceptions for the purposes of teaching subject matter. Hence, this study concentrated on these three aspects for the following reasons:

- Knowledge of the curriculum will enable the teacher to determine what goals, content, skills and values need to be taught.
- Knowledge of science learners concerns understanding their abilities and interests about IPW.
- Knowledge of instructional strategies includes knowledge of representations such as models, and especially activities such as experiments or investigative practical work (IPW) for teaching a specific topic. The nature of IPW that will be designed

for a group of learners will depend on the knowledge that their teacher has of orientations towards science teaching, the curriculum, assessment, learners and instructional strategies.

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The South African Life Sciences curriculum assumes that teachers have developed adequate pedagogical content knowledge in order to implement the curriculum. Hence, the imperatives of the curriculum specify what concepts and skills need to be learned and understood by learners. For example, in practical work when analysing, interpreting and evaluating data, teachers will need to facilitate how learners are taught to recognise patterns and trends, and to critically evaluate information (DBE, 2011b). Furthermore, teachers must possess knowledge and understanding and strategies to teach investigations in the Life Sciences.

Despite the complex interaction between the sub-categories of PCK and GPK teachers require more than just the knowledge of how to teach within a particular subject, they also require appropriate conceptual and procedural knowledge that is, knowledge and understanding of the subject matter in order to implement IPW in the Life Sciences.

(d) Curriculum Knowledge

Shulman (1987) sees curriculum knowledge as knowledge of what should be taught to a particular grade of learners. It also requires knowledge of learners' learning potential, national syllabuses, school plans, and year plans. In addition, it requires teachers to take into account information contained in examination guidelines. According to Geddis and Wood (1997), 'curriculum saliency' refers to the teacher's understanding of the place of a topic in the curriculum and the purpose(s) for teaching it. Curricular saliency may be manifested for example, in teachers' decisions to leave out certain aspects of the topic, and in teachers' awareness of how a topic fits into the curriculum (Rollnick et al., 2008) or how various topics may be linked even though the topics may be presented separately in policy document and textbooks. Such competencies of the teacher cannot be independent of the teachers' understanding of SMK.

Within the South African context knowledge of the curriculum is of vital importance because teachers have been trained and have worked in different separate systems

during the apartheid-era. Democracy in South Africa has resulted in a single education system and hence, a common National curriculum.

As indicated in Chapter Two of this study various curriculum documents have been distributed to teachers. In addition, teachers have undergone training with respect to the curriculum requirements for the various subjects. Furthermore, in addition to a common curriculum being developed for all the Life Sciences learners in South Africa with respect to content, it also highlights and explicates certain aspects such as, details of LOs and SAs. The Life Sciences curriculum underwent more changes than other subjects as indicated in Chapter Two, sections 2.6 and 2.7. These changes could have influenced teachers' practice. Therefore curriculum knowledge has been elevated to a separate category from PCK in this study.

(e) Pedagogical Context Knowledge (PCxtK)

Rollnick et al., (2008) distinguishes between knowledge of students and knowledge of context. The authors refer to the nature of knowledge of students as *"Appreciation of students' prior knowledge, how they learn, their linguistic abilities, and interests and aspirations"* (p.19).

According to Rollnick et al., (2008) knowledge of context involves all the related factors that influence the teaching environment. It includes facts such as, the availability of resources and class sizes.

Within the context of this study 'pedagogical context knowledge' incorporates both categories of this definition that is, knowledge of the learners as well as knowledge of the context.

Barnett and Hodson (2001) contend that effective or successful teachers do not always teach in predictable ways and therefore, what they do to inspire and motivate their learners is not always immediately apparent. Accordingly, there is no package of instructions to inform student teachers on how to behave in each and every lesson (Barnett & Hodson, 2001). Instead good teachers work differently to suit a variety of situations which are affected by the various factors within the teaching and learning environment (Barnett & Hodson, 2001). This therefore implies that good teachers are capable of responding to changing contexts in appropriate ways (Barnett & Hodson, 2001).

Wells (1994) highlighted that classrooms are very diverse – within a school or across schools, districts and provinces. Individual learners have their own interests, abilities and limitations. According to Barnett and Hodson, (2001) individual teachers have particular styles of teaching that is based on personal beliefs, values and past experiences. Hence, together the teacher and learners make up a classroom community that is distinct, with its own possibilities and challenges. Therefore, teaching cannot be a simple matter of implementing curriculum packages. That teacher's pedagogical context knowledge that is, knowledge about the characteristics of the learners and the school environment, for example, the availability of equipment and other resources, is also crucial in the implementation of IPW. Numerous studies (e.g., Zohar, 2006; Richardson, 1996, 2003; Aguirre & Speer, 2000; Pajares, 1992; Prawat, 1992; Brickhouse, 1990; Nespor, 1987) have shown that the transition from a content-oriented and transmission mode of instruction to a process-oriented practice depends critically on teachers' pedagogical knowledge and beliefs about teaching and learning.
Despite the elusiveness of 'good teaching', some understanding can be gained into the knowledge, understanding, and skills that good teachers deploy in the classroom (Barnett & Hodson, 2001). In this regard, Heylighen (1996) refers to Lawrence Stenhouse's concept of praxiology, or knowledge about practice/theory, which was central to curriculum design. When teachers design and implement lessons they make use of more than just knowledge of subject matter (Barnett & Hodson, 2001). In fact it implied that teaching required important knowledge about teaching and learning.

Connelly and Clandinin (1988) combined early ideas about teachers' practical knowledge (Elbaz, 1981, 1983) and teachers' personal knowledge (Lampert, 1988) and came up with the idea of 'personal practical knowledge'. The important aspect of this 'teacher's knowing of a classroom' is that it is dynamic and not a pre-existing body of knowledge to be retrieved by teachers and later applied to classroom practice. It is subject to change, and situated in personal experience both inside and outside the classroom. (Clandinin, (1986 p.19) refers to this knowledge as "experiential, value-laden and oriented to practice"

Both inexperienced teachers as well as teachers with many years of experience, encounter periods of anxiety. Knowledge that enables teachers to feel more

comfortable in the classroom and to enhance their sense of self is likely to be embraced while knowledge that increases anxiety and makes teachers feel inadequate will be resisted or rejected (Clandinin, 1986). Teachers like learners, also have to integrate their understanding into the various social contexts in which they are located in ways that are socially acceptable. Often it is consensus within social groups that gives status and stability to knowledge and understanding, and provides the confidence that is needed for its effective deployment (Clandinin, 1986).

Hence, teachers' personal practical knowledge has two essential functions. Firstly, it provides teachers with a sense of personal control in that they need the comfort of knowing what they are doing and the confidence to feel that they can do it. Secondly, it provides them with a secure social location as a teacher. That is, they need to feel validated as a teacher (Clandinin, 1986).

The concept of pedagogical context knowledge within this study has been derived from the notion of 'knowledge of the milieu' after its proponents, Elbaz (1983) and Grossman (1990). They viewed 'knowledge of the milieu' as incorporating knowledge of the classroom, school, community and the Education Department. It was further enhanced and adapted by Adams and Krockover (1997) and Barnett and Hodson (2001) who included, professional knowledge as part of the education milieu/pedagogical context knowledge.

In summary, what a teacher knows about his or her subject matter (Crawford, 2007) (conceptual Life Sciences knowledge), in addition to what he or she knows about what investigative practical work entail (procedural knowledge or knowledge of inquiry), and what a teacher knows about classroom management and pedagogical strategies (general pedagogical knowledge), will determine the choice of the lesson structure. The teachers' pedagogical content knowledge will also determine how the teacher might interact with his or her learners with respect to a particular topic. In addition, teachers' understanding of pedagogical context knowledge will assist him/her in anticipating and meeting the various teaching and learning demands of the environment. Figure 3.5 towards the end of the chapter, illustrates the relationship and interplay between the different categories of teachers' knowledge and teachers' beliefs and its role in the teaching of investigative practical work (IPW).

3.3.2 Teachers' Beliefs

Although beliefs have been regarded as a significant and valuable psychological concept in education, it is also one of the most difficult to define (Savasci-Acikalin, 2009). The reason for this is that because a belief "does not lend itself to empirical investigation" (Pajares, 1992, p. 308). Mansour (2009) indicates that since teachers' beliefs tend to be more experienced-based and lacks a theoretical underpinning, it can therefore not be defined with any sense of clarity. Hence, different researchers provide different definitions for beliefs. For example, Pajares's (1992) review of literature reported that belief was defined in most studies as a "conceptual tool" (p.316).

According to Aguirre and Speer (2000) the education literature definition of beliefs concentrates on how teachers' cognition about the nature of teaching and learning impacts on their practice. Therefore, in this context beliefs may be regarded as, "conceptions" (Thompson, 1992, p.132), and as "world views" and "mental models" that shape teaching and learning and teaching practices (Ernest, 1989, p.250). Standen (2002) classified the definition of beliefs in terms of personal assumptions about relationships, knowledge and society; professional beliefs about teaching and learning; and beliefs about change and development.
Some researchers such as, Kagan (1992) refer to beliefs and knowledge as similar since they both guide teachers' actions and determine the decision making process. Other scholars, (eg., Gess-Newsome, 1999; Pomeroy, 1993; Richardson, 1996) have indicated that beliefs in comparison to knowledge are highly subjective, have a significant emotional component, include attitude, and are derived from significant episodes that one experiences, including episodes in classrooms and out of classrooms (Crawford, 2007).

Beliefs also includes feelings about the nature of learners, is value laden and may be developed on existing opinions or assumptions (Nespor, 1987). Nepor's (1987) work established beliefs as a theoretical construct and asserted that teachers rely on their core belief systems rather than academic knowledge when determining classroom actions. Such decision making is based on core affective constituents and assessments instead of step-by-step problem solving. He views teacher beliefs as an integration of knowledge and feelings acquired through teaching experience.

A study by Munby (1984) recognised that teachers are not likely to be convinced to adopt modern teaching strategies based solely on scientific evidence from research studies. Instead,

teachers will interpret and evaluate the effectiveness of such strategies for their particular contexts or learners. Munby (1984) concluded that the participant teacher in his study, had deep seated beliefs that steered her practice. The participant teachers' emphasis to teaching was pragmatic rather than theoretical. This meant that the participant teacher would review and filter new curriculum innovations for those that resonated with her core beliefs.

A cognitive framework for science teaching was published by Van Driel, Beijard and Verloop (2001). In this framework they portrayed beliefs as a subgroup of teachers' practical knowledge. Teachers' practical knowledge is regarded as being action-oriented, personal and context-bound, tacit and integrated. Together with beliefs, teachers' practical knowledge influence classroom practice. Van Driel et al., (2001) asserted that beliefs act as a "filter" through which newly acquired information passes before it is integrated into the knowledge base. This notion of beliefs serving as a filter for knowledge is similar to Munby's (1984) original assertion that teachers will search for aspects of reform-based practice that are compatible with their core beliefs.

Some researchers are of the opinion that beliefs are different from factual knowledge because beliefs can be doubted more than facts (Bingimlas & Hanrahan, 2010). Savasci-Acikalin (2009) distinguishes between beliefs and knowledge by suggesting that beliefs refer to suppositions, commitments, and ideologies and do not require a 'truth condition' while knowledge refers to factual propositions and the understandings that inform skilful action and must satisfy 'truth condition'. According to Mansour (2009) while knowledge often changes and is subject to be evaluated and judged, beliefs are 'static' and cannot be evaluated and judged because of a lack of criteria for such evaluation.

Teachers have individual beliefs in addition to entire belief systems that may be static, resilient and difficult to change. In addition, such belief systems may be more influential than knowledge in deciding on a teacher's actions (Crawford, 2007; Bryan, 2003; Nespor, 1987).
A teacher's beliefs may be complex and nested (Crawford, 2007), and it may constrain a teacher's ability to enact inquiry-based instruction (Crawford, 2007; Bryan, 2003). While teachers may believe that inquiry-based strategies for teaching science supports learner cognition and conceptual understanding, other beliefs related to the transmission of knowledge and coverage of content may be in conflict (Bryan, 2003; Bryan & Abell, 1999). It is therefore important to try and understand the Life Sciences teachers' beliefs, and how this influences the creation and enactment of investigative practicals in the classroom. The

interaction between knowledge and beliefs is complex. Therefore, decision making for classroom practice by teachers is a complex one (Bryan & Abell, 1999). This study will attempt to understand this complex interplay among teachers' knowledge, beliefs and practice.

For this study, the researcher subscribes to the notion of beliefs as espoused by Tobin, Tippins and Gallard (1994). According to these authors, the term 'beliefs' refers to all mental representations that teachers possess consciously and unconsciously in their minds, and which may be formed as a result of their experiences, both formal as well as informal (Mansour, 2009). From this perspective, all beliefs are personal constructs, which are influenced by knowledge, experience and societal backgrounds.

Research has shown that teachers' attitudes and beliefs are entrenched in an interrelating arrangement or network of belief systems (Jones & Carter, 2007). Keys and Bryan (2001) argued that every aspect of teaching is influenced by the attitudes and beliefs of teachers. Moreover, studies maintain that new knowledge about teaching and learning is created in relation to these existing networks of beliefs (Putnam & Borko, 1997). According to Haney, Czerniak, and Lumpe (1996) implementation of reform is a direct result of teachers' attitudes towards the reform actions, apparent social norms in their school context, and perceived behavioural control, or an assessment of the barriers and resources available to implement such actions. An individual's relevant beliefs underpin his/her attitudes, perceptions of social norms and perceptions of behavioural control and are thus indirectly at the root of the intention to implement reform-based teaching. Survey results have indicated that indeed, "teacher beliefs are significant contributors of behavioural intention" (Haney et al., 1996, p. 985). The study concluded that teachers' attitudes towards reform were the greatest contributor to the planned intentions. Since attitudes towards reform were so important, the authors asserted that developing positive attitudes could be the most important factor for achieving reform. They further suggested that feelings of self-efficacy or success with reform-based teaching experiences might foster positive attitudes about reform.

The findings of a relatively recent study by Savasci-Acikalin (2009) indicated that the relationship between teacher beliefs and practice is controversial and that it has a complex nature. Bryan (2003) and Haney, Czerniak and Lumpe (1996) support the assertion that teachers' beliefs have an essential role in teaching practices. They have argued that

educational reform efforts are doomed to fail if the emphasis is placed on developing specific teacher skills unless teachers' cognition and beliefs are also taken into account. However, it is still not fully understood how classroom practice is influenced by beliefs (Kagan, 1992; Luft, 2001; Richardson, 1996). This study will endeavour to shed more light in this regard.

According to Pajares (1992) teacher beliefs, like knowledge, influence the many decisions that teachers make. The concept of 'beliefs' is often used in science education research to express opinions that may result in findings or decisions about why teachers engage in classroom practices in the way they do (Beck & Lumpe, 1996). Furthermore, teachers' beliefs about teaching and learning always resemble traits of beliefs that are particular to their subject or discipline (Koballa, Graber, Coleman, & Kemo, 2000). Bandura (1996) considers beliefs to be the best indicators of why a person behaves, handles information, and makes decisions in the way s/he does.

Science teachers possess beliefs about teaching and learning that influence their performance and practice. Bryan (2012) and Riggs and Enochs (1990) contend that if teachers understand the nature of science and how students learn science this will assist in developing a set of beliefs that will guide practice and performance within the classroom.

Other studies, such as those of Brickhouse (1990) and Gallagher (1991) reported that teachers' beliefs about the nature of science as a body of knowledge, which is derived through empirical means and created by an inflexible, universal "scientific method" had resulted in the teachers teaching science with an inaccurate view of inquiry.

In an evaluation of a professional development programme which was aimed at developing inquiry-based teaching, Evans (2011) reported a long-term improvement in teachers' efficiency. This programme made use of activity based approaches to enhance teaching. Hashweh (1996) characterised science teachers into several categories based on their beliefs about the nature of science. His description of science teachers was based on the differences of teachers' epistemological beliefs about the nature of science. He also noted that the beliefs that the teachers held about the nature of science also influenced their classroom practices. On the basis of such observations he therefore characterised them as 'learning constructivists', 'learning empiricists', 'knowledge constructivists', and 'knowledge empiricists'. The empiricists (both learning and knowledge) did not recognise the importance of learners' prior

knowledge, but believed in reinforcement as a method of learning, and emphasised the scientific method as both a universal method for scientist and for science instruction. The constructivists (both learning and knowledge) on the other hand, sought and recognised learners' prior knowledge. In addition, they used a variety of teaching and learning strategies to promote the construction of conceptual understandings (Hashweh, 1996).

Teacher beliefs about learners and learning, such as their ability levels and interests or the need for drill and practice, represent challenges to implement IPW. Cronin-Jones (1991) conducted two case studies of teachers implementing a constructivist-based curriculum and found that both teachers held strong beliefs that science is a body of factual content and that learners did not have the necessary skills for autonomous learning. These beliefs led to teaching practices that did not match the intended curriculum.

A teachers' perception or beliefs about how learners acquire knowledge can have a powerful influence on how s/he will design instruction for her/his learners. In addition, it will also have a strong influence on her/ him in carrying out this instruction in the classroom. For example, if a teacher is concerned with how learners make sense of science concepts, then the teacher's goals of classroom practice may include strategies on how to promote learners' deep thinking, rather than approaches that will foster learner's rote learning factual and discrete information (Crawford, 2007).

Many studies have shown support with the *NSES* and have reported the importance for learners to understand the processes of science, or science as a discipline, which emphasises its tentative and social nature, rather than focus solely on the content or the procedure of science (Lederman et al., 2002; Matthews, 1994; Brown, Luft, Roehrig and Kern, 2006).

Teachers' beliefs about themselves also influenced teaching practice (Laplante, 1997). For example, when teachers regard themselves as the end users of science knowledge, and view science as a body of knowledge, their practice reflect these beliefs. As such they tend to employ more teacher-centred approaches where authority is regarded as the source of knowledge and is controlled and transmitted by the teacher. However, where teachers' hold a constructivist view about science and science teaching, where they believe knowledge is constructed within a social context then they are more willing to use open-ended science activities (Bryan, 2012; Woolfolk Hoy, Hoy, & Davis, 2009). Such teachers tend to practice

and employ a more problem-based approach to science teaching and learning (Brickhouse, 1990). This finding is more in line with the post-modern understanding of the nature of science.

Effective teaching resulting in the successful accomplishment of a specific teaching task can be influenced by a teachers' belief about his or her ability to plan and execute the sequence of actions imperative within a particular context (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). Gibson and Dembo (1984) maintain that, "Teachers who believe students' learning can be influenced by effective teaching (outcome expectancy beliefs) and also have confidence in their own teaching abilities (self-efficacy beliefs) should persist longer, provide a greater focus in the classroom, and exhibit different types of feedback than teachers who have lower expectations concerning their ability to influence student learning" (p. 570).
Teachers' learning, development and working performance is related to the degree of elaboration or sophistication of their system of epistemic beliefs. That is, the more sophisticated teachers' systems of epistemic beliefs are, the more they understand their workplace environment as a resource for learning and professional development (Harteis et al., 2010).

Studies by Lakshmanan, Heath, Perlmutter, and Elder (2011) on the impact of standards-based professional development on teacher efficacy and instructional practice found that there was also significant growth in the extent to which teachers implemented inquiry-based instruction in the classroom and a positive correlation was observed between changes in self-efficacy and changes in the use of inquiry-based instructional practices.

Khourey-Bowers and Simonis (2004) analysed the influence of programme design on achieving gains in personal science teaching self-efficacy and concluded that "Teachers' attitudes toward teaching science affect choices they make in classroom content and strategy." (p. 193). In addition, the role of science teachers' beliefs is significantly related to how they implement the curriculum (Bencze, Bowen, & Alsop, 2006; Laplante, 1997).

As elaborated above, the body of research indicates that teacher beliefs about the nature of science, perceptions about their learners, how learners learn science, and perceptions about themselves, greatly affect curriculum planning, preparation, teacher instruction, assessment and delivery of lessons. If teachers are to sustain the vision of the science curriculum

reformation as set out in the *NCS*, it is therefore important for those responsible for providing support to the teachers, for example, officials of the department of education, curriculum designers as well as teacher educators, to understand and carefully consider the role of beliefs and how they shape teachers' opinion and the practice of a reform-based science education programme, especially with respect to the implementation of IPW.

3.3.3 The relationship between knowledge and beliefs

While several distinctions between knowledge and beliefs have been recorded in the literature there are however, a number of important and fundamental resemblances. Pajares (1992) has indicated that beliefs influence and play a crucial role in the acquisition and interpretation of knowledge, task selection, and course content interpretation. Mansour (2008) goes on further to indicate that beliefs controlled the gaining of knowledge but knowledge also influenced beliefs. Thompson (1992) argued that, while it is very difficult to distinguish between beliefs and knowledge, it is important for educators and researchers to understand the distinction since it is possible for teachers to treat their beliefs as knowledge. Zembylas (2005) indicated that teacher beliefs are important components of teacher knowledge and like teacher beliefs, teacher knowledge is needed in understanding teachers' practice. In this regard, Standen (2002) stated that when it comes to understanding teachers' practices, it is crucial to consider the importance of teachers' knowledge and how it impacts on teachers' thinking. It is possible to get a better understanding of the two constructs, knowledge and beliefs by examining the relationship between them and by considering beliefs as a form of knowledge (Mansour, 2009). Beliefs may be regarded as a form of personal knowledge (Nespor, 1987) or teachers' professional knowledge (Kagan, 1992).

Figure 3.5 illustrates this relationship.

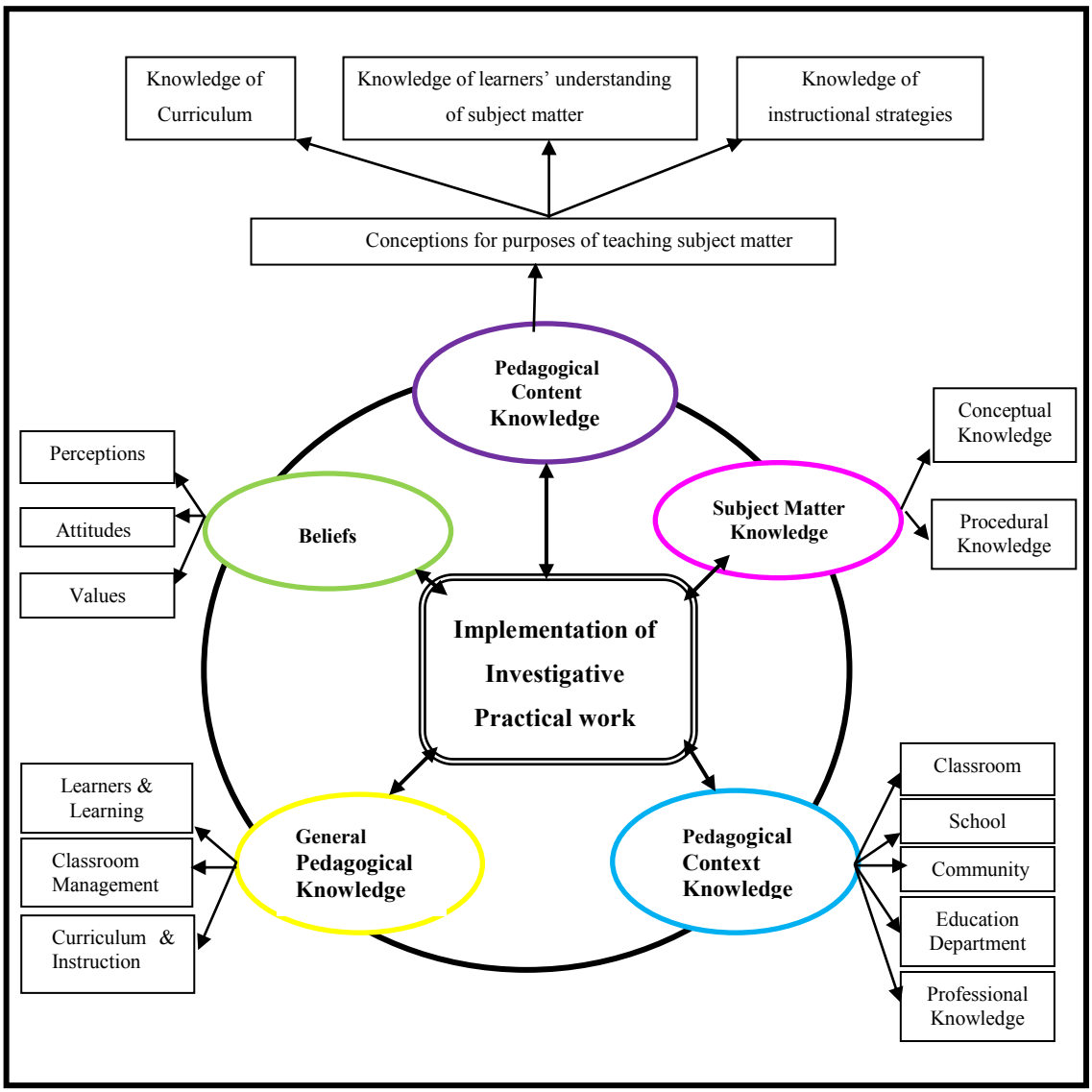


Figure 3.5: A Model of teachers' knowledge and teachers' beliefs and its relationship with teaching practice (adapted from: Adams and Krockover (1997) and Barnett and Hodson (2001))

3.4 CONCLUSION

The review of the relevant literature supporting this study reveals that promoting inquiry teaching and learning in science classrooms may help enhance scientific literacy. Various studies have highlighted the different skills and attributes that are required in the development of improved scientific understanding. However, implementing inquiry-based teaching and learning is not an easy and straightforward task due to the existence of several barriers. It has been argued that one of the major barriers for implementing inquiry practices in science classes is teachers' knowledge and beliefs about teaching, learning, and classroom management. A number of researchers (e.g., Nespor, 1987; Pajares; 1992; Richardson, 1996) have found that teachers' beliefs influence their practices. Furthermore, teachers' knowledge

drives the decisions they make in their classrooms, while teachers' epistemological views about science influence their beliefs about instructions and classroom practices (Lederman, 1992). Other studies have shown that teachers' beliefs about learners, learning, teaching, and the nature of science also influence teaching practices.

The chapter that follows will delve into the theoretical and conceptual frameworks, namely, constructivism, conceptual change theory, epistemological beliefs about teaching knowledge and the changing role of the teacher in relation to curriculum change.

CHAPTER FOUR

THEORETICAL AND CONCEPTUAL FRAMEWORK

4.1 INTRODUCTION

The aim of this chapter is to review and discuss literature relevant to the theoretical and conceptual frameworks that underpins this research. This chapter has six sections to it. The first section, under this heading of 'introduction' outlines the structure of the chapter. The second section under the heading 'constructivism', discusses the constructivist theory of learning and its place in science education with particular focus on inquiry-based teaching and learning. Constructivism is the overarching theory that underpins the study. The third section discusses 'conceptual change' in science teaching and learning. The fourth section discusses 'epistemological beliefs about teaching knowledge' and its impact on teaching practice with particular reference to inquiry-based teaching and learning. The fifth section discusses 'the changing role of the teacher due to curriculum reform'. The penultimate section summarises the structure of the theoretical framework by illustrating the inter-relationship among the different concepts. The last section is a brief concluding paragraph.

The discussion that follows highlights the alignment between the imperatives of the South African Life Sciences curriculum with respect to IPW and the principles of constructivism. In addition, the interaction of the concepts or constructs of 'conceptual change', 'epistemological beliefs' and 'the changing role of the teacher due to curriculum reform' and how these relate to the principles of constructivism is the lens through which teachers' knowledge, beliefs and practices with respect to teaching and learning IPW in the Life Sciences classroom was analysed and interpreted.

4.2 CONSTRUCTIVISM AND ITS APPLICATION TO THE TEACHING AND LEARNING PROCESS

The role played by Life Sciences teachers' knowledge and their beliefs about teaching and learning of science, particularly investigative practical work in the current study are discussed within the constructivist paradigm. To answer the key research questions and analyse and interpret the results of the study a theoretical framework is constructed based on the description of 'inquiry-based' teaching and learning. Table 3.1 in Chapter Three highlighted the similarities between the imperatives of the South African Life Sciences curriculum and its alignment to inquiry-based teaching and learning. The discussion which follows will illustrate

how the South African Life Sciences curriculum, particularly the imperatives of IPW and inquiry-based teaching and learning are aligned with the characteristics of constructivism.

How people learn is a very complex phenomenon and many theories have been advanced in this regard (Schunk, 2008). Each of these theories of learning defines the concept of learning from its own perspective and conveys a different approach to the learning process (Senemoglu, 2004). However, these theories can be broadly classified as either objectivist or constructivist (Bas, 2012). The traditional learning theories are regarded as objectivist, according to which knowledge depends on an objective reality and is an absolute truth. One example of such a traditional approach is 'explicit teaching' or 'directed teaching' or transmission mode of teaching. On the other hand, the constructivist approach emphasises that learning is the learners' construction of his/her own knowledge or understanding in his/her mind (Arısoy, 2007).

As indicated in the previous chapter the limitations of traditional teaching and learning methods have been recognised and acknowledged by science educators and therefore science education around the world is affected by curricula reformation. These curricula changes have given a great deal of attention to constructivism as a learning theory as well as a basis for the development of teaching or instructional approaches for the science classroom (Feyzioglu, 2012; Cheung, 2007; Van Driel, Beijaard & Verloop, 2001). Furthermore, constructivism has been debated widely and it has influenced a number of national curricular policies and education statements (Matthews, 2002). As such, it is plausible that any curriculum that emphasises inquiry is framed on constructivism, which is described as a more overarching theory that can incorporate a number of teaching strategies, such as co-operative learning, collaborative learning, and inquiry-based learning (Seigel, 2004). While the South African curriculum does not explicitly state it to be underpinned by the constructivist theory of learning, characteristics of constructivism are evident in its policy for example, within the statements of the COs, DOs and the LOs as indicated hereunder.

Within the COs:

- Identify and solve problems and make decisions using critical and creative thinking.
- Work effectively with others as members of a team, group, organisation and community.
- Organise and manage themselves and their activities responsibly and effectively.
- Collect, analyse, organise and critically evaluate information.

- Communicate effectively using visual, symbolic and/or language skills in various modes.
- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation (DoE, 2003a).

Within the DOs:

- Reflect on and explore a variety of strategies to learn more effectively.
- Participate as responsible citizens in the life of local, national, and global communities (DoE, 2003a).

Within the LOs of the Life Sciences:

LO1: The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem-solving, critical thinking and other skills.

LO2: The learner is able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences

LO3: The learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the inter-relationship of science, technology, indigenous knowledge, the environment and society (DoE, 2003b)

Hence, the implication of the outcomes of the curriculum in a post democratic South Africa makes inquiry an imperative. Table 4.1 illustrates the close alignment among the South African Life Sciences curriculum, inquiry-based teaching and learning and constructivism. It is for this reason that constructivism was chosen as the overarching theoretical framework for this study.

Table 4.1: Similarities among Inquiry-based teaching & learning, the South African Life Sciences curriculum and Constructivism

Inquiry-based teaching and learning	South African Life Sciences curriculum	Constructivism
➢ Learner centred and learner directed	➢ Learner centred (Comparison between old and new model of teaching and learning -DoE, 1997a)	➢ Promotes learner -centred or learner-driven and self-directed learning
➢ Active involvement	➢ Active learners (Comparison between old and new model of teaching and learning -DoE, 1997a)	➢ Learners are active participants, hence greater learner engagement
➢ Connects new evidence to prior knowledge / understandings ➢ Involves searching the task environment, evaluating data, linking to prior understanding	➢ Identify and solve problems using critical & creative thinking. (CO – D0E, 2003a)	➢ Learning is meaningful because it promotes the eliciting of prior knowledge and previous understandings.
➢ Encourages meaningful learning. ➢ Use critical and logical thinking, reasoning and thinking skills. ➢ Encourages higher level learning. ➢ Reflection of scientific knowledge and scientific process	➢ Use cognitive and social strategies such as reasoning, researching, collaborating, expressing opinions and debating (CO – DoE, 2003a) ➢ Reflect on and explore a variety of strategies to learn more effectively (DO – DoE, 2003a)	➢ Promotes higher-level learning such as critical and creative thinking and reasoning. ➢ Learners required to examine thinking & learning processes. ➢ Meta-cognitive skills involved to regulate and manage learning ➢ Learning is reflective – promoting the reflection on previous understandings
➢ Nature of learning is both individual and social activity ➢ Promotes collaboration.	➢ Work effectively with others as members of a team, group, organisation or community. (CO – DoE, 2003a) ➢ Be culturally and aesthetically sensitive across a range of social contexts (DO – DoE, 2003a)	➢ Learning is dependent on social or physical environment. ➢ Nature of learning is both individual and social. ➢ Promotes collaboration which enhances critical thinking
➢ Answers the research question	➢ Promotes inquiry-based learning and teaching (LO1 – DoE, 2003b)	➢ Learning is inquiry -based
➢ Active construction of knowledge	➢ Construction of knowledge is advanced ➢ (LO1, LO2 & LO3 – DoE, 2003b)	➢ Promotes the construction of knowledge
➢ Approach to learning involves process of exploring the natural world in search of new understandings ➢ Consider alternative explanations	➢ Demonstrate an understanding of the world as a set of related systems, by recognising that problem –solving contexts do not exist in isolation (CO – DoE, 2003a)	➢ Knowledge is situated in real - life and therefore actively construct meaning and sense-making of world ➢ Knowledge is dynamic

➢ Process skills involved ➢ Involves the use of process skills: observing, inferring, predicting, measuring, classifying	➢ Promotes the development of skills (LO1 – DoE, 2003b)	➢ It is skills based ➢ Involves inquiry stage, analysis stage, inference stage and evaluative stage
➢ Involves a sequences of steps: stating a problem, generating / stating asking questions/ hypotheses, - Identifies assumptions	➢ Identifies and questions phenomena and plans investigation ➢ Identifying a problem ➢ Hypothesising (LO1 – DoE, 2003b)	➢ Formulate questions and hypotheses that can be tested experimentally
➢ Planning the investigation, and conducting investigations, controlling and manipulating variables	➢ Conducts investigation ➢ Handling equipment and apparatus ➢ Selecting apparatus and/or materials ➢ Identifying variables ➢ Selecting ways of controlling variables ➢ Planning an experiment ➢ Planning ways of recording results ➢ Understanding the need for replication or verification	➢ Design and conduct informative experiments
➢ Using tools to collect, analyse, interpret data and state conclusion	➢ Collect, analyse, organise and critically evaluate information Analyses, synthesises and evaluates data ➢ Accesses knowledge ➢ Collects data ➢ Manipulates data ➢ Making observations ➢ Recording information ➢ Interpreting (LO1 – DoE, 2003b)	➢ Collect, record, analyse data ➢ Interpretation is personal
➢ Formulating explanations and using evidence to respond to questions ➢ Encourages the development of more appropriate understandings of science	➢ Interprets and makes meaning of knowledge ➢ (LO1 – DoE, 2003b)	➢ Explanations and conclusions based on evidence from experiments ➢ Modify theories / explanations on basis of evidence from experiments
➢ Communicating explanations and justifications	➢ Communicates findings effectively using visual, symbolic and/or language skills in various modes (LO1 – DoE, 2003b)	➢ Communicate findings effectively to peers

As indicated in Chapter Three of this study the information in the first two columns of the table that is, under the headings inquiry-based teaching and learning and the South African Life Sciences curriculum was extracted from the literature that was surveyed for the discussion in Chapter Three and from the relevant *NCS* Life Sciences policy documents respectively. Information on constructivism in the third column was determined through the review of literature and as discussed in this chapter. As is evident from the data in Table 4.1, there is a distinct alignment across the three constructs, namely, inquiry-based teaching and

learning, the Life Sciences curriculum, and constructivism, for all the identified characteristics. This therefore, is justification for the claim that the Life Sciences curriculum is underpinned or has leanings towards the learning theory of constructivism. The assumption being made with respect to the Life Sciences curriculum is that teachers are well qualified and sufficiently prepared to implement the new curriculum. Hence, the characteristics of constructivism were used as a backdrop to analyse the lessons that were observed.

According to Fosnot (1996) the US National Council for Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA) advocates reform that are mostly constructivist. The Netherlands, also introduced a new curriculum which promoted active and autonomous learning (van der Valk & de Jong, 2009). Korea has been implementing the constructivist approach since 1982 (Kim, Fisher & Fraser, 1999). Curiculum reform in Turkey took on a constructivist approach in 2005. In Turkey the curriculum essentially regards constructivism as a learning theory (Under, 2010) and also incorporates teaching strategies. The Turkish plan also explicates support for teachers to use constructivism in science lessons (Özdemir & Guneysu, 2008). In this way, targeted changes of the programme are expected to be reflected in the classroom practices of the teachers.

Within the South African context, whilst the transformed curriculum advocates a constructivist approach implicitly, there is a lack of adequate support for its implementation at the classroom level in a sustained manner. The only kind of support was an orientation to the curriculum – a 'one shot' training session. The orientation programme/training was a piece-meal affair, beginning with teachers of Grade 10 in the year prior to implementation in this grade, followed by training of the Grades 11 and 12 teachers in subsequent years. None of the policy and guideline documents provide any guidance on teaching strategies for the implementation of practical work.

Constructivist learning is a learner-centred or learner-driven approach whereby learners construct or build their knowledge and understanding of information as they interact and grapple with ideas and reason about their processes (Tetzlaff, 2009). That is, constructivist learning is based on learners' active participation in the learning environment involved with problem-solving, and critical and creative thinking (Fer & Cirik, 2007). Hence, knowledge cannot be transferred or transmitted from teachers to passive learners; it has to be conceived (Von Glasserfeld, 1996) for meaningful learning. Recently a practicing teacher, (Fouché, 2013) commented: *"Constructing meaning trumps being presented with meaning. Don't*

short-circuit students' struggles to achieve understanding as they grapple with their own beliefs" (p.46). This was in reference to the success of a physics investigation with her students. This activity embraced the constructivist approach which succeeded in bringing about conceptual change (Fouché, 2013). In support of her efforts Bransford et al., (2000) and Kapur (2008) indicates that by removing the struggle learners may be denied the opportunity to understand the mechanism they need to replace their alternate or naive conceptions with more accurate mental models. Instead, Kapur (2010) suggests that learners should experience being wrong within the confines of a supportive classroom. In the learning process, learners are expected to develop their own products or understandings by searching, doing, collaborating, using higher order thinking skills and using their own creativeness and decision-making attributes (Demirel, 2005). Hence, proponents of constructivism believe that these activities and enrichments in the learning environment such as, active learning, use of visual and auditory modalities, creating opportunities for dialogue, fostering creativity and providing rich, safe and social interactive, engaging, opportunities can enhance the meaning-making process (Brooks & Brooks, 1999; Saban, 2004; Fer & Cirik, 2007; Karadag & Korkmaz, 2007). In this scenario, the learners are seen as the co-constructors of knowledge by the constructivists (Ozkal, 2007).

In the more explicit or objectivist approaches learners receive information from a single influential source such as the teacher or the textbook, that are considered to have the "right" answers (Tetzlaff, 2009). In constructivist learning on the other hand, the learners include their own experiences and understandings as well as those of their peers to construct their own knowledge of concepts (Glenda, 1996). As a learner-driven approach to learning, constructivism fosters experience to multiple viewpoints, and it presupposes that each individual seeks contribution from the outside which is screened by his/her own experiences (Tetzlaff, 2009). Therefore each learner will have a little different link with an understanding of external input and new information (Duffy & Jonassen, 1992).

While teacher-driven approaches assume that learning occurs as learners receive information from the external world, constructivism advocates active knowledge construction which is based upon learners' previous knowledge and experiences. Hence, new knowledge is integrated with the learners' previous understandings (Schunk, 2008) or information from the outside is assimilated with their prior schemas of knowledge to develop their own understanding or meaning-making (Collay, Gagnon & Schmuck, 2006). In addition,

constructivist learning claims that learners actively construct their own concepts through interaction with the physical and social environment with which they interact (Lunenburg, 1998; Treagust et al., 1996). These constructions are then continually tested and modified in the light of new experiences (Bodner, 2003). One of the drawbacks of this position is that learners may not develop accurate knowledge of their experiences. Accurate knowledge here refers to established science knowledge. It is therefore important that the teacher provides the necessary support and guidance. In order to be successful the teacher must therefore be knowledgeable about content or concepts as well as hold positive beliefs about teaching knowledge.

In general therefore, constructivism is a theory of learning or meaning making, which individuals create for their new understandings based on their prior knowledge (Richardson, 2003). It is for this reason that the curricula changed in accordance with the theory of constructivism to allow learners to engage in scientific activities in which they can make sense of their learning (Kift & Nelson, 2005).

An important epistemological assumption of constructivism is that knowledge is a function of how an individual creates meaning from his/her experiences or circumstances and this is the crux of the constructivist learning theory (Loyens & Gijbels, 2008). Two views of constructivism have been identified, namely, *personal or cognitive constructivism* and *social constructivism* (Bodner, 2001).

Personal constructivism concentrates on the individual knower and acts of cognition. Learning in this regard is an individual process that involves linking new ideas and experiences with what the learner already knows. In other words, it is assumed that knowledge is not discovered but rather that it is actively constructed. That is, learners construct meaning through interactions with the physical and/or social environment. S*ocial constructivism* focuses on social interactions that explain how members of a group come to share an understanding of specific life circumstances (Bodner, 2001).

According to Von Glaserfeld (1995) there are as many types of constructivism as there are researchers. However, whatever the type, the primary notion of constructivism concerns a particular way of both conceptualising and acquiring knowledge, which results in learning (Duit, 2001). Learning is a complex process that occurs within a social context as the social constructivists point out, but it is ultimately the individual who does the learning, as the

personal constructivists would argue. Social interaction among individuals plays an integral part in how people learn (Rogoff, 1998). From a constructivist perspective interactions between learner and learner and between learner and teacher are important ingredients of learning. According to Piaget's (1970) cognitive development theory, peer interaction is a source of experience that evokes *cognitive conflict or disequilibrium* in children, and human beings all have a tendency to reduce this conflict and re-establish equilibrium at a higher level. Bodner (1986) indicates that Piaget's view that knowledge is constructed in the mind of the learner was based on research on how children acquire knowledge. The learners' mental activity is the focus of Piaget's approach, and the teacher's role is that of creating the most suitable conditions or situations in which the learner can link his/her previous and current knowledge for meaningful learning to occur (Moore, 2004). Piaget viewed knowledge construction as a process rather than as a state, consisting of a relationship between the knower (learner) and the known (the knowledge). In this relationship the knower constructs his/her own representation of what is known (Martin, 2006). Vygotsky (1978), indicated that cognitive development is dependent on social and cultural factors where learners (knowers) construct knowledge through interaction between the child and a more knowledgeable other like the parent or teacher, and the social processes are then transformed into the child's internal mental processes. That is, the construction of knowledge is socially oriented (Cole & Wertsch, 2002) and as Martin (2006) argues,

"Vygotsky was a social constructivist who believed that learners should utilise the input of others, as they formulate their construction and not rely solely on themselves" (p.195).

The only difference between the personal constructivist school of thought and that of the social constructivist school is that Piaget emphasised the individual nature of learning while Vygotsky emphasised the social nature of knowledge construction (Cole & Wertsch, 2002).
Osborne (1996) criticises Piaget's notion by indicating that according to this assertion knowledge is only found in cognising beings and not in other sources such as textbooks. However, Piaget's view may be interpreted as one where textbooks for example, are important sources of knowledge but the learner will need to actively engage with the information to make sense of it by integrating it to existing schemas. Further, sense making is then also possible during interactions with their peers, or knowledgeable others during collaboration, conversation, and reflection (Tetzlaff, 2009).

Constructivism seems to be a learning theory of choice in transforming education, particularly science education where it is used to guide the development of new teaching strategies (Baviskar, Hartle and Whitney, 2009). The most shared interpretation of what constructivism means is the change in the focus of classroom practice, putting the learners' own efforts to understand at the centre of the educational enterprise, which in the context of the present study has a focus on inquiry but more specifically investigative practical work (IPW) which is open-ended.

As a theory of learning, constructivism is often opposed to the behaviourist model of learning, which centres on learners' efforts to accumulate knowledge of the natural world and on the teachers' efforts to transmit it (Murphy, 1997). However, the teacher can play a role in designing lessons in a way that will promote constructivist ideals. Understanding communicative tools and strategies help teachers to develop individual learning methods such as discovery learning, and social interactive activities to develop peer collaboration (Powell & Kalina, 2009). Notwithstanding this, the researcher contends that this may only be possible if the teacher has the requisite knowledge and beliefs including attitude, commitment and determination to do so.

Learning requires self-regulation and knowledge to focus on concept development and deep understanding, rather than on behaviours or skills as the goal of instruction (Fosnot, 1996). Hence, constructivist's believe that a learner must construct meaning himself/herself and as a result, learning will take place when it is "connected to the individual's already existing knowledge, experiences or conceptualisation" (Martin, 2006, p. 183).

To understand what knowing means and how one comes to know something is framed in constructivism. In this respect Fosnot (1996) contends that reality is not knowable but is a theoretical construction. According to Bodner (1986) Piaget believed that knowledge is acquired through a life-long constructive process in which one tries to organise, structure, and restructure or re-organise one's experiences in the light of existing schemes of thoughts, and thereby steadily adapt and increase or develop these schemes. The two concepts namely, the *conceptualisation* of knowledge based on a certain epistemology and the *acquisition* of knowledge as a way of learning, which constitute the essence of constructivism is highlighted within this cognitive processing (Duit, 2001). The processes of organising, structuring and

restructuring reflects a constructivist view of knowledge acquisition as an active process of meaning–making based on the use of prior knowledge and new information as experienced.

4.2.1 Assimilation and Accommodation

In the process of meaning-making two complementary phenomena namely, assimilation and accommodation, sometimes takes place through the intermediate situation of *disequilibrium* followed by *equilibration* in the best cases (Bodner, 1986). Bavishkar et al., (2009) also alludes to this disequilibrium referring to it as *cognitive dissonance*. According to Bavishkar et al., (2009) the theory of constructivism states that the knowledge possessed by an individual is connected in a comprehensive 'construct' of facts, concepts, experiences, emotions, values, and their relationships with each other. The facts and concepts relate to knowledge and experiences, while emotions and values are related to beliefs within the context of this study. If the construct is insufficient or incorrect when compared with the information the individual is gathering from the environment, the individual will experience a form of cognitive *dissonance* that will act as a motivation (Lorsbach & Tobin, 1993). In addition, the *disequilibrium* or cognitive *dissonance* may be due to problems in achieving the instructional goals. The individual will therefore be motivated to reject the new information or incorporate it into his or her construct (Sewell, 2002; Novak & Gowin, 1986; Berger, 1978). *Equilibration* is then restored by modifying these existing schemes until the discrepancies are resolved, enabling them to fit the newly assimilated information that allows accommodation to take place. In order to make any changes to the knowledge construct permanent the learner must be able to apply the changed construct to novel situations, receive feedback about the validity of the construct from other sources, and establish further connections to other elements in the construct. The notion of rejection and incorporation is reflective of models of conceptual change in science education and as elaborated in section 4.3 in this chapter.

It can therefore be asserted that the learner's background combined with his/her previous experience is the foundation of effective learning. This idea is supported by Applefield et al., (2001) who asserts that meaning is constructed by a learner when s/he engages actively with new experiences and in so doing relate it to what is already known or believed about the topic. This can be realised in a number of ways, which support the construction of a block of understanding that is based on given information and past experiences, purposes and interests.

Some educators and researchers (e.g. Ozden, 2005; Brooks & Brooks, 1999; Karadag, 2007), refer to constructivism as a paradigm shift in learning, education and schooling nowadays.

They see constructivism as a way of perceiving teaching and learning by observing how people construct understanding of our world, which is the central thrust of learning science. Due to the reform efforts in education across the world, the practice of constructivism is viewed as an effective paradigm in the twenty-first century (Ozgur, 2008). The constructivist ideas that underpin science teaching and learning vary considerably among science educators and researchers (Good, Wandersee, & Julien, 1993). Despite the variety of views, the common central idea of constructivism is human knowledge, which Taylor (1993) describes as a process of individual cognitive construction, undertaken by one who is attempting to make sense of one's social or natural environment. It is for this reason that constructivism seems to have gained a great deal of popularity in science education, mainly in trying to make sense of the natural world. In order to understand the practice of constructivism its principles are unpacked and discussed in the next section.

4.2.2 Principles of constructivism

Several authors have contributed to the essential features of constructivism (e.g., Fritcher 2008; Tetzlaff, 2009; Applefield et al., 2001; Baviskar et al., 2009; Bonk & Wisher, 2006; Seigel, 2004). These have been synthesised and elaborated on hereunder. At least three common features are highlighted in all the contributions. These are: active participation, construction of knowledge, and social interactions. In addition, the studies have added to the group other peculiar essential features as will be indicated in the elaboration below.

(a) Active participation

In a constructivist approach learners engage and make use of concepts instead of merely receiving information from a more knowledgeable other. Being told *about* some topic may be enlightening but it does not groom learners to *use* and *do* things (Johnson, Johnson, Sheppard & Smith, 2005a). Providing activities and tasks together with resources and ideas for learners to engage with both mentally and physically encourages learners to be involved in approaches that help build knowledge and understandings through thinking about and reflecting on such participation. In this way active engagement with resources, ideas and instructions fosters the development of a relationship with the information and concepts involved. Such lessons do not have a lengthy and detailed introduction from the teacher. Instead the teacher prepares lessons, which has prospects for active engagement, and construction of knowledge (Tetzlaff, 2009). Furthermore, the teacher provides support and guidance during the learning process by way of questions and feedback (Johnson et al., 2005b). This questioning and

feedback plays a significant role in supporting and guiding learners as part of the scaffolding process.

(b) Construction of appropriate and relevant knowledge

Constructivist learning takes into account that learners enter a learning environment with some prior knowledge or preconceptions. It also takes into account that individuals may have different understandings of the same phenomenon as well as different styles of learning. Hence, these differences in the learning environment are taken into account in a constructivist approach to teaching and learning. This allows for the creation of bases which serve as foundations on which learners can construct new knowledge, which will be relevant and therefore result in meaningful learning (Tetzlaff, 2009). When there is successful integration of new information with currently established and recognisable information then learners are able to build their own, personally meaningful understanding of this new information (Collay et al., 2006). This is a criticism of constructivism, in that learners if left on their own may construct inaccurate science concepts. The changed role of the teacher thus becomes significant. What mechanisms need to be put in place so that teachers can safeguard learners against the inaccurate construction of knowledge? (Olson, 2003). While some theorists take a hard-line approach to constructivism and allow learners to arrive at their own outcomes with little or no guidance by the teacher (Duffy & Jonassen, 1992), this need not be the case. Learners must be supported by the teacher. As teachers provide the necessary support and guidance in understanding and thinking, their growing or changing knowledge becomes more intricate (Tetzlaff, 2009) and they can then develop more complete and more multi-faceted conceptual relationships between concepts (Brooks, 2005). The South African Life Sciences curriculum does not subscribe to such a hard-line approach as described above. Instead it describes a more moderate approach to Life Sciences education, which encourages mediation by the teacher and thereby reduces concerns about learners developing inaccurate understandings of new information (Tetzlaff, 2009). Furthermore, as stated earlier in the chapter, teachers in a constructivist learning situation do not provide lengthy detailed lesson introduction but encourages learners to work things out for themselves (Tetzlaff, 2009). In addition, teachers are however, also expected to guide learners' by posing questions and by providing opportunities for learners to raise questions and seek clarity, for example. Also, learners should be given opportunities to explain their processes and demonstrate the use of their new knowledge

in new contexts. Such mediation by the teacher minimizes or eradicates fears about the accuracy of learners' understanding of new information. However, this is only possible if the teachers possess adequate subject matter and general pedagogical knowledge as well as knowledge about the learning environment including knowledge of the learners and knowledge of self. In addition, teachers' beliefs ought to be consistent with the transformed approach of the Life Sciences curriculum.

(c) Social or physical interactions

Learning in a constructivist environment promotes collaboration, co-operation and conversation in order to allow for multiple perspectives or interpretations (Tetzlaff, 2009). Even though individuals can learn from their own independent experiences, social interactions in the teaching and learning situation has an advantage over learning from one's own individual experiences in that it helps to extend one's thinking and thereby exposes one to new ideas and perspectives (Tetzlaff, 2009). In collaborative or co-operative learning environments there is a need for individuals to strike a balance between their reliance on others with their own responsibility and accountability to the group in order to reach shared objectives (Johnson et al., 2005b). As individuals work to communicate, resolve disagreements, and achieve goals, they are obliged to examine their own thinking, behaviours, and relationships with others, thereby creating opportunities to modify their own thinking, behaviours, and relationships (Costa, 2000). Collaboration can also improve individuals' self-confidence because self-confidence is needed for the group. When group members share responsibility and support one another individuals within that group can develop an emotional sense of self-worth and usefulness because they are needed to advance the common goal of the group (Biehler & Snowman, 2003).

The exchange of ideas and personal involvement that occurs in conversation can help learners recognise their similarities, develop bonds, and learn from one another (Tetzlaff, 2009). As learners interact and share their thoughts and ideas with one another, a sense of trust and understanding can be built that can open those involved to new ways of thinking (Baker, Kolb & Jensen, 2002). Furthermore, when people articulate their ideas and explain their thinking to others, they think through their reasoning and re-examine their ideas (Biehler & Snowman, 2003), a process of reflective thinking.

(d) Eliciting prior knowledge and creating cognitive dissonance

Some researchers (e.g., Fritcher, 2008, Applefield et al., 2001; Baviskar et al., 2009) include eliciting of prior knowledge as an essential feature of constructivism. In addition, Baviskar et al., (2009) also added the importance of creating cognitive dissonance when eliciting prior knowledge as an essential feature of the constructivist approach to learning. According to these authors, prior knowledge is taken into account and utilised as a foundation on which to construct further knowledge so that meaningful understanding occurs. It is therefore important for teachers to be knowledgeable about the mechanism and be able to elicit prior knowledge of the learners so that the new knowledge can be presented in a way that can be incorporated into the learner's existing construct. Similarly if the learners' attention is not drawn to his/her prior knowledge, the learner will either ignore or incorrectly incorporate the new knowledge. Hence, the dependence of new learning on learners' existing understanding. The key element in the criterion of eliciting prior knowledge is to ensure that the activity/task assesses learners' prior knowledge and relate it to the new information.

(e) Learning is goal oriented

This particular essential feature of constructivism is referred to as 'intentionality' by Tetzlaff (2009). According to her all human behaviour is goal-directed. One type of educational goal is the process of learning (Grabinger, 2001). For learners to successfully understand concepts it is imperative that they focus their attention on their thinking processes and on the content that needs to be understood. Being able to focus on the new information as well as on the thinking process indicates an awareness of the learning situation and the task at hand. Such awareness enables learners to raise questions in order to gain clarity and thus improvement in their understanding of the new information. Learning environments designed with specific learning goals therefore help learners understand why the information they are working with is important and relevant (Grabinger, 2001). With respect to the Life Sciences curriculum, LOs are regarded as its goals and LO1 in the *NCS* and SA2 in *CAPS* are specific goals for the implementation of practical investigations.

(f) Learning is contextualised

Bonk and Wisher (2006) and Tetzlaff (2009) included contextualisation of learning as part of their repertoire of essential features of constructivist learning. The sense of specific concepts and information develop, as these concepts or ideas are made explicit in certain situations. Such realistic learning settings or tasks help learners to identify the appropriate use of information and concepts (Grabinger, 2001) and so become more meaningful to learners. For example, the concept of a fair test and hypothesis becomes more meaningful if they are provided with opportunities to practice this within an authentic task. If learners are able to make a connection with their classroom learning with everyday experiences, they will see the advantage of what they are learning for use outside of the classroom. It is therefore important for teachers to provide opportunities to learners to engage in tasks that are situated in real-life.

(g) Complexity of learning

The significance of oversimplification of concepts has been highlighted by Tetzlaff (2009) as a component of her list of essential features for constructivist practices. The growth and physique of a body builder is dependent on the challenges of physical exercise. Similarly, cognitive growth is enhanced by the challenge of complex thinking (Tetzlaff, 2009). When adults consistently oversimplify problems and concepts for learners, this has the tendency to negatively impact on the view of the world for the learner. That is, they will develop oversimplified world views. Hence, learners lack the necessary training for the intricacies of real-life problems (Tetzlaff, 2009). There are many reasons why teachers oversimplify problems and concepts. The learner's age, teachers' own knowledge, social circumstances, and time constraints are some of these reasons. However, while these issues may be relevant in some situations, learners do need to be exposed to and permitted to engage in complex discussions in order to develop higher order thinking skills. This does not imply that teachers ought to discuss complex issues with learners in the same way they would with adults. Instead the kind of activity that the teacher designs must take into account the learners' existing cognitive development and the potential the learner has to succeed when assisted by a more knowledgeable person. That is, the 'zone of proximal development' (Vygotsky, 1978) should be identified. Hence, exposing learners to ideas and tasks that are more complex than those that they are already familiar with helps them develop more elaborate cognitive processes (Wertsch, 1988). This in turn will help develop confidence

in learners to perform more complex tasks and are therefore better prepared to later build more complex knowledge structures (Collay et al., 2006).

Osborne (1996) who criticises minimal guidance as in the case of constructivism indicated that learners who were exposed to strongly guided approaches performed better than those exposed to minimal guidance. It is not clear, what form the assessment of such a comparison took. For instance, the report does not indicate whether the assessment of such learning was for lower cognitive processing, higher cognitive processing or a combination of these, and whether it was a 'one-shot'/once off assessment. As indicated earlier, Fouchés' (2013) success was due to her allowing her learners to work out a solution to their practical task on their own. All she did was provided a conducive learning environment for this engagement by for example, posing appropriate questions.

(h) Reflection, application and feedback

Social interactions provided during a lesson allow learners to engage in reflective practice by way of analysing the process/es they used to reach certain opinions, ideas and conclusions. That is, once the learner has acquired the new knowledge and verified it, the learner needs to be made aware of the learning that has taken place. By providing reasons and explanations to others, and by responding to feedback from the teacher or their peers learners engage in reflective thinking when they think through their responses and reasoning and thereby re-examine them (Biehler & Snowman, 2003). Such practices may help learners to endorse their own thoughts or it may cause them to reconsider the meaning which they have attached to it. Misinterpretation or rejection of new knowledge is likely if the learner does not interpret and modify prior knowledge in the context of new knowledge. However, in either instances reflective thinking allow learners to follow their own thought processes (Lockhead, 2000). Engaging in metacognition will help learners to identify any shortcomings in their understanding of information and can thereby ask questions and seek clarity (Swartz, 2000). Reflection also helps learners build new concepts, because as they reflect on their thinking and thinking processes they relate their own personal experiences and relations to the information and make that knowledge their own (Martin, 2002). This personal identification and the act of metacognition help the learner retain information and increase his/her ability to transfer or apply that knowledge to other contexts (Johnson &

Johnson, 2000). In addition to testing the validity of their constructs, application allows the learner to further define the inter-connectedness of the new knowledge to a greater variety of contexts, which will integrate the new knowledge permanently (Baviskar et al., 2009)

Based on the principles or essential features of constructivism and the focal issues discussed, it can be argued that constructivism has common features to that of IPW. In addition, constructivism is widely accepted as the most popular underpinning instructional reform in science education in the world today, in addition to the great attention it received in the past decade or two (Richardson, 2003). With the introduction of the *NCS* in South Africa, teachers were expected to have knowledge and beliefs that are consistent with inquiry-based teaching and learning and therefore constructivism. What this knowledge and beliefs are and how it impacts on the practice is the focus of this study.

Irrespective of the vast volume of literature on constructivism and the complexity of its nature, there is a common thread, which emphasises the need for active participation by the learner together with the common recognition of the social nature of learning. Hence, the achievement of the critical and developmental outcomes of the *NCS* in creating thinking beings who will be able to make meaningful and deeper understanding of the world around them is possible within a constructivist learning environment. Such a learning environment is entirely consistent with an inquiry approach, since it is acknowledged that one of the advantages of inquiry-based teaching and learning is that it enables learners to learn in a constructivist way (Richardson, 2003). Furthermore, since investigative practical work (IPW) is an example of inquiry-based teaching and learning it is therefore possible to analyse its implementation in Life Sciences using constructivism as a framework.

4.2.3 Instructional strategies underpinned by constructivism in science lessons

Although constructivism may be seen as a theory about learning rather than a description of teaching, there is an obvious relationship between theory and practice, with important pedagogical implications (Grabinger, 2001). Contemporary science mirrors the ideas of constructivism and contains many of the characteristics of constructivism. In fact inquiry learning reflects the constructivist paradigm of learning. An analysis of the South African Life Sciences curriculum and as indicated in Table 3.1 in Chapter Three and Table 4.1 in this chapter highlights the commonalities and closeness of the practice of constructivism, with

inquiry-based teaching and learning and the South African Life Sciences curriculum. The 5Es sequence of stages of instruction or learning processes and the scientific and engineering practices of the *NGSS* have been shown to align with the inquiry skills as illustrated in Table 3.3. This therefore, implies that the features of 5Es and *NGSS* are in line with the inquiry skills and therefore the South African Life Sciences curriculum and the practice of constructivism. Supporting this approach to teaching, Duit (2001) emphasises the popularity of constructivism in science education, stating that constructivism has become a most valuable tool for science educators not only for science teaching and learning but also for research in these fields.

Constructivist educators strive to create classroom environments where science learners are required to critique the thinking and learning process, gather, record, and analyse data; generate and test hypotheses; reflect on previous knowledge; and create their own meaning (Crotty, 1994). Kuhn and Dean (2008) described constructivist scientific activity as involving four stages: inquiry or intent, analysis, inference and argument.

- During the inquiry/intent stage, investigators identify or formulate questions that can be tested experimentally.
- In the analysis stage, they design and conduct informative experiments and interpret data.
- In the inference stage, they draw conclusions.
- In the argument stage they communicate their findings and assertions.

Although the educational potential for inquiry learning is significant, this learning cannot be achieved by merely placing learners in the midst of a complex scientific field for free-reign investigation (Germann, Aram & Burke, 1996). Learners may still not have the necessary pre-requisite knowledge for such activities and therefore will need to be guided and supported by teachers. The South African Life Sciences curriculum ensures that there ought to be a gradual surrendering of much of the control by the teacher in the lessons involving practical investigations from Grades 10 to 12.

Constructivist approaches transfer the control of the teaching and learning situation to the learners. In order to achieve this teachers need to understand learner's curiosity and their needs so that they will be able to design appropriate lessons. These lessons should consist of instructions that are flexible enough to allow time for learners to experiment, think, and

reflect about what they are doing and learning (Brooks & Brooks, 1999). However, this flexibility does not give learners a license for a 'free-for-all' or 'anything goes' whereby the teacher has no role or purpose. Instead, constructivism supports the reconsideration or changing role of the teacher from one that controls authority to one who is a guide and a mediator or from an authoritarian controller to an authoritative facilitator. In this respect, the teacher guides and supports the learning process by asking probing questions, making suggestions and getting learners to make suggestions, providing appropriate and relevant feedback and explaining concepts instead of trying to explicitly transfer correct information to the learner (Tetzlaff, 2009). Furthermore, in a constructivist set-up the learners are responsible for developing and improving their own understanding and meaning-making of their experiences. The teacher on the other hand is responsible for ensuring that a conducive learning environment prevails by providing the necessary and appropriate opportunities and resources to enable such learning (Tetzlaff, 2009) rather than being a director of teaching. One of the ways of accomplishing this is by making use of appropriate questions and by providing learners with opportunities in asking questions, and by providing appropriate feedback to guide and support learners.

However, this role of the teacher can only be successful if the teachers' knowledge and beliefs is taken into account and supported appropriately to be in sync with the requirements of the reformed curriculum. The common view of an evaluation process and as indicated in Chapter One is that reform efforts should take the beliefs of teachers into consideration since a teachers' belief can lead to an active manifestation of reform in the classroom (Van Driel et. al., 2001; Powell & Anderson, 2002). In addition, teachers' knowledge must also be taken into account in order to evaluate the successful implementation of the curriculum. Teachers' knowledge, beliefs and practices are intertwined because what a teacher knows and believes affects what and how s/he will do things (Crawford, 2007; Mansour, 2009).

Constructivist learning applications require a rich and interactive learning environment, which supplies learners with the requirements to access knowledge, to analyse it, organise and use it in order to solve problems (Gagnon & Collay, 2001). From a teaching and particularly from an instructional point of view, constructivist classrooms are more open in the sense that they allow for learner autonomy, freedom to engage with a variety of resources and build on prior knowledge and experience to solve problems. However, the role of 'guidance' or 'scaffolding' cannot be overlooked. The role of 'scaffolding' provided in guiding social interaction thus becomes central to the Vygotskian view. Based on Vygotsky's theory, one

important step in designing instruction to develop complex mental functions is the analysis of the 'zone of proximal development' as mentioned earlier. The zone of proximal development is created in the interaction between learners and the teacher or in co-operative problem solving with peers (Vygotsky, 1978).

This however, refers to solving unstructured problems (Karen, 2002) and not structured problems where the solutions may be retrieved from the textbook. The current study involved open-ended investigative practical work which is unstructured. This understanding of learning from the constructivist perspective makes the distinction between meaningful learning and rote learning. For meaningful learning to occur, individuals must choose to relate new knowledge to relevant concepts and propositions which they already know (Bodner, 1986). In rote learning, on the other hand, new knowledge may be acquired simply by verbatim memorisation and arbitrarily incorporated into a person's knowledge structure without interacting with what is already there.

Penner (2001) argues that constructivism suggests that as we experience something new, we internalise it through our past experience or knowledge construct we have previously established. He further purports that,

> *"Learning activities begin by considering the role of learners' current knowledge, how knowledge is constructed, and the role of the activity in building knowledge"* (p.3).

According to Baviskar et al., (2009) within a constructivist classroom there may be a variety of common practices. However, not all of these lessons may be regarded as being constructivist lessons. To be regarded as being constructivist the lessons ought to be underpinned by the principles of constructivism as discussed in section 4.2.2 in this chapter**.**
Science education from a constructivist perspective therefore, provides learners with science knowledge in such a way that they not only understand the scientific concepts and principles, by memorising and learning the definitions and formulas, but they also understand the importance of scientific knowledge in their everyday life (Duit, 2001). When one considers the essential characteristics of a constructivist classroom, it seems obvious that it differs from the traditional classroom, both from a teaching and learning perspective. Furthermore, knowledge is viewed as being dynamic for both the teacher and the learner (Educational Broadcasting Corporation, 2004).

In a traditional classroom setting the teacher is in charge of a great deal of intellectual work in the classroom. S/he plans the scope and sequences, presumes and pre-packages a lot of learning. In the constructivist classroom on the other hand the learner is in charge of that pre-packaging. The learner gets vague information and unformulated problems, and then has to put together his/her own personal question and figure out how to go about answering it with the teacher being the mediator of that meaning–making process (Brooks & Brooks, 1999). This may seem like a recipe for the lack of learning. However, this situation need not arise if the lesson is well planned to allow for appropriate guidance from the teacher. In fact the active role of the teacher in constructivism cannot be dismissed as claimed by some conservative educators (Seigel, 2004). Rather, it modifies the traditional role by assigning the teacher the role of guiding learners to construct knowledge by connecting it to their prior knowledge rather than reproducing a series of facts and transmitting it to learners. By doing so, a constructivist teacher provides tools such as problem-solving and inquiry–based learning activities with which learners formulate and test their ideas, draw conclusions and inferences, and convey their knowledge in a collaborative environment. Knowledgeable teachers with a great deal of enthusiasm and determination become facilitators who engage and guide their learners in investigative activities by providing the necessary scaffolding to assist learners in developing new insights and connecting them with their previous knowledge or experiences. They are therefore no longer classroom leaders who traditionally used to instruct learners to do what they deemed the only way of proceeding in an investigation towards a pre-determined result.

Although there are specific teaching methodologies that are strongly constructivist, such as inquiry-based teaching methods, it is not necessary to use one of these methods to be constructivist. Likewise, simply following a methodology in a ‘cookbook’ fashion will not guarantee constructivism (Baviskar et al., 2009). The constructivist approach to teaching and learning promotes critical and creative thinking and collaborative learning. Moreover constructivist methodology promotes the act of self-motivation, self-directed learning to begin a life-long quest for new skills and knowledge.

While constructivism is widely accepted and it has been extremely influential in science education globally, as pointed out in the introduction to this chapter, it is not without criticisms. For example, Kirchner, Sweller and Clark (2006) have pointed out that the minimal guidance supported by constructivism is not efficient or effective compared to most

guided instruction. However, these authors do not provide a definition of 'efficient' or 'effective' instruction. Kirchner et al., (2006) reported that when learners learn science in classrooms with pure-discovery methods and minimal feedback, they often become lost, frustrated, and their confusion can lead to misconceptions. In addition, they indicated that since false starts are common in such learning situations, unguided discovery is most often inefficient. In order to counteract the above claims, the following argument is presented with respect to this study: As pointed out earlier the South African Life Sciences curriculum does not follow the hard line approach of 'discovery learning'. As far as investigations are concerned there is a continuum from closed-ended to open-ended activities from Grades 10 to 12. This involves a gradually increasing complexity from Grade 10 to Grade 12. An analysis of this increasing complexity is illustrated in Table 3.2 in Chapter Three. The implication here is therefore one of a decreasing degree of guidance by teachers from Grades 10 to 12. Kirchner et al., (2006) also make an assumption that in explicit or strongly guided methods the feedback to learners is greater and only minimal or absent in constructivist lessons. Feedback is really dependent on the teachers' knowledge and teachers' beliefs, the abilities of learners and the goals of the particular lesson. Hence, whatever methodology is utilised appropriate feedback is important. Since the strongly guided lessons have more details provided to the learners there should be fewer queries and therefore less feedback because the learners will be in a fairly 'secure' environment. In the constructivist lessons there should be a greater amount of queries due to minimal information provided to learners. Hence, there ought to be greater interactions between peers as well as between the learner and the teacher seeking clarity. Therefore, there should be a greater degree of feedback enhancing the meaning-making process through dissonance/disequilibrium, equilibration and assimilation and accommodation resulting in appropriate conceptual change. Questioning by the teacher and the learners is encouraged in a constructivist setting. The responses and the interactions in such a setting allows for continual clarification and hence, feedback for meaningful learning and understanding.

The claim, that 'false starts' are rife in constructivist settings because such learning situations are inefficient. These so called 'false starts' should in fact serve as a motivation for the teacher to provide the necessary guidance for the linking or integration of the learners' prior knowledge with the new knowledge.

With respect to cognitive load, Kirchner et al., (2006) notes that cognitive load theory suggests that the free exploration of a highly complex environment may generate a heavy working memory load that is detrimental to learning, particularly amongst novice learners. This suggestion is particularly important in the case of novice learners, who lack proper schemas to integrate the new information with their prior knowledge. With respect to the current study, the context involves Grade 12 classes. As pointed out earlier, there is an increasing complexity from Grade 10 to Grade 12 with respect to the demands of the investigative practical work (IPW). At the Grade 12 level there ought to be open-ended tasks with minimal guidance, since these learners are not regarded as novices within the schooling context. They would have had opportunities and experiences with investigative practical work (IPW) which would have been less complex in Grades 10 and 11. Therefore, in Grade 12 open-ended tasks with minimal information should be promoted.

Despite their sympathy with constructivism, Tobias and Duffy (2009) found that the lack of empirical evidence for the effectiveness of constructivist teaching methods turned constructivism into a theoretical model rather than a pedagogical method. While this study showed a qualitative link between constructivism and the teaching and learning of IPW it is possible to use the finding as a base for empirical studies in this regard.

Boden (2010) acknowledges and accepts that “scientific concepts are generated and constructed by human minds as supported by constructivism; it cannot be denied that realism is the foundation of many well-proven processes in science and engineering" (p. 84).

When one considers the advantages and the criticisms described above, it becomes necessary for the teacher who engages with the constructivist approach to teaching and learning to find the right mix of methods for optimising the learner’s benefits. In order for this to happen the teacher will need to use a number of support strategies such as, questioning to see how learners may have constructed information related to the topic; engaging learners in investigative activities that enable them to explore on their own and come to their own conclusions; interacting with each learner to see how s/he is constructing the new information; and helping them to devise reliable and meaningful conclusions.

It is therefore of critical importance for science teachers to keep abreast of not only scientific knowledge but also knowledge relating to pedagogy. Furthermore, from teacher cognition

point of view teachers construct their own schema from their experiences in order to comprehend, plan for, and respond to the demands of their classrooms. This therefore depends on teachers' "self-reflections; beliefs and knowledge about teaching, learners, and content; and awareness of problem-solving strategies endemic to classroom teaching" (Kagan, 1990 p. 419). This study is concerned with understanding the relation between teachers' knowledge and teachers' beliefs, and its impact on the implementation of IPW in the classroom.

In summary, the views of a number of authors have been presented to highlight both the advantages and disadvantages of constructivism. While the pros and cons were identified, the common denominator is that "constructivism shifts the focus of attention from the prepositional 'knowing that' to the pragmatic 'knowing how'" (Riegler, 2005, p.4) which is central to learning science. The South African Life Sciences curriculum seems to have been guided by such a shift. An analysis of the curriculum, literature on constructivism and IBTL, resulted in findings which show commonalities among constructivism, inquiry-based teaching and learning and the South African Life Sciences curriculum as illustrated in Table 4.1. While there are controversial views around constructivism, its closeness to inquiry-based teaching and learning approaches and particularly IPW makes this to be the most viable and valuable overarching framework for analysing, interpreting and understanding the data in this study.

4.3 CONCEPTUAL CHANGE THEORY

Research in science education and cognitive science focuses on how people learn science and how this knowledge is applied in their daily lives (Özdemir & Clark, 2007). Hewson (1981) highlighted three aspects of science education knowledge namely, that the knowledge which people possess is very significant in order to make sense of their experiences; that people strive to make sense of natural phenomena; and that different individuals construct alternative conceptions from the same information.

Several studies over the years have shown that learners possess preconceptions and beliefs or views about scientific phenomena that is often different from the accepted scientific facts (Cinici, Sozbilir, & Demir, 2011; Alparslan, Tekkaya, & Geban, 2003; Palmer, 2003). This knowledge is sometimes referred to as 'naive' knowledge or 'prior conceptions'. Educators and researchers who are concerned with this issue have tried to answer questions such as, where do these non-scientific conceptions come from; why do some conceptual difficulties

exist; and what can be done by teachers or (those more knowledgeable) to facilitate conceptual change (Bilgin & Geban, 2006).

Educators have further acknowledged the persistence of these non-scientific conceptions in their practice, even after teaching. Moreover, they also realise that these conceptions have possible influences on later learning (Beeth, 1993). To counteract this state of affairs, reform documents suggest a need to reduce the volume of information covered through shallow traditional teaching and learning, which places a great deal of importance on committing concepts, rules and generalisations to short-term memory and which prevents understanding (AAAS, 1993). Other studies have shown that children begin to acquire their knowledge from the social environment in which they grow, through the influence of everyday culture and language. This is then organised into narrow, but coherent, explanatory frameworks that may not be the same as currently accepted science (Vosniadou, 2002). Also, that knowledge constructed by learners characteristically has two properties in that, it can be incorrect, and it can often hamper the learning and understanding of commonly established knowledge (Chi & Roscoe, 2002). In addition, Chi and Roscoe (2002) differentiates between two types of naive knowledge namely, preconceptions that can be simply and readily reviewed through instruction and misconceptions that is robust and resilient to change, even when not supported by concrete artefacts.

According to Cinici and Demir (2013) conceptual change can best be achieved through learner-centred, active learning experiences based on the constructivist approach to learning. Learning methods based on constructivism require that teachers not only recognise their learners' existing ideas but also take them into account in planning their teaching so that the aim of conceptual change is fulfilled (Tsaparlis & Papaphotis, 2009).

Posner, Strike, Hewson and Gertzog (1982) used Piaget's notion of assimilation and accommodation, and built on these basic concepts to enunciate a theory referred to as a "conceptual change" learning model (Geelan, 2000). Assimilation and accommodation are different mechanisms which bring about conceptual change. They asserted that if a learners' current conception is useful and if the learner can solve problems within the existing conceptual schema, then the learner does not feel a need to change the current conception. When the current conception does not successfully solve some problems, the learner may

make only moderate changes to his or her conceptions (Özdemir & Clark, 2007). In such cases, the assimilations go on without any need for accommodation (Özdemir & Clark, 2007).

According to Zirbel (2008), since learners come to class with non-scientific conceptual understanding, a more radical approach is needed to change these flawed understandings. This more radical conceptual change is through the process of accommodation based on Piaget's notion (Piaget, 1985). This process of accommodation involves replacement or reorganisation of the learner's conceptions to more scientific ones when the learners' current conceptions are deficient to allow him/her to grasp some new phenomena successfully (Alparslan, et al., 2003; Tao & Gunstone 1999).

In an attempt to clarify the concept of conceptual change, various theorists have offered competing views of the central process/mechanism. It is a construct that is peculiar to science education. Duit (1994) states that, conceptual change has become a hallmark in constructivist teaching and learning. Conceptual change is regarded as a process of learning a concept starting from another concept (Duit, 1994), so that it facilitates understanding.

According to Vosniadou (2002) conceptual change is a process that enables learners to create mental models starting with their current explanatory structures or frameworks. This is considered to be a gradual process that can result in a progression of mental models. It is related to the constructivist principle of 'eliciting prior knowledge and creating dissonance'. Accordingly, conceptual change occurs when new and meaningful understanding is built upon the prior or existing knowledge.

Mortimer (1995) argues for a conceptual profile change because the process of construction of knowledge may sometimes occur independently of previously held conceptions. Although their arguments differ, the views of Duit, Vosniadou and Mortimer are related and acknowledge the importance of prior knowledge to learning.

The mechanism by which such conceptual change occurs may differ. For example, Chi and Roscoe (2002) regard conceptual change as repair of misconceptions or misunderstandings. Beginning with naive conceptions, learners must identify their defective conceptions and rectify them. In this view, misconceptions are incorrectly grouped or miscategorised,

therefore the ensuing conceptual change results in the reassignment of concepts to correct categories.

According to diSessa (2002) conceptual change is the restructuring or reorganising of assorted kinds of knowledge into complex systems in the learners' minds. In this view, conceptual change is really about cognitively systematising or re-arranging disjointed naive knowledge.

Ivarsson, Schoultz, and Saljo (2002) take a more radical stance in that they think naive conceptions do not serve a function in conceptual change because conceptual change is the adoption of intellectual tools. In this view, conceptual change results from changes in the way that learners use the tools in diverse contexts, and the change actually occurs at the societal level. This view therefore, highlights the social nature of obtaining knowledge through participation in socio-cultural activities (Rogoff, 1998). Active participation and verbal interaction are necessary for internal restructuring as well as cognitive change. 'Social or physical interactions' and 'active participation' are essential principles of constructivism. According to Vygotsky, cognitive change is linked to collective interactions (Gupta, 2008). In practicing IPW various concepts and processes pose challenges to learners as well as to teachers, for example, the concepts of 'hypothesis', variables and how to control variables as part of the experimental design. It is therefore important for teachers to understand how conceptual change occurs and thereby develop strategies for social and/or physical interactions and active participation to successfully implement IPW. Niaz et al., (2002) have also established that learners' understanding can go beyond the simple recall of investigational detail if they are given the opportunity to argue, reason, debate and discuss their ideas with their peers. Rather than working alone, learners often solve difficult tasks more effectively in small groups that provide some opportunities to share information and to engage in constructive cognitive conflict (King, 1989). Hence, from a practical point of view, if teachers can combine a co-operative learning environment with conceptual change-based strategies, then it is possible to help the learners to scaffold scientifically correct understanding.

This view has been very influential to determine a learner's specific conceptions that result from the interaction of his/her beliefs and knowledge. According to Posner et al., (1982) a learners' conceptual ecology consists of his/her conceptions and ideas rooted in his/her epistemological beliefs. Hence, it is important to understand teachers' epistemological beliefs

about teaching knowledge. From a conceptual ecology perspective, the essential ideas, ontological groups, and epistemological beliefs greatly influence a learner's exchanges with new thoughts and problems. Having knowledge and understanding of such interactions and inter-relationships, will help the teachers plan and prepare appropriately for lessons involving IPW. Misconceptions are therefore not only inaccurate beliefs; misconceptions shape and constrain learning in a manner similar to paradigms in science. In other words, prior conceptions are very resistant to change (similar to beliefs) because concepts are not independent from the cognitive artefacts within a learners' conceptual ecology (Strike & Posner, 1992). Some concepts are attached to others and they generate thoughts, and perceptions. Due to this webbed relationship between concepts, a revision to one concept requires revisions to others.

Studies on conceptual change may be broadly grouped into two schools of thought, namely, 'knowledge-as-theory and 'knowledge-as-elements (Özdemir & Clark, 2007). A brief discussion of this will follow in the subsequent section.

4.3.1 Conceptual change perspectives: Knowledge-as-theory and Knowledge-as-elements

In a synthesis of conceptual change theories by Özdemir and Clark (2007) two prominent but competing theoretical perspectives regarding knowledge structure coherence were identified. One perspective they characterised as 'knowledge-as-theory' and the other, 'knowledge-as-elements'. They classified the various studies on conceptual change into either one of these categories on the basis of the following questions: Is a learners' knowledge most accurately represented as a clear integrated structure of theory-like character (e.g., Chi, 2005; Chi & Roscoe, 2002; Vosniadou, 2002; Ioannides & Vosniadou, 2002; Carey, 1999)? Or is a learners' knowledge more suitably considered as an ecology of quasi-independent elements (e.g., Clark, 2006; diSessa, Gillespie, & Esterly, 2004; Linn, Eylon, & Davis, 2004; diSessa, 2002; Harrison, Grayson, & Treagust, 1999)?

The supporters of the 'knowledge-as-theory' school of thought argue for a wide-ranging graded or ranked conceptual structure with theory-like properties that limits or restricts a learner's interpretation of minor models and ideas. Within this group knowledge is viewed as cogent structures based in assiduous ontological and epistemological compulsions (Özdemir & Clark, 2007). However, novices' or learners' alternative conceptions do hinder future

learning and allow novices to make consistent predictions across conceptual fields (Özdemir & Clark, 2007). This school of thought claims that learners at any given time maintain a small number of well-developed coherent naive conceptions based on their everyday experiences and that these conceptions have the ability to make consistent forecasts and justifications across significant fields. The kinds of conceptual changes postulated by the knowledge-as-theory perspectives involve radical change in knowledge structures through several mechanisms. These mechanisms include Piaget's notion of assimilation and accommodation or Kuhn's notion of a paradigm shift; and the notion of ontological shifts and the evolution of mental models (Zirbel, 2008).

According to the knowledge-as-elements perspective, elements interact with each other in a developing manner where the increasing complexity of the system constrains learners' interpretations and understandings of phenomena. The supporters of the knowledge-as-elements perspective postulate that naive knowledge structures consist of a number of conceptual elements or basics including, phenomenological primitives, facts, facets, narratives, concepts, and mental models at various stages of development and sophistication. Learners or novices instinctively connect and activate these knowledge pieces according to the importance or relevance of the situation (Özdemir & Clark, 2007).

Conceptual change according to the knowledge-as-elements perspectives involves a review and improvement of the elements and interactions between the elements through addition, elimination and reorganisation in order to strengthen the network. From this perspective, conceptual change involves a fragmented evolutionary process rather than a general theory replacement process (Özdemir & Clark, 2007).

According to Özdemir and Clark (2007) the debate between researchers in each school is critical because these models imply totally different pathways for curricular design (and classroom practice) to help learners reorganise their understandings. Therefore, understanding the mechanism of conceptual change will go a long way in helping learners develop the correct science concepts. This however, can only be achieved through mediation by the knowledgeable other, the teacher, through appropriately planned, prepared and practiced lessons.

4.3.2 Practical implications to foster conceptual change

On a more practical level, Posner et al., (1982) listed four conditions that promote accommodation in learner thinking:

- They must be *dissatisfied* with their existing conceptions about natural phenomena so that it can be abandoned to allow for the acceptance of scientific conception for successful conceptual change.
- A new conception must be *intelligible* ensuring that it is clear enough for the learner to make sense of it.
- A new conception must appear *plausible* in that it must be seen to be possibly true and have the capacity to solve problems that the previous one did not.
- A new concept should suggest the possibility of *fruitfulness*, in that it must appear potentially productive to the learner for solving current problems and be able to open up new opportunities for thinking and learning.

Teachers who accept and understand these four conditions as essential for conceptual change to occur are confident to take intervention steps to create appropriate classroom interactions that address these conditions. Learners shape their lives around opinions that they hold about experiences. Therefore some conceptual changes that teachers consider desirable or correct from a science point of view may be highly resistant to change, and possibly affect learners negatively (Özdemir & Clark, 2007). To become more effective in encouraging conceptual change, teachers should seek to understand learners' naive conceptions so they can be addressed directly through appropriate instruction.

While there are different views about the process of conceptual change, these views all reflect the principles of constructivism. The constructivist principles of active participation, learner-centeredness, social interactions and eliciting of prior knowledge have been identified as teaching and learning strategies that promote conceptual change. For example, Wiser and Amin (2002) suggest the use of computer models coupled with verbal interactions, with the teacher promoting the scaffolding of ideas in accordance with Vygotsky's theory of learning. Niaz et al., (2002) have also concluded that if learners are given the opportunity to argue and discuss their ideas then their "understanding can go beyond the simple regurgitation of experimental detail"(p.523). Mikkila-Erdmann (2002) argues for the use of written questions and statements or text that guides learners to accepted conceptions.

4.4 EPISTEMOLOGICAL BELIEFS ABOUT TEACHING KNOWLEDGE

Epistemological beliefs are individuals' simple opinions and understanding about the nature of knowledge and about suitable ways to create knowledge in order to expand or change one's own and others' knowledge (Hofer & Pintrich, 2002; Schommer, 1990). Hence, such beliefs impact on and shape individual characteristics, which influence learning and professional activities (Harteis, Gruber & Hertramph, 2010). It is plausible that teachers perceive and interpret their school environment including the curriculum by applying their individual beliefs. From a socio-constructivist view, it may be regarded as a process of making sense of the world (Billett, 2006; Rogoff, 2003).

Epistemological beliefs have recently received much attention in the fields of educational and psychological research (Harteis et al., 2010). While the approaches in psychology focuses on the development and constancy of epistemological beliefs, educational research focuses on how epistemological beliefs affect teaching activities (Harteis, Gruber, & Lehner, 2006) and learning processes (Bauer, Festner, Gruber, Harteis, & Heid, 2004). Within the education context, learning can therefore be considered to be a process of making sense of the world.

Various conceptualisations of individuals' views of knowledge and knowing have been developed over the years (e.g., King & Kitchener, 1994; Perry, 1970). In Perry's longitudinal study 84 male students in liberal arts were required to describe their university experiences. Responses to open-ended interview questions were regarded at first to be the result of certain personality characteristics. However, each year, as the students were re-interviewed a regular pattern of change was emerging with respect to how the students viewed the world (Perry, 1988). These patterns of change were related to their cognition or thinking, identity and ethical development. These changes were assumed to account for experiences both within, and external to the university context. Perry (1988) described changes in thinking as a type of evolution in the way individuals interpret their world. Perry (1988) identified four main epistemological positions, which progress in stages: *dualistic, multiplistic, relativistic and commitment to relativistic.*

Individuals who held *dualistic* views about the nature of knowledge believed that absolute truths (right/wrong) exist and such truths can be transmitted to an individual from an authority or expert.

When individuals began to consider knowledge in a *multiplistic* way, they accepted that in addition to absolute truths, there were some things that could not be known with any certainty. Such individuals believed that knowledge comprised both personal opinions and ultimate truths. They relied less on authorities for absolute truths but personal opinions and truths were still considered to be "right" or "wrong".

Individuals who considered that knowledge was actively and personally constructed, viewed knowledge in a *relativistic* way. Absolute truths could no longer exist because truth was considered to be relative to individuals' personal interpretations of experiences. Relativistic thinking therefore constituted a major shift in epistemological beliefs.

In *commitment to relativistic,* as the final epistemological position relativistic thinking was still a feature, but some beliefs were more treasured than others and were committed to in a flexible manner. These epistemological beliefs were considered to influence learning.

Schommer (1993a) and Ryan (1984) reported that the more learners regarded knowing as dualistic, the more likely they were to measure their understanding based on factual standards. Relativistic thinkers, on the other hand, were more likely to consider that comprehension was related to understanding and application. Individuals with relativistic beliefs are more able to reflect on different ways of thinking rather than focussing on content only. The ability to compare different ways of thinking reflects "meta-thinking, the capacity to examine thought, including one's own" (Perry, 1981, p. 88). Being able to practice meta-cognition enables learners to see other peoples' points of view. It also enables them to reflect on relationships so they can integrate information into relational wholes instead of maintaining isolated pieces of information.

Perry's study reflects a developmental approach to epistemological beliefs. Other studies (e.g. King & Kitchener, 1994, 2002; Kuhn & Weinstock, 2002; Moore, 2002) present a developmental model similar to that of Perry. These developmental models have been criticised for being one-dimensional and having a stage-like character (Kienhues et al., 2008).

More recently, epistemological beliefs have been viewed as a multi-dimensional and multi-layered aspect of individuals' belief systems (Buehl & Alexander, 2001; Schommer, 1990; 1993a, 1993b; Schommer-Aikins, Mau, Brookhart, & Hutter, 2000; Schommer-Aikins 2002;

Schraw, Bendixen, & Dunkle, 2002). According to this model individuals may have either naive or sophisticated beliefs. Schommer (1990; 1993a, 1993b) established five dimensions of epistemological beliefs namely, (1) belief about the source of knowledge / omniscient authority, (2) belief about the certainty of knowledge / certain knowledge, (3) belief about the structure of knowledge / simple knowledge, (4) belief about the pace of acquiring knowledge / quick learning, and (5) belief about the stability of knowledge / innate ability (Schommer 1990, 1993a, 1993b).

According to the multidimensional structure of epistemological beliefs individuals who possess naive epistemological beliefs maintain that knowledge is definite, that is, accurate or correct; that knowledge is simple or straightforward in that it consists of disconnected or separate parts; that the source of knowledge is from a wise or well informed authority and transmitted to learners; that the ability to learn is inherited and fixed; and that the speed of learning is fast or never (Schommer 1990, 1993a, 1993b).

On the other hand, those who possess sophisticated or developed beliefs are thought to believe that knowledge can be correct or incorrect depending on the context or situation; that knowledge has a multifaceted structure consisting of many interrelated parts; that knowledge is constructed individually by using logic or tentative experimental evidence; that the ability to learn can be improved; and learning depends on the effort put-in by learners (Erdamar & Alpan, 2013).

Buehl and Fives (2009) claim that, while the role of teachers' epistemological beliefs with respect to teacher education and practice has been studied (e.g., Hofer & Pintrich, 1997; Patrick & Pintrich, 2001; Woolfolk- Hoy & Murphy, 2001) relatively few empirical studies have been reported on. However, as cited in Buehl et al., (2009) qualitative studies through interviews and/or questionnaires, have found that pre-service and practicing teachers' beliefs about knowledge: Are varied and may change depending on the context (e.g., Olafson & Schraw, 2006; White, 2000; Yadav & Koehler, 2007); Can change as a result of instruction (e.g., Brownlee, Purdie, & Boulton-Lewis, 2001; Gill, Ashton, & Algina, 2004); May influence how and what they learn in teacher education classes (e.g., Ravindran, Greene, & Debacker, 2005); May influence teaching practices (e.g., Sinatra & Kardash, 2004; Yadav & Koehler). Ravindran, et al., (2005) found that pre-service teachers' beliefs about the simplicity of knowledge were related to shallow levels of cognitive processing. With respect

to teaching practices, Yadav and Koehler (2007) found that pre-service teachers' selection and interpretation of effective video cases were reflective of their beliefs about the simplicity of knowledge and students' metacognitive ability.

Olafson and Schraw (2006) found that there were inconsistencies between the beliefs expressed by practicing teachers and their classroom practices. Studies have also acknowledged that teacher beliefs are complex, in that; beliefs may not necessarily fall into discrete categories (e.g., Olafson & Schraw, 2006; White, 2000). Instead, individuals may hold multiple beliefs that are both general and specific to a field. Furthermore, Many, Howard and Hoge (2002) found evidence that pre-service teachers hold different beliefs about knowledge, depending on whether they are focused on teaching or learning (i.e., considering themselves in the role of the teacher in a classroom or considering themselves in the role of the learner in a teaching education program). This is significant in that, the teacher participants in this study may be regarded as learners to the programme and to the imperatives of the new curriculum.

Piaget's (1985) notion of assimilation and accommodation are also viewed as learning processes. Hence, teaching provides opportunities for these processes by involving learners both in routine tasks and in challenging new tasks (Billett, 2006). This reflects a constructivist view of learning. With the influence of previous experiences, biases, and beliefs on learning and knowledge, it becomes clear that learning, knowledge, and realisation or understanding are individual units establishing a particular view of the world, which makes sense for the individual. Thus, bias as the control of an individual's feelings, interpretations, and expectations may be seen as the essence of an individual's attitudes and aptitudes (Harteis, Gruber & Hertramph, 2010).

While various studies in epistemological beliefs (e.g., Perry, 1970; Kuhn & Weinstock, 2002; Schommer, Calvert, Gariglietti, & Bajaj, 1997; King & Kitchener, 1994; Schommer, 1993b) may have different underlying theoretical assumptions, they all claim that there is change over time from the so-called naive epistemological beliefs towards sophisticated beliefs. It is possible for example, that a teacher may initially believe that knowledge is firm and unchanging, either correct or false, and is passed down by an expert, but with time s/he becomes induced into believing that knowledge is more multifaceted and relativistic, accepts the uncertainty and changeability of truth, and changes to the notion that knowledge is

construed individually (Kienhues, et al., 2008). Within the context of this study and based on the assertion about changing epistemological beliefs, it may be possible to identify such changes in the practices of teachers from traditional towards reformation.

4.5 THE CHANGING ROLE OF THE TEACHER DUE TO CURRICULUM REFORM

Teachers as classroom practitioners play a central role in nearly all formal instructional organisations (Borko, 2004). Hence, they are regarded as the "cornerstone" or "the most influential factor" in educational reforms (Fishman & Davis, 2006; Van Driel, Beijaard, & Verloop, 2001). Understanding their new roles in the implementation of reformed curricula is crucial for teachers. The new roles that teachers find themselves in could pose a great deal of challenges in their practice of the reformed curriculum if no attention is paid to it.

4.5.1 New roles of teacher for implementing reform-based science lessons

The changing role of the teacher includes being regarded as a facilitator of the teaching and learning process rather than an authoritarian figure who will control the teaching and learning situation. That is, the teachers' role changes from being an 'authoritarian controller' of teaching and learning to an 'authoritative facilitator' within the teaching and learning situation. The teacher will have to change his/her teaching styles which emphasised teacher-centeredness to one that will enhance a learner-centred approach, encouraging co-operative and collaborative activities. In such a role as a facilitator the teacher will have to organise the teaching environment, pay attention to guiding the learners during activities and helping them in the decision making process. In addition, it will entail encouraging learners to share and discuss their ideas and reach consensus through reflective practice. Furthermore, the teacher will have to make links with scientific concepts and everyday existence. Within the new roles teachers will also require knowledge and understanding of new pedagogies (Guo, 2007) and new learning theories. They will also need to learn, understand and practice different teaching strategies, which are in line with the constructivist approach to teaching and learning.

Hence, in order to understand the changing role of the teacher in curriculum reformation it is important to analyse teachers' knowledge, beliefs and practices. The participant teachers in this study did not have any formal training specifically in respect of the investigative practical work (IPW). It is therefore critical to understand their existing knowledge and beliefs and how these influence their classroom practices.

Against the backdrop of teacher's essential role in implementing reforms in curriculum, this study attempted to understand the acceptance and/or adjustment or non-acceptance of the transformed South African Life Sciences curriculum by interpreting teachers' knowledge, beliefs and their practice of IPW in the classroom. In doing so, it also provided insight into the change factors or challenges that could have influenced or affected their decisions in the enactment of IPW.

4.5.2 Classroom teaching practices: Traditional versus Reform Science Teaching

In order to understand changes in the Life Sciences classroom with respect to the implementation of investigations, from the traditional practice to the expected transformed practice, it is necessary to understand the characteristics of each. In this regard, Table 4.2 provides a description of the differences between traditional practices and reformed practices, for the different aspects of a lesson. This has however, been limited to lessons involving IPW in order to make it relevant for this study.

Table 4.2: Differences between traditional and reformed classroom practices with respect to science investigations

Aspects of lesson	Traditional practice	Reformed practice
1. General design of lesson	Prior knowledge is not explicitly considered.	Prior knowledge of learners is considered in order to create dissonance so that meaningful learning and understanding may occur.
	Exploration is in the form of verification of concrete experience of formal presentation.	Learner exploration precedes formal presentation.
	Concepts are taught in isolation rather than as the inter-relatedness of scientific thinking.	Subject matter concepts and processes are at the heart of the lesson and the lesson promotes conceptual understanding.
	Knowledge is generally accessed individually by learners.	Learners engage as members of a learning community.
2. Teacher knowledge	Teacher knowledge is important to transmit content knowledge.	Teacher senses the potential significance of ideas as they occur in the lesson and shows eagerness to pursue learners' thoughts for pursuance of conceptual understanding.
	Content knowledge usually transmitted as isolated facts without connection to other disciplines and the real world.	Connection to other disciplines and the real world is created for conceptual understanding.

3. Teacher activities	Teacher follows a narrow, prescribed path of reasoning, to the exclusion of alternatives.	A variety of ideas are allowed resulting in rigorous debate and the challenging of ideas.
	Low cognitive level questions requiring short responses is common.	Teacher poses a variety of cognitive levels of questions which trigger divergent modes of thinking.
	Lack of opportunities created for learners to pose questions.	Learners are encouraged to pose questions and challenge the ideas posed by the teacher, text books and peers.
	Teacher generally provides the question, hypothesis, and detailed procedure for the investigation in the form of a worksheet.	Learners are encouraged to generate conjectures, hypotheses, alternative solution strategies and ways of interpreting results.
	Activities are directed by the teacher – verbally or through worksheets and / or textbooks.	Teacher acts as a facilitator and resource person rather than a director of activities. This also implies that s/he is a good listener.
	Teachers are the most active participants with learners being relegated to passive recipients of instructions and directions to carry out structured experiment.	Active participation of learners is encouraged and valued. Active participation implies agenda-setting as well as "minds-on" and "hands-on" participation.
4. Learner activities	A single method of experimentation promoted.	Encourages learners to seek and value alternative modes of investigation.
	Direction of lesson is predicted in advance by the teacher and requires learners to follow a set of instructions and/or sequence as set down by the teacher or text book. The solutions are also 'known in advance'.	The focus and direction of the lesson is often determined by ideas originating with learners, their comments and their questions.
	Teacher generally provides the question, hypothesis, and detailed procedure for the investigation.	Learners generate hypotheses, predictions and devise ways of testing these.
	Teacher provides the method of data collection, the format of recording data, and the manner in which the data will be analysed and presented.	Learners devise and use a variety of ways of collecting, recording, analysing data and presenting these.
	It is more important for learners to be involved in the physical 'doing' of the investigation.	Learners engage in critical assessment of investigation procedure.
	The intensity of following pre-determined procedures do not allow learners to actively think about how what they do affects the next steps in their investigations.	Learners engage in re-examining or re-assessing their thinking. They engage in metacognition through reflection.
	Communication is generally limited to the presentation and pooling of results at the end of the investigation.	Learners are involved in the communication of their ideas to others using a variety of means and media in order to reflect on their contribution to the richness of the lesson. They are allowed to raise questions with their peers as well as with the teacher.
	Teacher does most of the talking.	There is a high proportion of learner talk and a significant amount of it occurs between and among learners.
	Respecting what others have to say is more about listening politely. The teacher is the authority figure.	Encourages and allows every member of the learning community to present and express their ideas and opinions without fear of censure or ridicule.

Adapted from Piburn and Sawada (2000)

Changes in classroom practices are dependent on the changes in teachers' knowledge and beliefs (Kubitskey & Fishman, 2005; Van Driel et al., 2001). Furthermore, teachers'

knowledge and beliefs are regarded as the main links between Professional Development (PD) and teaching practice (Borko, 2004; Kubitskey & Fishman, 2005). Moreover, teachers' knowledge and beliefs can be changed through professional development and/or classroom practice (Kubitskey & Fishman, 2005; Putman & Borko, 1996).

Ni and Guzdial (2008) proposed a 'teacher change model' consisting of four categories or factors that may influence teachers' decisions to adopt reforms. They referred to these factors as 'adoption factors' (p.3). These adoption factors included the following: (1) Teachers' knowledge, attitudes and beliefs about curriculum; (2) Teachers' knowledge, attitudes and beliefs about learners; (3) Teachers' knowledge, attitudes and beliefs about self (the teacher); (4) Quality of intervention (PD) activities such as workshops, conferences and other teacher education opportunities. While Ni and Guzdial (2008) incorporate such aspects as learning goals, content coverage, preparation time and contextual factors into category (1) that is, knowledge, attitudes and beliefs about curriculum, for the purpose of this study, these aspects have been separated. In addition, these categories were modified to read as, 'Teachers' knowledge and beliefs……' Attitude has been left out because within the context of this study 'teachers' beliefs' incorporates attitudes. Hence, analysis involved data with respect to: (1) Knowledge and beliefs about the Life Sciences Curriculum; (2) Knowledge and beliefs about subject matter knowledge; (3) Knowledge and beliefs about general pedagogical knowledge; (4) Knowledge and beliefs about pedagogical content knowledge; (5) Knowledge and beliefs about pedagogical context knowledge; (6) Knowledge and beliefs about self (teacher). The data with respect to the abovementioned six categories was analysed and compared with the data from classroom observation to determine whether the participant teachers practiced IPW using transformed strategies, partially transformed strategies or traditional strategies.

4.6 SUMMARISING THE FRAMEWORK

Figure 4.1 illustrates the framework which guided the study in analysing the participant teachers' knowledge, beliefs and practices. It illustrates the inter-relationship between the over-arching theoretical concept of constructivism, and the constructs of conceptual change, epistemological beliefs, the changing role of the teacher, and how it relates to the practice of IPW in the classroom. A brief description of the inter-relationships is articulated after the illustration.

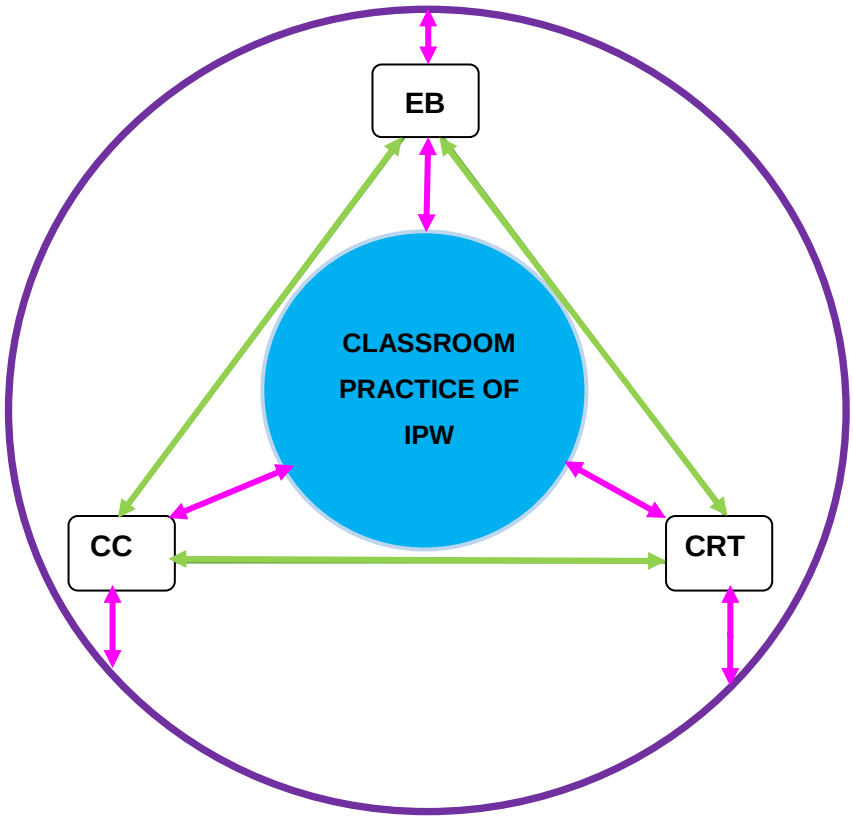


Figure 4.1: **The inter-relationship between constructivism, epistemological beliefs (EB), conceptual change (CC), changing role of the teacher (CRT) and classroom practice of IPW**
Note: The outermost (purple) circle represents 'constructivism'

4.6.1 Conceptual Change and Constructivism

Different individuals construct alternative conceptions from the same information. Also, studies have shown that learners come to the classroom with preconceptions or beliefs or views about scientific phenomena, known as 'naive' knowledge or 'prior' conception that is often different from the established or accepted facts (Cinici, Sozbilir, & Demir, 2011; Alparslan, Tekkaya, & Geban, 2003; Palmer, 2003). In order to help bring about conceptual change, Cinici and Demir (2013) maintains that it can be best accomplished through learner-centred, active learning experiences based on the constructivist approach to learning. The mechanisms which bring about such conceptual change is based on Piaget's constructivist mechanisms of assimilation and accommodation, which underpins the "conceptual change" learning model of Posner et al., (1982). Utilising constructivist teaching and learning strategies will help teachers identify their learners' naive conceptions or ideas and plan their lessons accordingly with the aim of bringing about conceptual change. Conceptual change has become a hallmark in the principles of constructivist practice of teaching and learning (Duit, 1994). When teachers help learners to elicit prior knowledge and create dissonance,

conceptual change occurs as new and meaningful understanding is built upon the prior or naive knowledge. When conceptual change takes place due to the adoption of intellectual tools and the use of these tools in a variety of contexts, then such a change is construed as occurring at the societal level. This therefore highlights the social nature of knowledge acquisition. Active participation and conversation are necessary for restructuring as well as cognitive change. 'Social or physical interactions' and 'active participation' are essential principles of constructivism. The principles of active participation, learner-centeredness, social interactions, and eliciting of prior knowledge have been identified as teaching and learning strategies that promote conceptual change. Hence, the existence of this close interrelationship between conceptual change and constructivism.

When implementing IPW various concepts and processes for example, 'hypothesis', variables and how to control variables as part of the experimental design, pose challenges to learners as well as teachers. Understanding how conceptual change occurs, will help teachers plan appropriate constructivist strategies accordingly

4.6.2 Conceptual Change and Epistemological Beliefs

Conceptual change revolves around the restructuring and reorganisation of existing knowledge structures in order to overcome specific naive or distorted beliefs and knowledge about science concepts. According to Posner et al., (1982) a person's conceptual ecology consists of his/her conceptions and ideas entrenched in his/her epistemological beliefs. It is therefore important to understand teachers' epistemological beliefs about teaching knowledge. From a conceptual ecology point of view, the fundamental ideas and epistemological beliefs deeply influence a learner's interaction with new knowledge or beliefs and challenges. Similarities can be identified between fostering changes in epistemological beliefs and the task of promoting 'conceptual change' (Kienhues, et al., 2008). How and why, such changes take place, has been researched and addressed in the Conceptual Change Model of Posner et al., (1982) and the Cognitive Change Model of Dole and Sinatra (1998). These models highlight the issue of dissonance or disequilibrium between existing beliefs and new experiences, which may lead to dissatisfaction with current concepts. The discrepancy that results has to be resolved.

The ability to change is dependent on the potency and sense of the existing conception as well as the obligation to it. Dole and Sinatra's (1998) model also takes into account such motivation as, the need for reasoning and understanding and importance of a topic to an

individual. Hence, in order for a teacher to help facilitate conceptual change s/he must first be induced into transforming underdeveloped or naive beliefs about science teaching and learning, especially IPW and related concepts into more sophisticated beliefs thereof. In doing so the teacher may then be motivated to provide routine and challenging opportunities together with the necessary support and guidance to the learners to help bring about conceptual change.

4.6.3 Epistemological Beliefs and Constructivism

The ability to compare different ways of thinking reflects "meta-thinking, the capacity to examine thought, including one's own" (Perry, 1981, p. 88). Being able to practice meta-cognition enables learners to see other peoples' points of view. It also enables them to reflect on relationships so they can integrate information into relational wholes instead of maintaining isolated pieces of information. In this way ones thinking and beliefs strives for greater sophistication. To achieve this, social interactions and conversations play a significant role in reflective thinking. Understanding how constructivist teaching and learning strategies such as, co-operation, collaboration and conversation by the teacher, may be employed in the classroom is of importance to help accomplish conceptual change. Therefore, it is of paramount importance for teachers to have an understanding of the role of epistemological beliefs, conceptual change, and constructivism in bringing about changes in the practice IPW. Co-operation, collaboration and conversation are strategies that can be utilised to bring about such changes.

4.6.4 The Changing Role of the Teacher and Constructivism

The role of the teacher will now change to that of a ‘facilitator’ of learning within the reformed Life Sciences curriculum. Hence, the teacher will need to operate within a constructivist paradigm. This will therefore entail making adjustments to aspects such as classroom management, planning, preparation and design of lessons and/or activities. The model developed as part of the theoretical and conceptual frameworks will therefore help in analysing and interpreting the changing roles of the teacher.

4.7 CONCLUSION

The model presented here as the theoretical and conceptual frameworks guided the study to analyse and interpret what the teachers said and how they acted. The use of the above theoretical and conceptual frameworks provided insight into the subtleties and interplay

between teachers' knowledge and their beliefs and how these were translated into classroom practice by using constructivism as a backdrop to reforms in science education. The teachers' verbal and written responses were triangulated with their actions. Interpreting their responses required an understanding of the inter-relationship among: conceptual change, epistemological beliefs, and the changing role of the teacher on the one hand and how these related to the practice of constructivism.

Chapter Five which follows elaborates on the research design and methodology used in this qualitative interpretive study.

CHAPTER FIVE

RESEARCH DESIGN AND METHODOLOGY

5.1 INTRODUCTION

A research design is a plan for collecting and analysing evidence that makes it possible for the researcher to answer questions posed (Flick, 2007). A good research design, according to Babbie and Mouton (2001), is a plan or strategy with two aspects: one, to specify what needs to be found out and the other to find the best way of finding out how.

Research methodology focuses on the research process, the kind of tools and procedures used and the specific tasks employed for gathering data (Mouton, 2001). Hence, the foundation of the research process rests on an overarching methodological framework consisting of questions, designs, data structures and decisions about analysis (Heck & Thomas, 2000).

Chapter Five focuses on the research design and methodology applied to understand the relationship between teachers' knowledge and beliefs about science education and the teaching and learning of IPW. In this regard, the Chapter describes the interpretive research paradigm within which this study locates itself. The rationale for the qualitative research is then discussed. A motivation for the sampling and selection of the research sites and participants is subsequently provided. Following on this motivation, the data collection techniques and processes utilised, and the procedures followed and observed with respect to ethical issues are elaborated on. Finally, data analysis and the issues of validity / trustworthiness and reliability are discussed.

The discussion about the research design will begin with an explanation of the paradigm perceived to be most suitable for this study (Creswell, 1994).

5.2 INTERPRETIVE RESEARCH PARADIGMS

Since the focus of this study is exploratory, a qualitative, interpretive research design was selected as the most appropriate one. In this regard, a qualitative multiple case study approach (Creswell, 2002; Abrahams and Millar, 2008) was utilised. Since the participants or respondents to this study have different backgrounds, experiences and understandings and work in varying contexts it is possible that their responses to the changes and demands of the curriculum may be different. Therefore interpreting and understanding the different responses requires the researcher to be knowledgeable about interpretive theories.

The discussion that follows indicates how the current study falls within an interpretive paradigm. In order to answer the various questions pertaining to this study, data was

generated and collected from questionnaires, interviews, observation of lessons, and document analysis. The documents included tasks completed by the participant teachers, and teacher and learner artefacts. Interpreting these results also took the context or situatedness of the teaching and learning environments into account. Cohen, Manion and Morrison (2007), contends that the interpretive paradigm is characterised by a concern for the individual. Hence, the researcher was personally involved during the data gathering and data processing stages of the study in order to understand how the Grade 12 teacher participants interpreted their classroom experiences and what meaning they attributed to their experiences with their learners (Merriam, 2009; Maree, 2007).

The discussion that follows will illuminate how the above issues were taken into account in this study.

5.3 QUALITATIVE RESEARCH

At the core of qualitative research is the acceptance that individuals construct reality in interaction with their social world (Merriam, 2009). The world or reality is not fixed, agreed upon, nor a measurable experience as assumed to be the case in positivist, quantitative research. Instead there may be multiple meanings and interpretations of reality that are in continuous flux and change over time Merriam (2002). Denzin and Lincoln (2005) contend that qualitative research is a more suitable approach to study socially constructed realities since it is a practice that ensures that the observer is part of the situation. Miles and Hubberman (1994) commented that qualitative research studies understand human behaviour by observing and communicating with people, questioning people's opinions and attitudes, and analysing documents such as teacher and learner artefacts and tasks.

By studying people in their natural environment through observations of their actions and by focusing on their stated meanings and interpretations of events as they experience them, it is possible to obtain a clearer perspective of their intentions (Maree, 2007). In other words, it captures the world in a series of interviews, observations and recordings, which is then interpreted in its natural settings because the final written report will include the voices of participants, the reflection of the researcher, and a multifaceted account and understanding of the problem (Creswell, 2007).

In view of the fact that research is about exploring relationships between events, seeking explanations about why things happen and comparing approaches to practice (McNaughton,

2000), as a curriculum specialist it was the logical approach to select a study design that provided the researcher with in-depth answers to the research questions.

For this study the researcher chose four different sites / cases to study the same phenomenon. The context of each of these sites and the biographical data of the participants is indicated in Tables 5.2 and 5.3 respectively. In addition, the researcher studied teachers in action within their classrooms. Furthermore, the researcher was personally involved in all aspects of data collection and processing. This therefore provided a condition that led to a better understanding of the actions and/or meanings of the participants during their classroom practice by linking and interpreting the various data that were collected. The active role of the researcher in data collection prevented the 'dilution' of information.

In short, the qualitative research study provided the researcher with the processes to obtain answers to questions about the selected Grade 12 Life Sciences teachers. This included issues such as what knowledge and beliefs they hold and how it impacted on their practice of IPW. The qualitative research methodology provided the researcher with the opportunity to interpret and understand teachers' practice through their actions, and through their written and verbal expression in order to develop a comprehensive picture of the topic being investigated (Hartslief & Auriacombe, 2009).

The aim of qualitative research is not to account for behaviour in terms of unanimously applicable rules or generalisations but rather to understand and interpret the sense and purpose that underlie everyday human action (Schurink, 1998). However, in order to interpret and understand such actions, the researcher used what may be regarded as acceptable knowledge and practice from literature. In an attempt to understand the interplay among teachers' knowledge, teachers' beliefs and how these relate to their teaching of IPW the researcher is focusing on a part of reality that is situated in the world of school education with the intention of improving practice in that context, so that the quality of Life Sciences teaching and learning is enhanced. School–based practice in the Life Sciences is selected because this is the area in which the researcher has gained some thirty years of experience.

The qualitative research method was chosen for the following reasons:

* It provided a deep description of phenomenon such as beliefs including attitudes regarding teaching and learning.
* It afforded descriptions and explanations with rich information, which was obtained through multiple data collecting strategies such as, questionnaires, interviews,

observations and the study of documents.

* It empowered individuals to use their voices and it minimised the power relationships that existed between the researcher who under normal circumstances is the curriculum advisor and the participant teachers in this study.

5.4 USING THE CASE STUDY APPROACH

A case study is a generic term given for the investigation of an individual, group or phenomenon that uses the qualitative approach. A case study, according to Bless, Higson-Smith and Kagee, (2006) allows a focus on the interpretation of the participants' actions and/or behaviour so that significant characteristics can be uncovered and thereby provide a rich and thick description of a particular phenomenon.

Yin (1994, p. 13) refers to a case study as, an investigation that studies a current phenomenon which is realistic; especially when the boundaries between phenomena and context are not clearly evident.

Stake (1994) argues that the case is a 'bounded system' and further asserts that the,

> *'more the object of the study is a specific, unique and bounded system, the greater the usefulness of the epistemological rationale"* (p.236).

However, in this study, there is not necessarily a clear boundary between the phenomenon and the context. The implementation of IPW is prescribed in the Life Sciences curriculum within the *NCS*. Hence, it is inextricably linked to its context since all schools are required to implement IPW irrespective of the differences in the educational environment. Indeed, knowledge is an inseparable product of activities and situations in which they are produced (Brown, Collins, Duguid, 1989). This study was conducted or situated within the context of the respective schools. Understanding such variations will help to interpret the actions of the participants in this study.

A more interpretive perspective on a case study is provided by Stake (1995), which claims that, a case study is the study of the individuality and density or complexity of a single case, getting to comprehend and understand its goings–on within important situations.

For the current research a multiple case study approach was used involving four schools and a series of four case studies in different settings. This was done to avoid what Firestone and

Herriott (1984) terms the 'radical particularism' of the traditional single in-depth case study. Furthermore, according to Schofield (1993), studying a number of heterogeneous sites makes multi-site studies a potentially useful qualitative approach to increase the generalisability of findings.

Picciano (2004) asserts that the case study method examines the descriptive question of 'what happened' or the exploratory question of 'how or why' did something happen. The key research questions of this study as indicated in Chapter One match these descriptive and exploratory questions.

Human systems have a particular wholeness or integrity and therefore it is important to do an in-depth investigation of the relationships between the parts and the patterns that emerge (Bassey 1999). Case study research assists us in understanding a complex issue or object and can extend experience or add strength to what is already known through previous research (Garbers, 1996).

Denzin and Lincoln (2003) argue that a case study constitutes both a process of inquiry about the case and a product of that inquiry. Hence, by researching a single case, that is, the relationship between Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of IPW a great deal of time, effort and diligence was given to each of the four cases. The amount of data collected for each case is testimony to this.

For a case study methodology the researcher has to be cautious as to the position he/she takes during the data collecting process. As an employee of the KwaZulu-Natal Department of Education, the researcher had access to participants. It is argued that the ideal research setting is when the researcher can secure easy access and establish rapport with the identified participants in the data gathering process (Taylor & Bogdan, 1984). Therefore, the researcher had to put aside his own prejudices and pre-conceived views on the implementation of IPW in the Life Sciences. Consequently, he had to also reassure participants that the process was highly confidential. This was achieved by obtaining ethical clearance from the University of KwaZulu-Natal as well as from the KwaZulu-Natal Department of Education. In addition, the researcher observed the first lesson of each participant teacher to familiarise himself with the relevant classroom environment, and to establish rapport with the learners and to also allow the teacher to be more relaxed in the presence of the researcher.

Furthermore, it must be noted that the researcher has been working as a curriculum specialist with the participants for more than sixteen years. During this period the researcher had built up an excellent professional rapport with the teachers of Life Sciences in the Umlazi District. His relationship with the participants is one of cordiality and professionalism. The willingness of the teachers to participate in this study bears testimony to this claim.

5.4.1 Advantages of the Case Study Method

By using the case study methodology the researcher had the opportunity to make direct observations and to collect data in a natural environment, as opposed to relying on secondary data derived from other sources.

The case study was desirable because of the small sample size. It further afforded the researcher some latitude to interact with the subjects because the qualitative investigation is somewhat informal. It also allowed the researcher to probe the subjects during the interview in order to elicit detailed responses.

While the focus of the case study methodology was to obtain a better understanding, it also showed causality Gustavasson (2007). By using the case study methodology no single data collection tool has complete advantage over the others (Maree, 2007). In fact, multiple sources of data provide a fuller picture or understanding of the phenomenon. Also, using a variety of strategies to collect data lends itself to an enhanced validation / trustworthiness and reliability and therefore credibility. In addition, the researcher determined in advance what evidence to gather and what analysis techniques to use with the data in order to answer the research questions Maree (2007).

In essence, the case study approach provides the opportunity for a case to be examined in depth and detail within a real life situation.

In this study, the bounded system that formed the case was the Grade 12 Life Sciences teachers at the four research sites. By using a case study approach for this study, multiple data gathering techniques were used to explore the research topic. This approach enabled the researcher to obtain a rich and thick description of the teachers' knowledge and beliefs and their practice (Bless et al., 2006).

5.4.2 Rigor of the study design

Qualitative research involves the analysis of data that is sometimes difficult to quantify because it focuses on observing the behaviour of subjects within their natural context (Cohen

et al., 2007). Rigor is usually achieved through a set of approaches that ensures its progress and accuracy. The study design being a multi–case study lends itself to verification with each case or site under study. Furthermore, it could be replicated in any other school with Grade 12 Life Sciences teachers as well as by other researchers. The findings of the study are relevant to Grade 12 Life Sciences teachers at these research sites but may also be reflective of Life Sciences teachers in other grades and / or schools in the district, province or country but not necessarily so. The researcher made every attempt to reflect on his subjectivity and bias as a Life Sciences curriculum specialist in the district and the limitations of the study. The study does however create the opportunity for other researchers to explore the phenomenon in South Africa. The researcher also acknowledges his bias, which is deeply embedded in the philosophy underpinning the curriculum by virtue of his participation in the writing process of the curriculum. In addition, the researcher was mindful of his bias of being influential in introducing IPW into the curriculum and of seeing it successfully implemented.

In qualitative research, data is collected in the field at the site where participants experience the issue or problem. The researcher attempted to understand the situation in its uniqueness as part of the specific context. The teachers involved were spoken to directly and their actions observed in the classroom so that their specific situation with its challenges could be more fully understood.

5.5 SELECTIION OF THE SAMPLE

Sampling, according to Maree (2007) refers to the process used to select a portion of the population for a study.

5.5.1 Population and Sampling

A population is defined as a specific unit being sampled usually by its geographical location and the temporal boundaries of the population (Neuman, 2006). All the Life Sciences teachers in the Umlazi District may be regarded as the population with respect to this study.

5.5.2 Purposive Sampling

Purposive sampling is also linked to theoretical sampling. The sample represents a theoretical 'population' in that they are the spokespersons for the topic of inquiry, hence the idea of theoretical sampling (Henning, Van Rensburg & Smit, 2004). Merriam (2009) stated that for a case study approach, a particular group of subjects that is a bounded system could be selected on the basis of typicality. Purposive sampling assumes that the researcher wants to discover,

understand, and gain insight and therefore must select a sample from which the most can be learned (Merriam, 1998). According to Maree (2007) with purposive sampling, participants are selected because of some defining characteristic that makes them the holders of data needed for the study. Patton (2002) stated that the logic and power of purposive sampling lies in selecting information-rich cases so that a great deal can be learnt about issues of central importance to the aim of the study. Therefore, an essential part of the process is the choice of criteria regarding the people or sites to be studied (Merriam, 2009, p. 77). This study therefore selected participants on the basis of being able to learn the most.

Hence, the first step was to determine the selection criteria essential to choosing the participants who were most desirable for the study. These criteria are described in 5.5.3 and were based on the knowledge of the researcher in respect of the topic under study as well as of the population of prospective participants and sites.

5.5.3 Selecting the Research Sites

The selection of the research site was done early in the study design in line with an objective of maximizing the opportunity to engage with the problem (De Vos, 2002). The researcher did a purposive sampling of schools to satisfy the criteria of geographical location, physical resources, Grade 12 examination results in Life Sciences and experience of the Life Sciences teacher. These criteria are elaborated on below.

(a) Geographical Location

The Umlazi District is fairly widespread and it consists of four circuits. Each circuit from a geographical point of view may be classified as urban, township, or rural. The schools in each circuit have their own set of circumstances and contexts. Hence, in addition to ensuring representation with respect to each circuit, the researcher also ensured that the four schools selected were from either an urban, rural or township locality. The urban schools are closer to various amenities and facilities, such as transport, libraries and shopping malls. In addition these schools are relatively better resourced, both in terms of human and physical resources. The township schools represent schools that are located in the old apartheid demarcation on racial lines. For this study two township schools were chosen - one from a previously Black township, and the other from a previously Indian township. As elucidated in Chapter Two of this study, these schools were funded differently during the apartheid era and would

therefore have a different character from for example, the urban schools. The rural schools are those schools which will be found some distance away from the urban areas. They may be located on the fringes of the urban locality in which case they are relatively easily accessed or they may be located deep into the rural setting and not easily accessed. In general, most of the rural schools are poorly resourced. Since the researcher works as a curriculum advisor within this District, and one of his responsibilities is to monitor the implementation of the Life Sciences curriculum, he was able to decide on the choice of schools, taking into account the other criteria listed below, as well.

(b) Physical Resources

In order to learn the most with respect to the research topic, the researcher decided that schools with moderate to good physical resources, such as laboratories, science equipment and libraries be selected. This was also an attempt at controlling the negative impact of the lack of resources such as a laboratory and/or equipment.

(c) Grade 12 Life Sciences results

The research sample was restricted to schools, which produced a result of a minimum of between 50%-60% of the learners achieving 40% and above in the Grade 12 Life Sciences Examination in 2010. The motivation for such a criterion and particularly the percentage pass was that these schools were regarded as average to good performers when compared to the pass rate of the KwaZulu-Natal Province (76.60%) and the National pass rate (74.57%). In addition, the researcher was mindful that in 2011 or 2012 when the actual data for this study was to be collected other teachers might be teaching the Grade 12 learners and not necessarily those who were responsible for the 2010 results. Furthermore, such results imply that the teachers of the learners at these schools have the requisite knowledge and commitment. Choosing such schools was also motivated by two other reasons. Firstly, the experiences of my supervisor and I indicate that data can be more readily collected from such high performing schools. Secondly, the researcher also attempted to control the factor of learner and teacher capability, by assuming that the good results is due to the personnel, resources and environmental conditions at the institution.

(d) Experience of the Grade 12 Life Sciences teacher

It was decided that the selection criteria for the teacher be a minimum of five years of Life Sciences and/or Biology teaching experience. This criterion was included to ensure that the teachers would have had experience teaching the new *NCS* curriculum. This would imply that sampled teachers would have had experience with Learning Outcome (LO1), which underpins the implementation of IPW.

Table 5.1 indicates how criteria (a) to (c) were satisfied, while table 5.3 summarises the biographical details of the teacher participants.

Table 5.1: Selected samples and how it satisfies the selection criteria

Sampled School	Location of school	Percentage pass in Life Sciences in Grade 12							Resources
		2010		2011		2012			
		No. Wrote	% Achieving 40% & over	No. Wrote	% Achieving 40% & over	No. Wrote	% Achieving 40% & over	Mean % pass (2011-2012)	
School A (State)	Umbumbulu (Rural)	76	96	48	100	108	91	95.5	Moderately equipped laboratory, no electronic equipment and no functional library. No teacher–based room
School B (State)	Phumelela (Township)	200	83	205	58	196	54	56	Moderately equipped laboratory, no electronic equipment and no functional library. Teacher-based room
School C (State)	Chatsworth (Township)	128	80	62	73	122	59	72	Moderately equipped laboratory, with a single computer and moderately equipped library. Teacher-based room
School D (State)	Durban Central (Urban)	88	93	81	77	117	80	78.5	Well- equipped laboratory with electronic equipment. Well stocked and functional library. Teacher-based room
Umlazi District as a whole		10992	64	7892	53	9750	51	52	

Source: Compiled from Annual Examination Statistics issued by KwaZulu-Natal Department of Education and National Department of Basic Education

By selecting a school from each of the circuits the criterion of location was satisfied. In this regard, one school selected namely, School D satisfied the urban location, one namely, School A, the rural location and two schools namely, School B and School C satisfied the township location.

Three out of the four selected schools have moderately equipped laboratories, while one of them has a well-equipped laboratory. Two out of the four schools (A and B) do not have any electronic equipment in the laboratory; one, (School C) has access to a single computer in the laboratory. The fourth school, (School D) has electronic equipment in the form of computers, flat-screen television and data projector. Two schools (A and B) do not have a functional

library; one school (C) has a moderately stocked library, while the fourth (D) has a well-stocked functional library.

The percentage pass in Life Sciences for the 2010 examinations ranged from 80% to 96% at the four selected schools with the number of learners who wrote ranging from 76 in School A to 200 in School B. This percentage pass was determined at the 40% level of achievement. In the South African context a candidate is deemed to pass Life Sciences if s/he attains a minimum of 30%. Hence, when schools' Grade 12 results are released/published by the Department of Education, the rate of achievement at the 30% achievement level and the 40% achievement level are provided. One of the pre-determined criteria for the selection of schools was a minimum of 50% of students achieving 40% and over. The 80% to 96% that was obtained by these schools for the 2010 examinations therefore adequately satisfies this particular criterion. Furthermore, the overall pass rate in the Umlazi District for the 2010 Life Sciences results was 64% and the total number of learners who wrote this examination was 10992. In addition, while preparing this thesis, the author studied the results of the 2011 and 2012 examinations in Life Sciences for these schools and computed an average of these for the years spanning from 2011 to 2012 as indicated in Table 5.1. The average/mean obtained by the selected schools ranges from 56% to 95.5% while the mean District pass rate was 52% for the two years. The proportion of candidates achieving 40% and over for the entire Umlazi District, is also indicated in the table. The reason for excluding the 2010 results from the computation of the mean is because it is based on the *NCS* 1 curriculum while the 2011 and 2012 results are based on the *NCS* 2 curriculum.

5.5.4 The Participants

The primary participants in this study were the four teachers who were the focus of each case. Grade 12 Life Sciences teachers were selected because these teachers would have implemented the new curriculum *(NCS)* for at least five years, beginning in 2006 with Grade 10. At the Grade 12 level the curriculum would have been implemented for at least four years, up until 2012. The secondary participants, the Grade 12 learners of the teacher participants become indirectly involved when their artefacts were examined and analysed, and when their participation was observed during the teacher's lesson. The (2012) cohort of Grade 12 learners would have studied Life Sciences for at least three years from Grade 10 to Grade 12. In these three years they should have experienced IPW in the Life Sciences, as per the SAG document (DoE, 2005b). Table 5.2 below indicates the teacher participants' biographical data.

Table 5.2: Teacher Participants' biographical data

	Teacher 1	**Teacher 2**	**Teacher 3**	**Teacher 4**
Total teaching experience	15 years	15 years	28 years	11 years
Duration of lesson taught in school	55 minutes	60 minutes	60 minutes	60 minutes
Teacher based classrooms	No	Yes	Yes	Yes
Subjects and grades taught in preceding years:				
2006	Biology – Gr 11 & 12 Natural Sc. Gr 9	Biology – Gr 11 & 12	Biology – Gr 11 & 12	Biology Gr 11 Life Sciences Gr 10 Natural Sc. Grs 8 & 9
2007	Biology– Gr 12 Nat.Sc. Gr 9	Life Sciences – Gr 10 Biology – Gr 12	Life Sciences – Gr 11 Biology – Gr 12	Life Sciences Gr 11 Life Sciences Gr 10 Natural Sc. Grs 8 & 9
2008	Life Sciences Gr 10, 11 & 12 Maths – Gr 8	Life Sciences – Gr 10 & 12	Life Sciences – Grs 11 & 12	Life Sciences – Grs 11 & 12 Natural Sc. Gr 8
2009	Life Sciences– Gr 12 Maths – Gr 9	Life Sciences – Gr 11 & 12	Life sciences – Gr 11 & 12	Life sciences – Gr 10 , 11 & 12 Natural Sc. Gr 8
2010	Life Sciences Gr 10 & 12	Life Sciences – Gr 10 & 12	Life sciences – Gr 11 & 12	Life sciences – Gr 10 & 12 Natural Sc. Gr 8
2011	Life Sciences – Gr 10 & 11	Life Sciences – Gr 12	Life sciences – Gr 11 & 12	Life sciences – Gr 10 & 11 Natural Sc. Gr 8 & 9
2012	Life Sciences – Gr 12	Life Sciences – Gr 10 & 12	Life sciences – Gr 11 & 12	Life sciences – Grs 11 & 12 Natural Sc. Grs 8 & 9
Position at school	Post Level –1 (PL1): Subject co-ordinator	Post Level-1 (PL1): Subject co-ordinator	Post Level-2 (PL2): Head of Department (HOD)	Post Level-1 (PL1):
Qualifications: Diploma	Higher Diploma in Education (HDE)	Secondary Teachers Diploma (STD)	-	Higher Diploma in Education

		+ Further Diploma in Education (FDE)		HDE (Post Graduate)
Specialisation subjects	Natural Science and English	Biology and Mathematics Biological Sciences and Environmental studies	Biology	Biology Environmental Biology
Degree/s	-	Bachelor of Arts (BA)	Bachelor of Paedogogics in Science Education (B. Paed. (Sc)	Bachelor of Science (B.Sc.) in Biological Sciences
Major subjects	-	Education & Sociology	Zoology & Education	Cell Biology & Environmental Biology
Post Graduate Degree/s	Bachelor of Education (B.Ed.) Honours	-	Bachelor of Education (B.Ed.)	-
Area of specialisation	Environmental studies	-	Didactics	-
Other	-	-	-	-
Total years of studying biology / life sciences	0	4	3	3

The table of information above may be interpreted as follows:

Post level 1 educators are classroom based teachers who in terms of the hierarchy of the schooling system are at the entry level. Their responsibility does not include supervising their colleagues.

The teacher with the least length of experience, namely T4 has been teaching Biology and/or Life Sciences for 11 years while the teacher with the greatest amount of experience, namely T3 has been teaching for 28 years. All participants teach in moderately to well-resourced schools with laboratories. Three out of the four teachers, namely T2, T3, and T4 have base rooms where they conduct all their lessons. In other words, it is the learners who move to these teacher–based rooms while the teacher remains in this room for all his/her lessons. The advantage of teacher-based room is that it could serve as the Life Sciences teachers' laboratory. Hence, teachers will not have to carry resources around to the classrooms. If schools do have laboratories then most schools will have two laboratories. One is used for

Physical Sciences and the other being allocated for Life Sciences. However, schools generally have more Life Sciences teachers than laboratories. Having teacher-based rooms prevents the avoidance of doing practical work. Furthermore, since these schools do not have laboratory assistants, having base rooms helps the teacher in clearing up at the end of the lesson in the time between periods. In these three schools each lesson is of sixty-minute duration. The fourth teacher namely T1, moves to the learners in order to conduct Life Sciences lessons. This means that the teacher will be conducting lessons in different classrooms. The duration of each lesson at this school is fifty-five minutes.

All four teachers have relevant primary qualifications for teaching Natural Science and Engllish. Two of them have degrees in science education or science (T3 and T4 respectively) with majors in a relevant Life Sciences course while the other two have diplomas in science education. One of these teachers namely T1, is qualified to teach Natural Sciences. However, this particular teacher also has a Bachelor of Education Honours degree specialising in Environmental studies. T2 with a Diploma in Education also has a Further Diploma in Education specializing in Biological Sciences and Environmental Studies. This teacher also has a Bachelor of Arts degree with majors in Education and Sociology. According to South African criteria, all four teachers are qualified although T1 is not adequately qualified for teaching Life Sciences at Senior Secondary level. Information about the institutions where the participant teachers studied, and details of the selection and depth of content studied by these teachers was not available. Therefore it is not possible to make a judgment on the adequacy of the qualifications of T2 – T4, whereas T1 is not adequately qualified for the subject. However, the teachers have a minimum of 11 years' experience teaching Biology and/or Life Sciences. The researcher is mindful that, whilst the issue of formal qualification does not directly pertain to this study, the findings could be influenced by it.

5.6 DATA COLLECTION STRATEGIES

The researcher was the primary instrument for data collection. He was personally involved in each of the data generating, collecting, and processing stages. This included the administration of the questionnaires; conducting the interviews and audio recording them; observing and video recording lessons; analysing the information in documents which included the teacher completed tasks as well as teacher and learner artefacts. Human instruments have shortcomings and biases that might influence the findings of a study (Merriam, 2002). To minimise such biases in this study, multiple data collecting strategies involving an open-ended

questionnaire, a semi-structured interview, lesson observation and document analysis were employed. The use of multiple data collection techniques facilitated the enhancing of the authenticity and trustworthiness of the findings (Merriam, 2009; Mouton, 2001). In addition, the multiple data collection methods complemented each other and any shortcomings were therefore balanced out (Mouton, 2001). While not all qualitative research requires triangulation, a case study however, is one that requires triangulation for the purposes of credibility (Richards, 2005). Triangulation and the eventual crystallization of data were enhanced through the accessing of data from multiple sources in this study. This therefore, ensures that transferability and credibility of the study is increased when the readers of this study reach the same conclusions. The ultimate goal of conducting qualitative research is to ensure transferability of the study (Lincoln & Guba, 1985).

The data from the variety of sources were integrated and analysed in order to intensify the interpretation of the findings (Creswell, 2003).

Due to a delay in obtaining permission from the KwaZulu-Natal Department of Education to conduct this study, the data collection only began in the year 2012. Prior to permission being granted, the researcher held informal discussions with prospective teacher participants in respect of this study. Once permission was granted, the researcher then followed the necessary protocol to seek permission from the principals of the respective schools. Initially this was done telephonically and then followed-up via personal school visits.

The discussion that follows elaborates on the various data collection strategies employed in this study and the processes and procedures followed in order to collect the data necessary for the study. After an elaboration on data collection strategies, a brief discussion on data processing will follow in section 5.7.

5.6.1 The Questionnaire as a source of Data

(a) Purpose of the Questionnaire

The questionnaire (Appendix D), was designed to elicit information with respect to the first two key research questions as indicated in Chapter One, namely,

1. What is the nature of Life Sciences teachers' knowledge?
2. What is the nature of Life Sciences teachers' beliefs about teaching and learning of investigative practical work?

In addition, the responses from the questionnaire also complemented the other data collecting strategies.

(b) Structure and layout of the Questionnaire

To ensure that the questionnaire was appropriate, unambiguous and user-friendly, due cognisance was taken in the planning of the structure and layout of the questionnaire. The questionnaire was also designed in a way to ensure reliability and validity of the process, with particular emphasis on reducing the potential of bias. Babbie and Mouton (2001, p. 265) define bias as,

> *"The quality in questionnaire items that encourage respondents to answer in a particular way or to support a particular point of view".*

In an attempt to curtail the possibility of bias, questions were structured with clarity, so that all respondents could understand that the questions were posed in the same way. Questions were phrased using simple and comprehensible language in an attempt to reduce the possibility of bias (McCracken, 1988). Also the instructions were clear, unambiguous and precise in order to maintain the interest and co-operation of the respondents (Preece, 1994). Prior to the commencement of the study, the questionnaire was given to Life Sciences teachers at a workshop that was conducted by myself during the normal course of my duty. This was an attempt at piloting the questionnaire in order to identify any difficulties or ambiguities that the study participants may encounter. After studying the responses of teachers a few adjustments were made specifically with respect to terminology and language.

Once the adjustments were completed and before finalising the questionnaire three colleagues examined this draft of the questionnaire. All three colleagues were PhD students. These colleagues were asked to comment on ambiguity, imprecision, and assumptions. Minor modifications to the questionnaire with inputs from the evaluators were made in compiling a final version before administering it to the teacher participants for the study.

The resulting questionnaire (Appendix D) consisted of six A4 pages and was divided into three parts. While the questionnaire may be described as being open-ended, part A contained several short items or factual questions (Dörnyei, 2003) to elicit the biographical data of the teacher participant. Parts B and C contained open–ended items. Part B was concerned with various aspects such as, the participant teachers' knowledge, beliefs and practice of practical work. Questions in part B reflected aspects of the

theoretical and conceptual frameworks. Examples of such questions included: *What do you understand by learners' prior knowledge?* and *Do you think it is important for teachers to have an understanding of learners' prior knowledge? Why?* Part C related to the challenges and/or constraints that the teachers experience when implementing IPW. This therefore allowed the participants to answer questions in their own words and to express any ideas they think apply since no choices or alternatives were provided (Struwig & Stead, 2001). To assist in this regard sufficient space was provided below the open-ended questions for the free expression of answers and comments by the participants (Cohen et al., 2007). Furthermore, it allowed the participants to express their ideas about the relevant phenomena freely and independently at their own pace.

(c) The Administration of the Questionnaire

The first visit to each school was arranged with the teacher participant. This was at a time during the day when s/he was not involved in teaching. During this first visit the principal was provided with the letter (Appendix C) seeking permission for the use of the site to gather data. In addition, a detailed verbal explanation about the study was provided to the principal by the researcher. Once the principal completed the consent form, the researcher held a discussion with the participant teacher, explaining the purpose of the research. After accepting and signing of the consent by the teacher the researcher discussed the completion of the questionnaire. At each site the teacher was also requested to provide the researcher with dates and times suitable to them for: an interview; a preliminary lesson observation and observation of a formal practical lesson. The teachers completed the questionnaire at their own convenience, outside the teaching – learning environment. This was to prevent any undue disturbance to the normal teaching and learning programme at the schools.

The questionnaire was administered to all four teacher participants to complete in their own time. The researcher provided the participants with his contact telephone number should they encounter any queries during the completion of the questionnaire. The researcher allowed two days for the participants to complete the questionnaire whereupon he collected it from the teacher participants.

The responses to Part A of the questionnaire were tabulated into a Word document. This is presented as Table 5.2 in this Chapter. The responses from parts B and C were also tabulated for the purposes of individual as well as cross-case analysis.

5.6.2 The Interview as a source of Data

(a) Purpose of the Interview

The interview allowed for flexibility in obtaining information with respect to the first two key research questions, about the nature of teachers' knowledge and the nature of their beliefs about teaching and learning IPW. In addition, it was used to triangulate data generated by the other methods. The interview was therefore a powerful way of understanding teachers' in terms of their knowledge, thinking and values (Fraenkel & Wallen, 2007; Punch, 2009). Being a two-way conversation (Nieuwenhuis, 2007) the interview was able to obtain rich data which helped the researcher to understand the participants knowledge, beliefs and actions in the implementation of IPW. The descriptive data collected in this study was the participant's own words about IPW so that the researcher was able to develop insights into how the teacher participants interpreted some aspects of the curriculum (Bogdan & Biklen, 1992).

Examples of questions which reflected the theoretical and conceptual frameworks included: *Is questioning by the teacher during the different phases of the lesson /activity important?* and *How important is allowing learners to ask questions during the different phases of a lesson/activity? Explain.*

Some of the questions complemented many of the questions in Part B of the questionnaire while others were different. For example, Questions 1, 2 and 3 of Part B of the questionnaire namely:

1. What is your understanding of the following concepts: practical work, investigative practical work, learner centred activities and learner directed activities?
2. What do you think is the value of practical work in Life Sciences? List at least five reasons.
3. Describe the type/kinds of practical work that you engage your learners with,

complemented interview questions 3.1, 3.2 and 10 namely:

3.1 Do you believe that practical work is important for effective teaching and learning of science? Explain.

3.2 Do you believe that investigative or inquiry based practical activity is essential for effective teaching and learning of Life Sciences?

10. Do you believe that IPW is a useful and effective teaching and learning method? Explain

Such questions in the interview, serves to verify and deepen the researchers' understanding of the teachers' knowledge and beliefs about investigations.
The questions in the questionnaire which differed from that of the interview were in Parts A and C of the questionnaire. As indicated in section 5.6.1 b Part A was concerned with the teachers' biographical data while Part C was concerned with the challenges of implementing IPW.

(b) Type of interview

A semi-structured interview was decided upon for this study. Since the researcher was beginning the investigation with a fairly clear focus with respect to the implementation of IPW, more specific issues could be addressed through the interview. Furthermore, the interview was guided and open-ended. Since this study involved multiple-cases there was a need for some structure in order to ensure cross-case comparability rather than an unstructured interview.

While the researcher had a list of pre-determined questions to be covered as an interview guide the researcher and the interviewees had a great deal of flexibility enabling the researcher to follow-up certain aspects that may have arisen during the course of the interview. In this way the participants provided a more detailed and fuller description (Greeff, 2005). The final interview guide (Appendix E) consisted of twenty-seven main questions, which were open-ended. Where the participants required clarification, the researcher who acted as the interviewer elaborated.

In preparing the interview guide, due cognisance was taken of the order of the questions, so that questions pertaining to a particular topic or theme flowed reasonably well from one into the other. For example, the first few questions dealt with teacher's views about practical work and IPW. The next group of questions pertained to teacher's experiences with practical work and IPW. Keeping questions on a particular theme or topic together without the questions being too specific was also reflective of the information that was required to answer the key research questions. While this was the general trend in the structure of the interview guide, it did allow for some degree of flexibility, which was used later in the analysis.

In addition to the ordering and sequencing of questions due cognisance was also taken to ensure that the language was simple and comprehensible. Furthermore, the researcher repeated questions in a simpler form when the need arose during the interview.

(c) Conducting the Interview

Due to the researchers' acquaintance and knowledge of the participant teachers through his professional responsibilities, it was decided to conduct face-to-face individual interviews with them instead of telephonic or focus group interviews. Individual face-to-face interview was chosen because the researcher wanted to understand each participant teachers' body language and ease of responses to the questions. Care was taken to ensure that the interview was a social, interpersonal encounter and not merely a data collection exercise. In this respect the researcher's cordial professional relationship and warm and friendly rapport with the teachers helped. Furthermore, the researcher created an atmosphere of openness and trust, by explaining to each participant that he was not there to judge them but to establish the current state of affairs with regards to IPW in Life Sciences.

In planning for the interviews the researcher held discussion with the participants to determine the date, time and location for the interview. In addition, the participants were informed that the interview would be audio-recorded and that if they had any objection to this they needed to let him know in advance. There were no objections in this respect. This discussion took place on the day that the researcher visited the relevant schools to collect the completed questionnaires. To ensure that the interview responses is analysed in detail it was imperative to capture the participant teachers' responses completely and in their own words. Audio-recording the interviews was the most appropriate mechanism of achieving this. Creswell (1994) affirms that audio recorders and note taking are techniques used by researchers to record information from interviews. McMillan and Schumacher (2001, p. 450) contend that tape recording the interview ensures completeness of the verbal interaction and provides material for validity checks. The audio recording of interviews also provided a permanent record that captured all conversations verbatim, with the tone and volume of the voices of the speakers and the emphasis, pauses and nuances. This allowed the researcher to listen to the recordings as often as necessary so as to accurately understand what was being said. A dictaphone was used to record the participants' responses in this study. By taking notes only, one could risk losing the phrases and language used. The researcher did not take detailed notes in this case, but opted rather to concentrate on the responses of the participant in case there was a need for follow–up questions. In addition, the participants were reminded of the audio recording of the interview and the confidentiality of the information before the commencement of the interview.

The interview was conducted at a time mutually agreed upon by the researcher and the participant teachers. In all cases, these were held on a school day but in the afternoon and in the absence of learners. In all cases the venues where the interviews took place was quiet so that little or no outside noise / interference affected the quality of the recording of the interview. In addition, the venues were private and therefore the participants did not have to worry about being overheard. The interview with teacher one (T1) was held in the office of one of the Heads of Department at the school. Interview with teacher two (T2) took place in her anteroom that is attached to her laboratory. Teacher three (T3) was interviewed in his office, while teacher four (T4) was interviewed in his classroom. Being familiar with the settings at each school by virtue of the researchers' professional activities helped to understand what the participant teachers said in their own terms.

Each interview lasted for about one and a half hours.

5.6.3 Lesson Observation

(a) Purpose of the Lesson Observation

The main purpose of observing lessons for this study was to collect data in order to answer the third key research question namely, How do Life Sciences teachers implement investigative practical work (IPW) in their classrooms? In this way a complex set of data could be accumulated for its richness and also to be able to make links with teachers' knowledge and beliefs with their practice. In addition, the lesson observation supplemented data that was collected through other sources. These multiple sources of data therefore enhanced triangulation. Nieuwenhuis (2007) contends that observation as a qualitative data collecting technique helps the researcher to gain a deeper insight and understanding of the phenomenon being observed.

A typical feature of observation as a data collecting method is that it provides the observer with the prospect of collecting live data from a naturally occurring social condition by observing what is actually happening rather than having to rely on a third persons' account of events (Cohen et al., 2007).

While questionnaires and interviews may provide information about participants' knowledge and beliefs, including attitudes, values and what they think and say that they do, there is no substitute for studying them in action if one wants to know what they actually do. According to Abrahams and Millar (2008) many quantitative studies of

school science practical work have provided insights into the views of teachers and learners. These studies did not, however, compare expressed views on practical work with observations during actual practice. These studies might therefore be seen as studies of the rhetoric of practical work, rather than the reality (Abrahams and Millar, 2008).

Furthermore, questionnaire–based surveys are unlikely to provide accurate insights into the reality of teaching within its natural setting but may be more likely to produce current rhetoric (Crossley & Vulliamy, 1984) or popular views. Cohen, Manion and Morrison (2000) and Hammersley and Atkinson (1983) criticise an interview study for the same reason. The present study explored the relationship between teachers' knowledge and beliefs about science education on the implementation of IPW in the classroom critically through the analysis of a variety of data. This therefore required a strategy to bring the researcher into close contact with the teaching and learning environments and the activities with which the learners engage. Hence, the researcher decided that the most suitable strategy to obtain the maximum information was to observe the lessons.

(b) Observation of Lesson

By prior arrangements with the participant teachers, a maximum of two lessons were observed in each teacher's class. The first lesson served merely to get familiar with the classroom environment, and especially establish rapport with the learners and allow the teacher to be free and relaxed in the researcher's presence. Also this first lesson observed was not necessarily a practical lesson of the IPW type. For this first lesson no feedback was given to the teacher by the researcher since this observation was not for the purposes of providing support, as is the case during the researcher's normal professional duties. This was in keeping with the purpose of the study as indicated verbally as well as in the letter seeking permission for the teacher to participate in this study. However, this visit to the school was also utilised to provide the teacher with the relevant information with respect to the tasks that were required for the study (Appendix H). The second lesson to be observed by the researcher had to be a practical lesson and more especially, an investigative practical lesson. This investigative practical is the type referred to as the 'hypothesis testing' type as described in the SAG (DoE, 2005b).

During the observation of the formal practical lessons as arranged with the teachers, the researcher was a non-participant observer. As a non-participant observer the researcher

ensured that his presence in the classroom did not influence and / or affect the lessons. The researcher was mindful that one of the reasons to use observation as a method of data collection was to validate information from the questionnaire and the interviews. In this regard, he occupied a strategic position, such that he was able to video record the entire lesson without missing out on any activities and any interactions between the teacher and learners and between the learners themselves and at the same time not interfere in the teaching and learning process. To ensure that the lesson was followed very closely without missing out on any aspect, the researcher concentrated on personally recording the lesson. Due to the technicality of the process of video recording the researcher was unable to keep any field notes. However, the detailed recording of every aspect of the lessons compensated for the lack of field notes.
The decision to video record the lessons was to ensure that all the activities, actions and interactions during the lessons could be viewed many times over, allowing the researcher to go back and forth in order to get a deeper understanding of the phenomenon. If the lesson was not recorded, completing an observation schedule could result in erroneous understanding if the opportunity did not exist for a review and / or reflection of the lessons.

At the end of the lessons a post-lesson interview was held with each of the teachers. This was to clarify issues that the researcher identified during the lessons. Each lesson yielded a video recording of approximately one and a half hours. Thus a total of six hours of recording was observed in order to process the data. In processing the data from the video recording the researcher as well as the research assistants had to play–stop-replay the video recording of each lesson several times in order to ensure that the transformation of the data mirrored the reality of the occurrence in the classroom. To enhance the credibility of the findings of this study the researcher sought to improve the reliability and trustworthiness of the data. In this respect the video recorded lessons were also examined and assessed by two colleagues who acted as research assistants. One of the assessors, a senior Life Sciences teacher is a PhD student, who also evaluated the draft questionnaire, while the other assessor is a Senior Curriculum specialist in another province as well as an external Umalusi moderator. An adapted version of the Reformed Teaching Observation Protocol (RTOP) of Piburn and Sawada (2000) was used as a tool to appraise the lessons. The RTOP was created by the Evaluation Facilitation Group (EFG) of the Arizona Collaborative for Excellence in the

Preparation of Teachers (ACEPT). The development of this protocol was also aimed at addressing the existence of the artificial dichotomy that exists between academic departments and colleges of education in the preparation of teachers.

The RTOP is an observational instrument designed to measure "reformed" teaching. It was designed to capture the reform movement and especially those characteristics that define "reformed teaching" (Piburn & Sawada, 2000). To this end, the theoretical and philosophical rationale of constructivism, which is regarded as the modern reform movement was used in the construction of the protocol. The researcher discussed each criterion of this tool with the assessors in detail in order to achieve a common understanding of the criteria before they could implement it in the appraisal of each lesson. Extensive discussion was intended to achieve a high degree of inter-rater reliability. In addition, the tool was designed in a way that also included the description of each criterion. Data processing for each type of data that was collected will be discussed in section 5.7 of this study.

5.6.4 Document analysis as a source of evidence

Document analysis is a systematic procedure for reviewing or evaluating documents. Similar to other analytical methods in qualitative research, document analysis also requires that data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Corbin & Strauss, 2008). Documents contain text (words) and possibly images that have been recorded without a researcher's intervention.

Atkinson and Coffey (1997) refer to documents as 'social facts', which are produced, shared, and used in socially organised ways (p. 47). Within the South African contexts the socialization of the curriculum documents began when curriculum developers collaborated and co-operated in order to produce it. Their work also involved interacting with other documents, such as the Constitution of South Africa and policies pertaining to education, as well as with other role-players, such as academics. Furthermore, once the curriculum documents were complete but prior to finalisation, and as one of the principles of democracy it was put out into the public domain for comments from a wider group of interested persons or groups. Hence, in this way the document became socialized.

Documents that may be used for systematic evaluation as part of a study take a variety of forms. In this study the documents that were analysed included curriculum policy documents, namely, the *Report 550* Biology syllabus, and *NCS, NCS* 2 and *CAPS,* the two tasks

completed independently by the teachers and teacher and learner artefacts, such as worksheets.

(a) Purpose of Document Analysis

The main reason for the using document analysis to collect data was evaluate the teachers' knowledge indirectly by studying what they do. That is, to compare what the policy requirements are and what the teacher actually does. Moreover, it assisted to verify whether teachers do what they say they do. For example, studying teacher artefacts such as worksheets and/or assessment tasks prepared by the teacher was used to understand their knowledge and understanding of the requirements for Life Sciences in general and practical work in particular. Also, by studying learner artefacts for example, their responses in worksheets after it was marked by the teacher helped to determine teachers' knowledge and understanding of concepts and processes. In addition, the data from this source added to the richness of the data that was collected by interviews and observations. More specifically, the analysis of these documents provided longer-term data than could be obtained from short-term lesson observation and an interview. Documents related to other formal practical lessons, which were not observed, were also analysed in order to get a deeper insight into aspects of lessons based on investigations. However, the greatest advantage of analysing documents in this study rests with enhancing the credibility of its findings. In this regard, the research process does not affect document analysis. That is, the documents are 'unobtrusive' and 'non-reactive' (Bowen, 2009 p. 31). Hence, document analysis counteracts the apprehension related to reflexivity (or the lack of it) inherent in other qualitative research data collection strategies (Bowen, 2009). For example, with regard to observation, it is possible for the participants to do things differently only because s/he is being observed.

An added advantage of document analysis is that the documents are stable. The investigator's presence does not alter what is being studied (Merriam, 1988). Documents are therefore also suitable for repeated reviews.

In summary, the advantages of document analysis includes, the provision of data on the context within which the teacher participants operate; it can suggest some questions to be asked or situations to be studied; it can provide supplementary data, thus adding to the knowledge base; it is a means of tracking change and development; it can verify findings or corroborate evidence from other sources (Bowen, 2009).

(b) Curriculum documents

The purpose of studying the curriculum documents was to determine the extent of similarities and differences among the different curricula, especially in respect of practical work in general and IPW in particular.

(c) Types of tasks

The researcher discussed the possibility of the participants completing a set of tasks when he visited the schools to observe the first lesson. However, the tasks were only given to the teachers on the day of the lesson observation after observing and recording the lesson. The tasks consisted of a set of questions based on investigations in the Life Sciences / Environmental Studies. The initial draft of these tasks was given to a colleague who is a National examiner to critique in order to address the issues of validity and reliability. The following aspects were to be evaluated by the colleague: the scientific correctness (allowing for minor discrepancies in task 2 – since the teacher participants were to moderate this task); language and ambiguities; appropriateness for the grade level and curriculum requirements. Minor adjustments were effected based on the input by the evaluator. The finalised document consisted of two tasks. The first task consisted of an example of an open-ended investigation. It provided a short passage on 'how long does it take for packaging materials to degrade'.

Refer to Appendix H. The task required the teachers to do three things:

Part 1:

- Identify the problem to be solved
- State a hypothesis related to the problem
- Design an investigation to test this hypothesis

Part 2

- Prepare this task for their class of Life Sciences learners

Part 3

- Prepare a set of criteria / memorandum / rubric to assess this task.

Part 1 was assessing teachers' subject matter knowledge and skills, Parts 2 and 3 were assessing teachers' pedagogical content knowledge.

For the second task the teachers were presented with a set of questions based on data from an investigation. Refer to Appendix H. The participants were required to:

- Moderate the task
- Provide answers to the questions.

The second task was assessing teachers' subject knowledge with respect to investigations as well as conceptual knowledge.

These tasks were to be completed by the teachers at their convenience outside of teaching and learning time. They were to complete it within two days. The researcher then collected the completed tasks after telephonic confirmation of completion of tasks. Initially all participants were willing to complete the tasks. However, after the lesson observation, one of the participants, namely, T2 indicated that her schedule was very busy and that she was unable to undertake the completion of the tasks. This became a concern for the researcher and it was discussed with his supervisor. It was decided to leave this set of data and continue the analysis without it. However, while analysing all the relevant data the researcher realised the incompleteness of the analysis. T2 was approached again, at a time when the academic year was not too demanding and requested the participant to reconsider the task completion. However, T2 was unable to complete the second task and she indicated that the first task was very difficult and that she was unable to do it. The non-completion of these tasks by T2 did not have any bearing on the findings of the study since the tasks were used to as additional data sources to compliment other sources of data.

(c) Teacher and Learner artefacts

Teacher and learner artefacts formed the second set of documents that were analysed. Teacher artefacts included lesson plans, materials or preparations, such as worksheets related to the lesson that was observed as well as other formal practical lessons, which were not observed. Learner artefacts included the completed worksheets and/or questions or follow–up tasks based on the formal practical lessons, which were marked by the teacher. Copies of the teacher artefacts were collected at the end of the lesson observation, while copies of the learner artefacts were collected two days later. Three learners were selected by the teacher to submit copies of their work for analysis. A discussion with the learners was held on the day of the lesson observation with respect

to the study and the role of their work in particular. Permission was then sought from them and the necessary consent form completed (refer to Appendix G).

5.7 ANALYSIS OF DATA

Analysis in the study was accomplished through the writing process. The behaviour and the context of the behaviour observed was recorded and analysed during the interview process as well as during observation of the classroom practice. This allowed for a broader perspective in the interpretation of findings.

These multiple data sources provided a 'holistic account' of the issue. Such diversity also provided multiple perspectives on the issue under study. The analytic technique involved a back-and-forth interplay with the data from the various sources to ensure that it fitted into the appropriate categories which were predefined. During this data analysis process there was a constant checking and rechecking for commonalities and differences among the data within the same source between participants as well as between the different sources. This was a necessary step to organise ideas and identify concepts that seemed to cluster together.

The researcher was satisfied that the processes of data collection and analysis were complete only when all the evidence from the different sources painted a fairly consistent picture of the way in which teachers' knowledge and teachers' beliefs relates to their practice of IPW.

The initial step required for the analysis of data involved data processing. This process entailed the translation or transformation of data into a textual and / or numerical or graphical form. The researcher collated all the data personally in order to get first-hand experience of the data so that this could help further in the analysis. In order to facilitate the analysis of data the researcher sought to lay out the raw data in a way that could highlight the individual cases and at the same time be able to make comparisons among the participants. Presenting this in a tabular form seemed to be most appropriate.

5.7.1 Data from the Questionnaire

In order to do an individual as well as a cross-case analysis the researcher created a table and recorded the information verbatim from the completed questionnaires. A sample of such a process is indicated in Table 5.3, which indicates the responses to one question from Part B of the questionnaire.

Table 5.3: Sample of Questionnaire Data Processing

Item	Teacher Responses				Comments
	T 1	T 2	T 3	T 4	
1. What is your understanding of the following concepts:					
1.1 Practical work	Construction of meaningful scientific knowledge through hands - on activities. A task that provide learners with an opportunity to acquire scientific skills, e.g. observation, recording, analysing, etc.	Whereby learners and educators use apparatus to learn and understand the subject matter	Hands-on study of specimens as well as investigations	Handling equipment in lab – using microscopes, Bunsen burners, beakers, scalpels, test tubes. Includes learning lab rules and techniques.	

In the column headed comments, the researcher highlighted commonalities and differences and other points of interest among the participants, which formed part of the analysis.

5.7.2 Data from the Interviews

The first step in the processing of the audio-recorded interview involved transcribing the data to a written format. By transcribing the interview word-for-word prevented the over-refinement and artificial clarity and loss of valuable information. However, on the negative side of transcribing interviews word–for–word results in a massive amount of data (Wellington, 2004). In order to increase the accuracy and quality of the data, the researcher painstakingly transcribed each interview personally.

Once the interview with each participant teacher was transcribed the researcher tabulated the answers to questions in order to highlight individual responses and identify commonalities and uniqueness among the responses of the interviewees. Table 5.4 illustrates a sample of such a process.

Table 5.4: Sample of Interview Data Processing

Questions	Teacher Responses				Comments
	T1	T2	T3	T4	
2.1 When you were in high school did you do practical work in Biology / Life Sciences	Hardly. Not as often as it supposed to be. Hardly – I suppose because there were not properly equipped laboratories and not enough resources as such – but I was only able to do more practical work when I started at Edgewood College	Not as I do it with my learners now – because err… with the resources we never had enough resources in terms of doing practical work. So it wasn't as it is we do it now	Yes I did! Yes I did!	We did. I even remember doing practical exams where they would set-up different stations and do practical work as part of our exam mark. So we did get to use microscopes, we did get to use test-tubes and Bunsen – burners. So we did have that opportunity.	

5.7.3 Data from the Lesson Observation

An adapted version of the Reformed Teaching Observation Protocol (RTOP) of Piburn and Sawada (2000) was used as a tool to appraise the lessons. To enhance the credibility of the findings of this study, the researcher sought to improve the reliability and trustworthiness of the data. In this respect the video recorded lessons were also examined and assessed by two colleagues who acted as research assistants. One of the assessors, a senior Life Sciences teacher, is a PhD student, who also evaluated the draft questionnaire, while the other assessor is a Senior Curriculum specialist in another province as well as an external Umalusi moderator. The researcher discussed each criterion of this tool with the assessors in detail in order to get a common understanding of the criteria before they could implement it in the appraisal of each lesson. In addition, the tool was designed in a way that included the description of each criterion. Refer to Appendix L. Each assessor as well as the researcher viewed the video recording and completed the data-gathering tool independently. The following are broad categories of the criteria that were used to assess the lessons:

- A description of the classroom setting
- General design of the lesson
- Teacher Knowledge
- Teacher Activities
- Learner Activities
- Skills addressed in the lessons

Table 5.5 is a sample of the tool for assessing the video recorded lesson:

Table 5.5: Sample of Data-Gathering Tool for the Lesson Observation

ASPECTS OF LESSONS	Occurrence		COMMENTS
1. GENERAL DESIGN OF LESSON	Yes	No	
1.1 The instructional strategies and activities respected learners' prior knowledge and the preconceptions inherent therein. A cornerstone of reformed teaching is taking into consideration the prior knowledge that learners bring with them. The term "respected" is pivotal in this item. It suggests an attitude of curiosity on the teacher's part, an active solicitation of learner ideas, and an understanding that much of what a learner brings to the science classroom is strongly shaped and conditioned by their everyday experiences.			

The results of the assessors were checked against that of the researcher for reliability. The results of all three assessors were pooled and where there was no consensus the majority decision was taken.

5.7.4 Data from the Documents

The analysis of the documents involved a superficial examination, or skimming, a thorough examination or reading, and interpretation and understanding. This iterative process combined elements of content analysis and thematic analysis (Bowen, 2009). Content analysis involves the process of organising information into groups related to the central questions of the research. With respect to document analysis it focused on the key research questions related to teachers' knowledge, beliefs and practice about the implementation of IPW. Content analysis entails a first-pass document review, in which significant and appropriate passages of text or other data are identified. In this regard the researcher was able to identify relevant information to the study (Corbin & Strauss, 2008; Strauss & Corbin, 1998).

Thematic analysis is a form of pattern recognition within the data (Fereday & Muir-Cochrane, 2006). This process involved a careful, more focused re-reading and review of the information. The researcher took a more detailed look at the selected data and engaged in classifying them to relevant categories related to investigative practical work and which were predefined (Bowen, 2009). In this study, predefined categories such as, learning outcomes, and skills in inquiry, were used, because the document analysis was supplementary to the

other research strategies like the interview and the lesson observation. Hence, this allowed for the integration of data collected by the different techniques.

Data from the curriculum documents were obtained by studying the relevant sections of the policies as well as documents which supported their implementation. Table 5.6 illustrates an example of such an analysis:

Table 5.6: Sample of document analysis data processing

LOs	Aims, Objectives and Approach
LO1: **Scientific inquiry and problem- solving skills** The learner is able to confidently explore and investigate phenomena relevant to Life Sciences by using inquiry, problem solving, critical thinking and other skills	1.3 An ability to make critical, accurate observations of biological material, and to make meaningful records of such observation. 1.4 An ability to analyse and evaluate biological information, to formulate hypotheses and to suggest procedures to test them. 1.5 An ability to communicate clearly when reporting information and expressing ideas. 2.1 Pupils should make their own observations of specimens and experiments. 2.2 Pupils should learn to handle and set up apparatus correctly 2.3 Organisms should be observed in their natural environment.

5.8 VALIDITY OR TRUSTWORTHINESS OF THE DATA

Validity or trustworthiness refers to a study's credibility. That is, a determination of whether the findings from the study are accurate from the standpoint of the researcher, the participant or the readers of an account (Creswell, 2003). To achieve validity/trustworthiness, various data sources were used (Struwig & Stead, 2001). Merriam (2009) suggested that from an interpretive perspective, the best strategy is triangulation of data collection methods. In addition, the analysis of documents as a source of data was used in combination with other sources of data as a means of attaining triangulation. One of the reasons for triangulation was an attempt by the researcher to provide a convergence of evidence that breeds trustworthiness, reliability and credibility (Eisner, 1991). This was achieved for example, when the analysed teachers' tasks produced similar results to the observed lessons. Collection of data through different methods helped in corroborating findings across the data sets and thus reduced the impact of potential biases or the accusation of the findings being an artefact of a single method, a single source, or a single investigator's bias (Bowen, 2009).

The following strategies as elucidated by Creswell (2003) were also employed to check on the accuracy of the findings and thus enhance the credibility of the findings:

- The researcher facilitated member-checking of the transcribed interview data as well as the video recording of the observed lesson with each participant teacher.
- The duration or length of time spent observing lessons may be seen as a weakness of this study, since only one lesson was observed for three of the teachers (T1, T2, T3) and three lessons for one teacher (T4). However, the document analysis supplements the time spent on the field. In addition, the researcher has spent 30 years in the field as a subject specialist and during this period he was attempting to understand the phenomenon under study. Furthermore, his previous study was also related to 'developing creative and critical thinking skills in secondary school Biology', which showed a link with practical investigations. This long and varied span on the field provided the researcher with many opportunities to develop a deep insight into matters related to practical work in general and investigative practical work in particular.
- With regard to researcher bias, the researcher admits that several biases could arise from the type of questions in the questionnaire, the interviews, as well as the analysis of the documents. In addition, there was the possibility that the researcher could have paid selective attention to details of data that he was looking for and thus also interpreted this data in a biased manner. This bias was minimised through the use of a variety of data collecting strategies, member checking and peer review processes. There is also the tendency in qualitative research to select participants that would reflect the researcher's views. This was however, avoided by the selection criteria being indicated up-front.
- The researcher also identified a peer de-briefer or reviewer who served as a sounding board with whom the researcher regularly discussed aspects of the research in order to obtain advice on the process and methods and to establish whether the researcher was complying with the principles of sound research. The de-briefer is a curriculum advisor and also a National examiner for the Grade 12 examinations in a field other than Life Sciences. In addition, the peer de-briefer holds a doctoral degree in the field of Public Administration but with an education bias.

5.9 RELIABILITY OF FINDINGS

Reliability in qualitative research studies refers to consistency. The extent to which research data or findings can be replicated is referred to as the reliability. Reliability rests with others agreeing that the results collected are both dependable and consistent and make sense

(Merriam, 2009, p. 223). The following strategies are used to ensure consistency: triangulation, peer examination, investigator's position and an audit trail (Merriam, 2009, p. 221). In this study the researcher used multiple data collection techniques to satisfy triangulation. In addition, data analysis occurred in consultation with the supervisor, a colleague who is also a curriculum advisor and a PhD graduate, and a senior Life Sciences teacher and PhD student for the purposes of peer examination. Member checking took place after data collection in the interview and the video recorded lesson so participants were given the opportunity to check their transcribed comments for accuracy before analysis.

5.10 ETHICAL CONSIDERATIONS

In keeping with the principles of ethics in research, the researcher commenced the data collection after receiving ethical clearance from the University of KwaZulu-Natal (Appendix B). All the relevant individuals and organisations stated that all were informed about the type of research and the reason for it (Bless et al., 2006). Since schools were selected as the research sites permission had to be sought and obtained from the Head of the Provincial Department of Education. Once permission was granted by the Education Department (Appendix A), this served as an authority to seek permission from the principals of the four schools where the study was conducted. The aims and objectives of the study were outlined to the principals of the selected schools. Consent from the principals was obtained in writing (Appendix C). The participant teachers for this study were given a clear explanation of their role and reason for the study prior to them granting consent in writing (Appendix F1 & F2). The need for openness and honesty in the responses to the different strategies was highlighted and the participant teachers were assured that the information provided during the data generation and data collection stages was done in strict confidentiality and anonymity, which was maintained throughout the process. All participants were referred to by a pseudonym to protect their real identity. Furthermore, the identity of the schools was also kept confidential and was also given a pseudonym.

The consent of the participant teachers to participate in the study and to audio record the interview, video record the lesson and allow for the viewing of teacher artefacts was obtained in writing. During the observation of the lesson the researcher ensured that his presence with the video recording equipment did not interfere or disturb the lesson to any extent. In this regard the researcher used a palm-corder and he positioned himself in a location of the class where he could observe the maximum activities and yet avoid being a distraction.

Consent was also sought from the learners to study their artefacts in writing (Appendix G1 & G2) after explaining the purpose of the study to them.

At the conclusion of the study all the data collected during the research study will be kept at the University of KwaZulu-Natal for five years in the event of a need to validate data.

5.11 LIMITATIONS OF THE QUALITATIVE APPROACH

This study acknowledges its limitations in the sense that the study was limited to Grade 12 teachers in only four moderate to high performing schools based on the final Grade 12 examination results.

A perceived limitation of the qualitative approach is that it becomes difficult to make generalisations because of the small sample. According to Yin (2003), the researcher, using the case study methodology is confronted with the challenge that case studies represent a small sample of a larger context. In this regard the researcher is mindful that the selected sample of participants may not be representative of all the Life Sciences teachers. Besides, Merriam cited in Creswell (1994), argues that,

"The intent of qualitative research, is not to generalise findings but to form a unique interpretation of events" (p.158).

Hence, in this study the researcher made use of multiple case studies involving four schools and a series of four case studies in different settings. That is, four sites enquired into the same issues resulting in the collection and analysis of data from multiple sources.

The limitation of case studies being not open to cross-checking, resulting in researcher bias and subjectivity Gustavasson (2007) were overcome by triangulation, which was built into the design process.

Since the researcher has to interpret the data and eventually present it from a particular point of view, it is therefore unavoidable that the data presented may be biased. To limit biased reporting regarding research findings, it becomes incumbent on the researcher to present the findings within a specific context. Ideally the researcher's argument should be based on a strong theoretical perspective, and it should be backed up by empirical evidence (Henning et al., 2004). In this regard there was a constant comparative analysis of all the data. In addition, the potential of bias was curtailed by triangulation of data.

5.12 CONCLUSION

This chapter provided a detailed description and rationale for the research design and methodology utilised in this study. The chapter also highlighted and justified the selection of

the sample and research sites, and the data collection, processing and analysis strategies that were employed. Finally, validity / trustworthiness and reliability, ethical considerations and limitations of the study were discussed.

Chapter Six discusses the data analysis and the findings of the study.

CHAPTER SIX

RESEARCH FINDINGS

6.1 INTRODUCTION

This chapter presents the findings of the study which set out to determine the relationship of Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW). The chapter is composed of four sections. The first section under the heading, 'introduction' provides a brief outline of the aspects to be discussed. This is followed by a section that presents the findings related to teachers' knowledge, teachers' beliefs, and teachers' practice. The next section discusses the reasons why teachers practice IPW in the way they do. The final section consists of concluding remarks for this chapter.

6.2 FINDINGS WITH RESPECT TO TEACHERS' KNOWLEDGE, BELIEFS AND PRACTICES

This section presents the findings of the study with respect to teachers' knowledge, beliefs and practices of investigative practical work (IPW). The findings for the first two guiding questions, namely, *"What is the nature of Life Sciences teachers' knowledge?"* and *"What is the nature of Life Sciences teachers' beliefs about the teaching and learning of IPW?"* will be combined and presented under the heading, "Nature of teachers' knowledge and beliefs". The findings with respect to the third research question, namely *"How do Life Sciences teachers implement IPW in the classroom",* is presented under the heading "The implementation of IPW by Life Sciences teachers".

In order to ascertain the nature of teachers' knowledge and beliefs, information had to be sought from all the data sources that were utilised in the study. The analysis involved initial processing of individual as well as a cross-case analysis of data as indicated in section 5.7. Further analysis involved combining data from within and between both the questionnaire and the interview. This entailed grouping and clustering questions or items and teacher's responses, according to predefined categories or themes. A sample of such a process is indicated in Table 6.1. However, it must be emphasised that in order to answer the first critical question, evidence was obtained from all the data sources, including responses to the tasks completed by the participant teachers, teacher and learner artefacts, lesson observations, and responses to the questionnaire and interview. With respect to the second question, evidence was retrieved predominantly from the interview transcript and the questionnaire.

Information regarding the third question was obtained mainly from the analysis of the lessons observed, and responses to the tasks completed by teachers. In order to understand and study any alignment between what the teachers believe, perceive and say with respect to their practice, relevant data from teacher and learner artefacts as well as the responses to the questionnaire and interview was also studied.

Table 6.1: Sample of questions and responses clustered from questionnaire and interview

Questions	Category	T1	T2	T3	T4
Questionnaire 9. What do you understanding by learner's 'prior knowledge'**?**	**Teachers' knowledge and beliefs about GPK**	Learners are not empty vessels; they have existing knowledge which could be a basic knowledge to the new knowledge.	The knowledge that the learner already has about the subject.	Knowledge which learners have gained in previous years of study as well as knowledge which they have gained through reading, and internet	Previous remembered knowledge from years of experience at home or at school
10. Do you think it is important for teachers to have an understanding of learner's prior knowledge? Why		It provides guidance and direction to teachers. It serves as an indication as to how much the learner knows and provides the teachers with an opportunity to extend and expand learners existing knowledge	Yes. It is very important for an educator to assess learners' prior knowledge so as to determine their level of understanding and be able to plan his/her lessons accordingly.	Yes. Teachers will determine the 'gaps' in their learners knowledge of certain concepts and will not assume the learners already know this	Yes – it is always better to build on knowledge than to repeat what learners have already worked out.
Interview 11. Do you believe that a teacher's understanding of learner's prior knowledge is essential for the successful implementation of IPW		I think if you want to ensure effective teaching and you don't want to bore your learners you will have to find out their existing knowledge so that it will guide you into how extensive you should go towards a particular concept	Yes –Yes. Especially when it comes to 'hypothesis – testing' practicals – I think it will be very difficult for them to state the hypothesis if they don't have a background knowledge	Yes	Prior knowledge is important – it's no use spending a lot of time explaining a problem or concept to learners who already understand it. It is important to build –on from what they already know

6.2.1 The nature of teachers' knowledge and beliefs

This section involves a discussion of the knowledge that teachers' possess about the teaching and learning of Life Sciences as well as the beliefs that teachers hold about this knowledge and practices. As indicated in the introduction to this chapter, it is an attempt at answering the first two research questions about the nature of Life Sciences teachers' knowledge and beliefs. The reporting of the findings of the first two key questions has been combined because of the inherent difficulty in distinguishing between knowledge and beliefs. Also, since teachers' beliefs are important components of teacher knowledge and therefore, like teacher beliefs, teachers' knowledge is needed to understand classroom practice (Zembylas, 2005). Furthermore, it is possible to gain a better understanding of the two constructs namely, knowledge and beliefs by exploring the relationship between them, and by considering beliefs as a form of knowledge (Mansour, 2009). In fact this form of knowledge may be referred to as teachers' personal knowledge (Nespor, 1987). Kagan (1992) argues that most of the teachers' professional knowledge can be regarded more accurately as beliefs since this knowledge becomes affirmed as true on the basis of evidence or agreement of opinion. The findings with evidence is presented under the following sub-headings which reflect the different categories of knowledge as presented in Chapter Three on the one hand and an adaptation of the categories as espoused by Ni and Guzdial (2008) for their teacher change model on the other hand:

(a) Teachers' knowledge and beliefs about the Life Sciences curriculum
(b) Teachers' knowledge and beliefs about subject matter knowledge (SMK)
(c) Teachers' knowledge and beliefs about general pedagogical knowledge (GPK)
(c) Teachers' knowledge and beliefs about pedagogical content knowledge (PCK)
(d) Teachers' knowledge and beliefs about pedagogical context knowledge (PCxK)
(e) Teachers' knowledge and beliefs about self (teacher)

The Life Sciences curriculum knowledge as indicated in Chapter Three has been elevated to a separate category from that of a sub-category in PCK because it is the curriculum which has changed or transformed, and implementing this change is dependent on teachers' knowledge, beliefs and understanding of the imperatives and approach of the new curriculum. This is further supported by Aguire and Speer, (1999); Richardson, (1996, 2003) and Zohar (2006) who claim that the successful implementation of a transformed science curriculum depends on teachers' in-depth understanding of the variety of knowledge with respect to science

education. In this regard, teachers require understanding of not only subject matter but also pedagogical knowledge. Zohar (2006) further signifies the importance of the possession of 'sophisticated' knowledge by teachers. Such knowledge may not be located in teacher education courses or texts, but one which develops through practice and experience. This is similar to the notion of Shulman's (1987) pedagogical content knowledge (PCK). Therefore, for teachers to develop an abundance of high quality PCK they will need to have a thorough knowledge and understanding of the curriculum in terms of the goals, content, skills and values that are targeted during classroom practice.

Beliefs, as pointed out in Chapter Three of this study include thoughts, attitudes, opinions, perceptions, values and experiences, which teachers possess about teaching and learning Life Sciences, including IPW.

(a) Teachers' knowledge and beliefs about the Life Sciences curriculum

The knowledge and beliefs about the curriculum within the context of this study relates to the teaching and learning of IPW in the Life Sciences. It involves aspects such as how a teacher understands and believes what to teach, how to teach it, and to what extent is the practice consistent with the prescripts and/or approach of the new curriculum.

FINDING KB1: [Knowledge and belief about the curriculum]

"All the teacher participants believe that practical work is essential because it makes learning more meaningful, and that investigative practical work (IPW) provides learners opportunities to acquire scientific skills. However, the teachers have limited knowledge and understanding of the different types of practical work and the implementation of IPW as set out in the Life Sciences curriculum".

In addition to the evidence for this finding being obtained from the analysis of the tasks completed by the teachers (Appendix H), the observed lessons (Appendix I) as well as teacher artefacts, its formulation also required the analysis of the responses to the following questions from the questionnaire (Appendix D) and the interview guideline (Appendix E):

Table 6.2: Examples of questions from the questionnaire and the interview

Part B of Questionnaire (Appendix D)	Interview protocol (Appendix E)
1. What is your understanding of the following concepts? 1.1 Practical work, 1.2 Investigative practical work 2. What do you think is the value of practical work in the Life Sciences? List at least FIVE reasons; 3. List/describe the types/kinds of practical work that you engage your learners with 4. List as many skills and attributes that may be developed through practical work 5. List as many characteristics of investigative practical work	1. What are your views about practical work in general and investigative practical work in particular in the Life Sciences? 4. Do you understand the difference between 'hands-on' and 'hypothesis testing' practical activities well? Explain 23.Do you have a good knowledge and understanding of each of the following: (b) Learning outcomes (LOs) and assessment standards (ASs)for Life Sciences and Specific Aims of CAPS (c) Skills involved with practical work (d) Strategies for investigative activities (e) The scientific method for investigative work (f) Assessing hypothesis testing activities

There were common responses from the participating teachers to the questionnaire. In addition, while the responses to the interview questions were more elaborate than the questionnaire response, the content of the responses was very similar, if not identical. When the responses to the questionnaire and the interview protocol are combined and compared among the four participant teachers, certain understandings about practical work emerge that are common to all of them. For example, all the teacher participants referred to practical work as some form of 'hands-on' activity and the development of psychomotor skills with the promotion of scientific skills such as, observation. A few peculiarities were mentioned by some of the participants.

For example, T1 referred to practical work as,

> *"The construction of meaningful knowledge through 'hands-on' activities"*.

The notion of "The construction of meaningful knowledge" is consistent with the curriculum as well as with the constructivist approach to teaching and learning. In fact, the construction of knowledge is one of the 'essential features' of constructivism as discussed in Chapter Four. Also, Justice, Rice, Warry, Inglis, Miller, and Sammon (2007); Kahn and O'Rourke (2004), regard the process of constructing knowledge and new understandings as one of the core ingredients of an inquiry-based learning approach.

T1 also indicated that,

> *"It encourages interpersonal relationships, team work and group co-operation*".

In this regard, Hofstein and Lunetta (2004) maintain that in addition to interest, practical investigations also facilitates collaboration between learners. This notion also supports learning in a constructivist environment, in order to allow for multiple perspectives. Such social interactions help to extend one's thinking and thereby expose one to new ideas and perspectives (Tetzlaff, 2009). This is also consistent with the prescripts of the curriculum.

T1, T2 and T3 also indicated that practical work helps to develop skills to manipulate apparatus, promote the development of essential scientific skills such as observation, writing reports and being able to follow instructions. In addition, T2 also maintained that practical work helps to enhance the understanding of subject matter. According to T2 IPW is concerned with.

> *"Practical work in which a particular scientific concept or hypothesis is tested".*

The responses of T2 is consistent with the requirements of the curriculum in so far as 'hypothesis testing' is concerned (DoE, 2005b). She indicated further in her interview that the weaker learners, which she refers to as 'low gifted' find it much easier to understand subject matter when practical work is conducted. She goes on further and states that,

> *"It enhances the understanding of [sic] the learners" and "develop the interest of the subject".*

This perception of T2 is similar to the perceptions of teachers and learners who believe that when learners do their own investigations it facilitates the understanding of science concepts (Ramnarain, 2010). Duggan and Gott (2002) and Haigh (2003) assert that such a practice improves learning capabilities.

What T2 meant by learners 'understanding subject matter knowledge' was not verified in this study. It is possible that T2 conflated 'not forgetting' with 'understanding', because it is possible to remember or memorise without understanding. It is also possible that T2 may have alluded to the integration of new information with existing knowledge for assimilation and accommodation to occur, resulting in meaningful learning. However, her classroom practice did not confirm this.

T1 and T4 also referred to practical work as following instructions. 'Following instructions' is one of the skills listed in the Life Sciences curriculum. Hence, this response makes it consistent with the curriculum requirements.

T3 responded to the questionnaire by referring to practical work as,

> *"Hands-on study of specimens as well as investigations" and that IPW involve, "the application of the scientific process".*

To this end, the teachers' response correlates with the curriculum requirements. In response to the interview question, T3 responded in much more detail indicating and also displaying a strong conviction and belief that Life Sciences cannot be taught without practical work. Furthermore, he claimed that IPW is an integral part of the Life Sciences curriculum. His response was as follows:

> *"Life Sciences is a subject that cannot be taught without the inclusion of the practical work. The very nature of the subject lends itself to practical work". Secondly, IPW is an integral part – and I'm glad it was introduced into the syllabus because as we know all scientific knowledge came about based on scientific investigation and formulation of hypotheses… and following the scientific process……"*

While T3 displayed a sense of acknowledgement of the significance of practical work in general, his comments about the role of hypothesis formulation and science knowledge generation reflect a misconception or a naive conception of the concept hypothesis. His misconception is in reference to development of all scientific knowledge through the initial formulation of a hypothesis.

In his response to what he understood by IPW, T4 responded as follows:

> *"Learners design their own method–experiment and investigate phenomena, generate hypotheses".*

Both T2 and T4 referred to hypothesis when questioned about IPW. This is perhaps an indication that they were able to link the 'hypothesis-testing' type of activity to IPW. This is therefore, consistent with the requirements of the curriculum.

T2 and T3 referred to practical work as helping to 'concretise subject matter' and 'validating the content found in textbooks' respectively. This is in reference to the verification and confirmation of established knowledge. This type of practical investigation is one where the outcome is already known and learners follow pre-designed instructions either by the teacher or the text book to reach a result which verifies text book or teacher knowledge. Such practical investigations are classified as the level 1 type according to Bell et al., (2005), or structured, teacher-directed, teacher-led and closed according to Wellington (1994).

When requested to describe the different types of practical work that their learners engage with, T1, T2 and T3 responded by mentioning the types that are prescribed in the curriculum policy, that is, 'hands-on' and 'hypothesis testing'. T4 however, gave specific examples of practical tasks for example, "dissection of kidney, heart and chicken wing". T2 indicated "hands-on" and "hypothesis testing", while T1 included "investigative task" and "research project" to this. T3 listed 'hands-on', 'minds-on' and "investigative (over a prolonged period)". While the teachers revealed knowledge of the type of practical work as classified in the curriculum policy, none of them classified it in terms of the amount of guidance that is provided to the learners (Bell et al., 2005) and Wellington (1994). That is, according to the degree of openness of the activity. In addition, there was no mention of categorisation of practical work, for example, into investigations, laboratory procedures and techniques, fieldwork, teacher demonstrations, designing and planning investigations and analysing data (SCORE, 2009). This is an indication that, the participants have a narrow or superficial knowledge of the variety of practical work in Biology/Life Sciences. Their knowledge base seems to be restricted to that of the Life Sciences curriculum and their own experiences.

The response to Q4 of the interview, "Do you understand the difference between 'hands-on' and 'hypotheis testing' practical activities?" also revealed a superficial knowledge and understanding of the two types of practicals as espoused in the Life Sciences curriculum. However, the details of the implementation of especially the hypothesis testing practical work were not as per the requirements of the curriculum. For the 'hands-on' practicals the participant teachers referred to it as activities which involve guided discovery where detailed instruction is provided (T1).

T3 referred to 'hands-on' as activities where,

"Learners use psychomotor skills and do things".

T4 referred to it as,

"Using your hands with some kind of equipment".

The notion of 'hands-on' practicals which the participant teachers hold is consistent with the curriculum requirements.

All the participant teachers revealed some knowledge of what the 'hypothesis testing' practical work entailed. They were able to highlight some basic features such as, identifying a problem, carrying out an investigation, collecting data, and either accepting or rejecting the hypothesis. The following are examples of teachers' responses:

"Learners have to identify the problem" and do some investigation and "come up with a solution" (T1).

"For the learners to do the hypothesis testing practical we have to formulate a hypothesis first based on the background knowledge that they have and then after that come up with a aim and then do the research and then after that based on their result they will have to say whether they accept or reject the hypothesis stated at the beginning" (T2).

The teachers' use of "we" is not readily recognised in the interview response. However, the observation of her lesson reveals that she used 'we' to refer to a collective of people in a classroom that is, the learners together with the teacher. This therefore implies that all the learners together with the teacher generates a hypothesis and then executes the plan. In such a case therefore, it is inconsistent with the curriculum policy. In terms of the curriculum it is the Grade 12 learners who should determine the design of the investigation on their own, with minimal guidance from the teacher.

T3 indicated that,

"Hypothesis testing is based on the scientific process where a problem is identified and then they will have to first hypothesise and then carry out an investigation to either accept or reject the hypothesis. So they will have to design their own experiments and controls based on the aim of the investigation as well as the hypothesis that they want to test".

According to T4,

> *"Hypothesis – based testing would be using the information that is provided, to identify a problem and then give a hypothesis to try and explain what is happening to [sic] that problem".*

The teacher refers to the use of the information that is provided in reference to a scenario which may be presented to the learners.

With respect to the list of skills that can be developed through practical work the teachers included the following cognitive and psychomotor or practical skills: observation, handling and manipulating apparatus, analysing and interpreting data, hypothesising, drawing, and cutting. While they did mention reasoning – both inductive and deductive reasoning, none of them mentioned creative and critical thinking skills development even though this is one of the critical outcomes of the South African curriculum. Investigative practical work has been shown to develop higher order thinking skills such as controlling variables, which are examples of creative and critical thinking skills and creative and critical thinking skills are examples of higher order thinking skills (Bransford et al., 2000; Chapman, 2001).

Furthermore, the teachers listed interest, patience, and co-operation as examples of attributes that may be developed by doing practical work.
In a recent study in South Africa by Ramnarain (2010), it was reported that teachers and learners perceive interest to be stimulated through autonomous science investigations. Similar findings were reported by DeBoer, (2002) and NRC, (2005). Co-operation as a social interaction is also one of the key features of constructivism. It is also a goal of the *NCS* as espoused by the critical outcomes.

In terms of identifying characteristics of IPW, teachers gave a list of some of the procedures that may be carried out in an investigation.
T2 for example, indicated,

> *"It is characterised by an aim which is the main objective directing the practical work, method of conducting the practical work, and recording and analysis of result in order to draw conclusions".*

This response is reflective of what is generally found in text books – a very systematic and step-by-step, 'cookbook' approach to practical investigations, which are of the verification type. However, while this structured form of investigation might be preferred and regarded as good practice by some researchers such as, Kirchner et al., (2006), it is inconsistent with the requirement of the South African Life Sciences curriculum policy. Moreover, Spronken-Smith and Walker (2010) reported that guided inquiry and open inquiry were more beneficial to the teaching and learning situation than structured inquiry. Their study therefore finds support with IPW of the South African Life Sciences curriculum.

T3 responded by stating that,

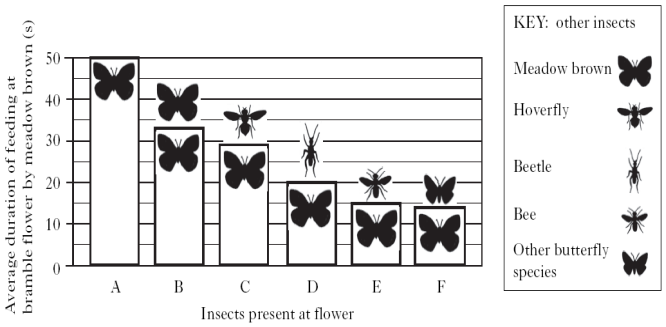
> *"It [IPW] must be based on a scientific problem, involves hypothesis testing through experimentation, scientific data must be collected and clinically analysed".*

The teacher participants did not mention that tasks representing IPW for grade 12 are open-ended, learner-directed or learner-driven, are not teacher-centred or teacher-directed, and that it is less structured and there should be limited guidance but a great deal of feedback from the teacher.

Further evidence was sought from the responses to the teacher tasks (Appendix H). Task 3, which is presented in figure 6.1 below, is based on an investigation.

TASK 3:

Bramble plants (*Rubus fruticosus*) are pollinated by a variety of nectar-feeding insects, such as the meadow brown butterfly (*Maniola jurtina*). Bramble flowers are one of many nectar sources for this species. A study focused on competitive interactions occurring between meadow browns and other insects at bramble flowers. The average time a meadow brown butterfly spent feeding when not disturbed by another insect is shown in the bar graph at A. The other bars show its feeding duration when another insect was also present.



1. Suggest a hypothesis for this investigation. (4)
2. Name the type of competition occurring at:

2.1 B
2.2 E

(2)

3. Which bar represents the greatest intensity of competition? (2)
4. Provide an explanation for your answer to Q3. (3)
5. State **one** general conclusion that can be drawn from the above data. (4)
6. Describe **two** shortcomings of the above experimental design. (4)

Sub-task 3.1: Moderate the above question.
Sub-task 3.2: Provide answers to Qs 1 to 6, above.

Figure 6.1: One of three tasks that was executed by the teacher participants
Source: Adapted from Scottish Examinations (2010)

Sub-task 3.2 required the participant teachers to answer a set of questions based on the data given to them. In this regard, T1 incorrectly stated a hypothesis for this investigation while the other teachers provided satisfactory responses. T3 also illustrated a limited understanding of the purpose or role of a hypothesis. Students' difficulty in understanding of the concept 'hypothesis' was also highlighted by Yip (2007). Yip (2007) maintains that the concept of hypothesis is usually confused with other related concepts such as 'prediction', 'assumption' and 'theoretical principle'. Dr Dempster, during her supervision of this thesis indicated that she has recently noticed that there is widespread misunderstanding amongst teachers of the concept of hypothesis and how it is generated. According to Yip (2007) a hypothesis can be defined as a tentative explanation for a phenomenon or an investigable question. The formulation of a hypothesis is necessary

when the investigation question requires an explanation of why something happens (BSCS, 1977; McComas, 1998).

A hypothesis has two functions. First, it must account for all the known facts or data relating to the specific problem. Second, it should lead to the prediction of new information,that is, it is testable. The formulation and testing of a hypothesis is an important aspect of the process of scientific inquiry (Yip, 2007).

Furthermore, sub-tasks 1.1 (iii) and 2.1 (ii) as indicated in Table 6.9 also required teachers to state hypotheses for each of the scenarios given (Appendix H).

Table 6.3: Tasks executed by the teacher participants

TASK 1	TASK 2
Information: **Particles given off from vehicle exhausts** *Particles in the atmosphere reduce visibility, and so are the most apparent form of air pollution. One can measure and compare the amounts of particles in air and the exhaust fairly easily. For example, one may find dust, ash, soot, smoke, pollen, and other substances suspended in air. Human activity produces a large percentage of these particles every year.*	**Information:** **How long does it take for packaging materials to degrade?** *A large part of municipal wastes is dumped into landfills every year. A significant portion of this waste is in the form of packaging materials for foods, clothing, and other household items. As suitable places for waste disposal become increasingly scarce, the waste stream must be slowed down or changed. One way to do this is to be sure that packaging materials can be decomposed or* recycled. ***Adapted from: Biology the Dynamics of Life***
SUB-TASK 1.1 (i) Design an investigation to compare the nature of the particles in the atmosphere and that which is given off by vehicle exhausts. (ii) Describe the problem that you investigated. (iii) State the hypothesis that you tested in this investigation. **SUB-TASK 1.2 :** Prepare this task for your class of Gr 12 Life Sciences learners. **SUB-TASK 1.3 :** How would you assess your learners' efforts? Prepare the criteria /rubric / memorandum to assess this task.	**SUB-TASK 2.1:** (i) Identify a problem to be solved from the above information. (ii) State a hypothesis related to the problem, which you have identified for investigation. (iii) Design an investigation to test this hypothesis. **SUB-TASK 2.2:** Prepare this task for your class of Gr 12 Life Sciences learners. **SUB-TASK 2.3:** How would you assess your learners' efforts? Prepare the criteria /rubric/ memorandum to assess this task.

T1 was again unable to state a satisfactory hypothesis for the observation.

Understanding the LOs and ASs of the Life Sciences curriculum in the *NCS* and specific aims (SAs) of Life Sciences in *CAPS,* the skills involved with practical work, assessing hypothesis testing type of practical work and strategies for investigative activities is related to the implementation of practical work in general and IPW in particular. When

questioned about their knowledge and understanding of these aspects of the curriculum that is,

"Do you have a good knowledge and understanding of each of the following: *LOs and ASs for Life Sciences and SAs for CAPS; the scientific method for investigative work; and assessing hypothesis testing activities* (Q23 of the interview, Appendix E), all the teacher participants with the exception of T4 answered in the affirmative. T1 while confident about some aspects was hesitant about her knowledge and understanding of assessing hypothesis testing practical work. T4 indicated that he did not have knowledge of strategies for investigative activities and assessing hypothesis testing activities.

While the participant teachers showed confidence in knowing about these features of the Life Sciences curriculum, the analysis of the tasks attempted by the teachers as well as the analysis of the observed lessons revealed a poor or lack of understanding of these in its application. For example, all three teachers, T1, T3, and T4 who attempted sub-task 1.2 did so by indicating that a detailed set of instructions would be provided to the learners. In other words, these lessons/activities would be highly structured and closed-ended. Evidence to further support this finding was also obtained from the observation of the lessons and will be elaborated in section 6.3.2. However, according to the analysis of the curriculum and as indicated in Table 3.2, LO1 and AS1 for Grade 12 require learners to "design tests and/or surveys to investigate…." In addition, it also indicates that the experimental design must be evaluated. The implication therefore is that it is the learners who must determine the procedure/s to be followed and that it should not be designed and presented to the learners by the teacher. This, therefore, highlights an inconsistency in the teachers' knowledge and beliefs of the curriculum.

Shulman (1986) maintains that,

> *"Curriculum knowledge includes a complete set of programs designed for the teaching of a particular subject and specific topics. Curriculum knowledge also includes a range of instructional materials for teaching specific subjects and topics"* (p 9).

In this regard, the Life Sciences policy provides the necessary details, such as the LOs and its related ASs in the *NCS* and SAs in the case of *CAPS*. However, knowledge, beliefs and understanding of details such as, LOs and ASs, which are the goals and objectives of the Life Sciences curriculum, the skills involved in IPW, the strategies in teaching and

assessing IPW, that is, the teachers' curriculum knowledge is inconsistent with the curriculum policy.

(b) Teachers' knowledge and beliefs about subject matter knowledge (SMK)

Knowledge of subject matter is the basis of a discipline which includes factual information, organizing principles, and central concepts (Grossman, 1989). SMK constitutes the 'intellectual tools' of the Life Sciences teacher. SMK includes substantive and syntactic structures of the Life Sciences discipline. Syntactic knowledge includes knowledge of scientific inquiry skills as well as many critical thinking skills such as the ability to formulate a hypothesis and the ability to identify assumptions upon which experimental designs are based. For the purpose of this study, the nature of the two components of teachers' SMK was determined. These two aspects included conceptual or content knowledge and procedural knowledge or knowledge of inquiry. Understanding the established content knowledge as well as scientific inquiry skills will help teachers plan, support and guide learners appropriately and not necessarily giving them the answers when implementing IPW.

FINDING KB2: [Knowledge and beliefs about SMK]

"All participant teachers assert that possession of good SMK is important to guide learners when implementing IPW. However, their practice of implementing IPW reveals a limited knowledge and understanding in this respect".

All the participant teachers maintain that having good SMK is important for conveying content knowledge to the learners.

T1, for example, indicated that it is important for teachers to have good content or conceptual knowledge so that conveying the relevant content will be easier.

T2 also stated that teachers must have a,

"Better understanding of things than the learners so that it could be explained to the learners".

T4 also indicated that the teacher would be able to provide the necessary guidance if s/he has good content knowledge. While the participant teachers believe that having excellent knowledge and understanding of the processes involved in the implementation of IPW, yet their practice displayed a lack knowledge in this respect. This assertion is based on the analysis of the responses to the teachers' tasks as well as on the observation of the lessons.

Sub-finding KB2.1: [Knowledge and beliefs about Conceptual or Content knowledge]

"All the participant teachers maintain that having good understanding of conceptual or content knowledge makes teaching easier. While the teachers possessed satisfactory content knowledge they found it challenging to help learners construct this knowledge for conceptual understanding".

The evidence for this finding emanates from the observation of the teachers' lessons which revealed their knowledge and ability in this regard. Evidence for their belief was retrieved from their responses to the interview question namely, *"Do you think that teachers need to have good conceptual/content knowledge and understanding about the different topics in order to guide learners when implementing investigative practical work? Why?"*

All the participant teachers indicated that possession of good content/conceptual knowledge is advantageous to ensure that teaching is made easier. They also indicated that it is important for the teacher to have a good grasp and understanding of the content/concepts so that they will be able to provide more guidance to the learners. The teachers responded as follows:

> *"Obviously if you know your content it is easy to teach and there [they] will be able to convey the knowledge the learners need to know….I believe that a teacher or anyone need to have a thorough knowledge of the content – subject that he is teaching*". (T1)

The notion of 'easy' is perhaps in reference to the mere transmission of established facts and not the intricacies of the relationships and connectedness of the facts and ideas that is, the organising principles and central concepts. The assumption the teacher makes is that possessing knowledge of the factual information is sufficient to ensure that teaching and learning will be made 'easy'.

> *"Because as an educator you have to understand things much better than your learners so that you should be able to explain to them exactly what is happening. If you as a teacher have a problem [lack understanding] … I don't think it will be possible to teach it properly – to avoid confusion in terms of the learners so that the educator has to be clear of what he is doing"*. (T2)
>
> *"I think teachers do– they need to provide the information that is well researched – so that they can give the learners a bit more guidance – so*

teachers need to be more prepared- but sometimes they don't have all the answers". (T4).

Both T2 and T4 allude to preparations for lessons by the teachers.

While a more in depth discussion of the findings with respect to teachers' practice will be the focus of section 6.3.2, a brief description in relation to SMK is presented here.

The observation of the lessons revealed that teachers had a relatively satisfactory knowledge of the subject matter content inherent in the lesson. However, there was very little evidence of the teachers attempting to promote strong coherent conceptual understanding by connecting the content with learners' prior knowledge, and other disciplines or the real world. There was no attempt at ascertaining learners' prior knowledge or identifying any naive conceptions they may have brought into the classroom. The teachers assumed that because they taught the learners the preceding topics, that the learners have a correct understanding of these. Research Assistant (RA)1 observed that T1,

"Guided the learners with questions to the answers she was looking for. She also gave feedback to learners that were on the wrong track".

RA1 went on to indicate that although the teacher posed a question on the significance of plants being positively phototrophic,

"The teacher didn't get to guide the learners to improved photosynthesis, production of more starch, and its application in agriculture and everyday life".

Similarly, while T4 displayed solid grasp of the knowledge on tropisms, but the link of tropism and its application to the real world was not evident. This is perhaps an indication of a lack of knowledge of the application of content information to real life situations. Furthermore, it also alludes to a lack of pedagogical knowledge as far as planning, preparation and presentation of the lesson is concerned.

Sub-finding KB2.2: [Knowledge and beliefs about procedural knowledge or knowledge of inquiry]

"According to the teachers, having knowledge of the processes that are involved in investigative practical work, helps to guide learners appropriately. However, such guidance was distinctly absent in their plans as well as during their implementation of the observed investigative practical work".

This finding has been derived from the analysis of the tasks completed by the teachers, the lessons observed and the responses to the interview question namely, *"Do you think that teachers need to have excellent knowledge and understanding of the processes that are involved in investigative practical activities? Explain.*

All the participant teachers believe that teachers' knowledge and understanding of the processes of science are of great importance in order to ensure effective teaching and learning.

T4 responded as follows:

> *"I think that's important – if you're trying to guide learners into a way of thinking or investigating then the teacher themselves need to be sure about what to do and how to do it".*

Sub-tasks 1.2 and 1.3 and sub-tasks 2.2 and 2.3 (Table 6.3 and Appendix H), required teachers to prepare investigative activities for their Grade 12 Life Sciences learners based on the scenarios presented. They also had to indicate how they would assess these tasks/activities. The intention of these tasks was to determine whether the teacher participants have the knowledge and ability to design open-ended activities on practical investigations and assess these as per the curriculum requirements. T1, T3 and T4 provided detailed instructions on how to go about doing the investigation, including how the results were to be recorded. That is, their lessons would be very structured and closed-ended with no room for the active involvement of the learners with respect to suggestions for the design or procedures and format for the recording of results. This therefore indicates a lack of understanding of the requirements for IPW in Grade 12 as indicated in Table 3.2 in Chapter Three. The following are examples of teachers' responses:

T1 presented the learners with a task where they must investigate the nature of the particles in the atmosphere. Learners will be divided into groups of six. The groups would be given instructions in the form of a worksheet to conduct an investigation. Each group had to

collect all the apparatus they needed to carry out the investigation and they were expected to conduct the investigation.

T3 provided a detailed worksheet outlining the aim with a systematic step-by-step method to be followed.

T4 responded as follows:

> *"Using your knowledge of [the] scientific method, examine the problem below:*
>
> *Car exhaust fumes are said to increase particulate concentrations in the air greatly and thus cause problems for people suffering with respiratory diseases. Investigate the percentage particulate increase between regular air and car exhaust fumes*".

He went on to provide the following information:

- Get the learners to come up with a hypothesis.
- Give a detailed method of obtaining results to the learners.
- Get the learners to record their findings.
- Compare and contrast between the particulate concentrations.
- Calculate the percentage increase.

While this task of T4 represents one of guided inquiry, it does not fit in with the requirements of the curriculum in that it is not open–ended.

From the evidence presented, it shows that the teachers lack adequate knowledge and understanding about IPW as an open-ended activity. The evidence highlighted here, shows that teachers have responded differently in the questionnaire, interviews and in their actions that is, in their tasks and classroom practice. The teachers' responses to the questions in the questionnaire and in the interview were inconsistent with their actions in the classroom and also inconsistent with the requirements of the curriculum. This is an indication that perhaps teachers do have some knowledge of inquiry teaching and learning, but they lack understanding thereof in its application in the classroom. Further elaboration of this finding will be illustrated in section 6.3.2, where observations of teachers' practice will be discussed.

(c) Teachers' knowledge and beliefs about general pedagogical knowledge (GPK)

According to Shulman (1987) general pedagogical knowledge is considered as the broad principles and strategies of classroom management and organisation that go beyond subject matter. This study considered higher order thinking skills, learner's prior knowledge, planning and preparation, and questioning as aspects of GPK.

FINDING KB3: [Knowledge and beliefs about GPK]

"The teachers are of the view that knowledge and understanding of aspects of GPK is essential for the successful implementation of IPW. However, there is a lack of evidence in its translation into effective classroom practice".

The evidence for this finding was obtained from the analysis of the participant teachers' responses to the questionnaire and the interview. Further evidence was sought from the analysis of the teachers' tasks and their lessons which were observed and which will be discussed in section 6.3.2.

The following questions about 'higher-order- thinking skills were posed to the teachers:

Questionnaire	Interview
6. What is your understanding of the concept *'higher order thinking"*? 7. List as many examples of 'higher order thinking' skills. 8. Do you believe that the skills named in 6 above can be developed during investigative practical work? Explain fully.	24. Do you believe that the use of investigative activities or inquiry- based learning promotes higher order thinking?

When questioned about the concept of 'higher order thinking' the teachers revealed their knowledge by providing examples of the 'higher order' thinking skills such as, the application of knowledge, comprehension, analysis, synthesis, evaluation, making valid deductions, extrapolating and making predictions. While these examples as well as the critical thinking skills such as, generating and formulating hypotheses, and drawing conclusions may be regarded as 'higher order' thinking skills they may be viewed within the context of SMK. However, the teaching and learning of such skills will be regarded as GPK since GPK addresses aspects such as, knowledge about how to ask questions on 'higher order' thinking skills or about how to assess inquiry learning. Metacognitive knowledge of specific thinking skills, including generalisations about them is normally part of what constitutes GPK (Brant, 2006; Turner-Bisset, 2001).

Since GPK deals with classroom organisation and management, instructional models and strategies, and classroom communication and discourse, understanding the processes involved in IPW as being 'higher order' thinking skills would help teachers prepare and act appropriately for the efficient implementation of IPW.

All the participant teachers indicated that the skills, which they named as higher order thinking skills, could be developed during investigative practical work (IPW). The following are extracts of responses from the questionnaire explaining how this may be achieved:

> *"Learners have to analyse their findings and design possible solutions to the investigative work. Learners are able to explore and investigate phenomena by using inquiry, problem solving and critical thinking"* (T1).
>
> *"Because during the process of doing the practical, learners have got to collect and analyse information in which case the comprehension, analysis is developed"* (T2)
>
> *"Investigative practical work normally involves collection of data. Valid deductions can only be made through careful analysis of this data"* (T3)
>
> *"Especially when finding conclusions and explaining results, in generating hypotheses"*. (T4)

It is evident from the responses that the teachers do have knowledge of 'higher-order' thinking skills and they were also able to link these to the some of the processes involved in IPW. They were however, unable to identify processes such as, formulating a research question, planning experiments, controlling variables, making inferences and creating and justifying arguments, which are directly linked with IPW (Zohar & Dori, 2003) as higher order thinking skills.

To ascertain teachers' knowledge and understanding and beliefs about 'prior knowledge' the responses to the following questions were analysed:

Questionnaire	Interview
9. What do you understand by learner's 'prior knowledge'? 10. Do you think it is important for teachers to have an understanding of learner's prior knowledge? Why?	11. Do you believe that a teacher's understanding of learner's prior knowledge is essential for the successful implementation of investigative activities? Explain

All the participant teachers did have some knowledge of what is meant by 'prior knowledge'. The teachers, while not having identical ideas about prior knowledge did refer to it as knowledge that learners possess when they enter their classrooms. That is, their existing knowledge from previous years of study and knowledge gained from years of experience in the home and school environments. This is evident in the following responses:

> *"Learners are not empty vessels; they have existing knowledge which could be a basic knowledge to the new knowledge"* (T1)

> *"The knowledge that the learner already has about the subject"* (T2)
> *"Knowledge which learners have gained in previous years of study as well as knowledge which they have gained through reading and [the] internet"* (T3)

> *"Previous remembered knowledge from years of experience at home or at school"* (T4)

According to the teacher participants, understanding learners' prior knowledge is important for the purposes of determining the learners level of understanding so that appropriate guidance may be provided to overcome any 'gaps' in their knowledge and understanding and also to build on existing knowledge.

According to T1,

> *"It provides guidance and direction to teachers. It serves as an indication as to how much the learner knows and provides the teachers with an opportunity to extend and expand learners existing knowledge".*
> *"I think if you want to ensure effective teaching and you don't want to bore your learners you will have to find out their existing knowledge so that it will guide you into how extensive you should go towards a particular concept [sic]".*

T2 maintained that,

> *"It is very important for an educator to assess learners' prior knowledge so as to determine their level of understanding and be able to plan his/her lessons accordingly…."*

T3 responded by stating that,

> *"Teachers will determine the 'gaps' in their learners' knowledge of certain concepts and will not assume the learners already know this. These 'gaps' will be rectified and educators will now confidently build on these basic concepts".*

T4 suggested that,

> *"It is always better to build on knowledge than to repeat what learners have already worked out".....It is important to build–on from what they already know".*

While T4 alludes to the 'building of knowledge' he, as well as the other participants however, assume that the learners' existing knowledge is correct even though he referred to prior knowledge as "previously remembered knowledge from years of experience at home or at school". It would seem that T4 is unaware that this existing knowledge could be inaccurate in terms of established scientific knowledge and therefore there will have to be the use of appropriate strategies by the teacher in an attempt to bring about conceptual change and therefore meaningful understanding.

Notwithstanding their interpretation of the importance of prior knowledge none of the participant teachers mentioned or attempted to link their understanding of 'prior knowledge' to 'constructivism', 'conceptual change' and 'epistemic beliefs'. The issue of eliciting prior knowledge and the integration of new information with this was not mentioned. The assumption made by the teachers is that, since the learners were taught certain aspects previously they therefore have the correct understanding of these and therefore there is a need to build on the existing knowledge irrespective of whether that knowledge is naive or sophisticated. This could indicate a lack of professional development among the participant teachers. This conjecture is supported by the responses by the teachers to Q11 of the questionnaire namely, *"Did you attend any professional*

development meetings/workshop/conference where practical investigation in science was the theme/topic?"

Only one out of the four teachers (T3) replied in the affirmative. However, this course attended by T3 was only of two hour duration and it involved a discussion on rubrics. It is therefore highly unlikely that aspects of any learning theory, such as constructivism in the context of IPW would have been discussed.
Further evidence of a lack of knowledge and understanding of the role of 'prior knowledge' in the teaching and learning process will be presented when the findings in respect of the teachers' classroom practice is discussed in section 6.3.2.

With respect to teachers' knowledge and beliefs about planning and preparation, the following question was posed to them during the interview: Q14. "*Would you regard planning and detailed preparation by the teacher as being essential for the successful implementation of investigative practical activities? Explain"*

While all teacher participants responded in the affirmative about the importance of planning and preparation, their responses and actions revealed a limited understanding of planning and preparation.
For example, T1 replied,

> *"... not detailed as such but one needs to be prepared and one needs to have a thorough knowledge as to what he wants to achieve – through preparation of course".*

T1 seems to be alluding to the understanding of the goals of the lesson which is an important 'compass' for any lesson.

T2 responded by saying,

> *"Yes. As for whatever practicals you are going to do with the learners– you as an educator have to do it before so that you will be able to evaluate and see if things might go wrong in the practical for instance and to be able to do some risk assessments".*

This may be true, but it is a very restricted understanding about the importance of lesson planning and preparation. Her response is only about the execution of the practical work in order to see that it goes according to plan or according to the text book. There was no reference to aspects such as questions planned and prepared for the different phases of the lessons or questions to trigger divergent modes of thinking and responses.

T4 displays his concern for assessment and not really about what should be taught and expresses how it ought to be taught, as follows:

> *"Definitely – there has to be some kind of planning ahead–so that the assessment given afterwards can be fair and the students have a very clear idea of where to go and what to do to get those marks that they need".*

This perhaps is highlighting the reason why these tasks are performed. It seems to be executed for the purposes of assessment rather than for the development and understanding of subject matter knowledge. While the formal CASS/SBA requires a single IPW task, the curriculum policy states that learners ought to be afforded numerous opportunities to practice and master these skills in the form of informal or formative assessments (DoE, 2005b).

The importance of the goals of the subject as well as, the objectives of teaching and learning of IPW were distinctly absent from the teachers responses.

The significance of questioning by the teacher as well as allowing learners to pose questions during lessons was articulated by the participant teachers in response to the following questions during the interview:

15. Is questioning by the teacher during the different phases of the lesson / activity important?
16. How important is allowing learners to ask questions during the different phases of the lesson / activity? Explain

According to the teacher participants questioning plays a significant role in facilitating the understanding of concepts through clarification and enhancing learner interest in the subject matter. Some of the participant teachers responded to the questions in the following manner,

> *"Yes of course – just to find out if the learners actually understand the concepts ……to steer the learners' interest in the topic"* (T1)

The teachers also indicated that the use of questions helps them to lead learners towards expected answers and to help learners follow instructions in order to do things 'properly'. 'Properly' in this context is probably referring to the teachers' or text book way.

T2 indicated that questioning is important because,

"It helps in leading them to do it–whatever they are doing properly".

T2 also alludes to a lack of confidence in managing the unexpected, when she says,

"So that at the end you don't find something that you didn't expect. So leading questions are quite good throughout the lessons".

According to T3, questioning by learners help to clarify any doubts that they may have about aspects under discussion thus leading to meaningful learning.

His response was that,

"Wherever a child has a doubt with regards to which variables he needs to control, which is going to have an impact on the final result, then he needs to clarify during the course of the process. So by all means he must ask [questions] because at the end of the day if the actual investigation is flawed then obviously you [will] have an invalid conclusion. So it is important that they query and do the correct thing step-by-step".

In general, science teachers ask questions to assess learners thinking or cognitive abilities and to foster learner motivation in learning (Yip, 2004). The evidence in this study reveals that the teachers have a limited understanding of the importance of questioning in a lesson. For instance, they were unable to relate questioning to the establishment of learners' prior knowledge. Furthermore, they did not mention how questioning by the teacher and/or the learners could facilitate the construction of knowledge by establishing relationships between existing knowledge and new information (Yip, 2004). That is, to show the link between the active construction of knowledge by eliciting prior knowledge and integrating it with existing knowledge as meaningful learning (Gunstone, 1995; Posner et al., 1982).

Science teaching and learning is further complicated by the fact that learners enter their classrooms with alternative conceptions or naive preconceptions. These preconceptions are different from the established scientific concepts and may persist even after instruction. In order for meaningful learning to occur, these naive preconceptions will have to be identified, reorganised or restructured, or modified in order to accommodate the new

concepts or ideas through a process of 'conceptual change'. For this conceptual change to be successful, the teaching and learning strategy has to promote the active construction of knowledge rather than the one-way transmission of information such as, through a structured worksheet. The use of questions has the potential to create an active engaging environment in order to achieve meaningful science understanding. Meaningful learning in science thus involves assisting learners to develop conceptual understanding by themselves on the basis of their pre-existing knowledge rather than through the rote learning of factual information (Yip, 2004). Further elaboration in this regard will be discussed in section 6.3.2 with the findings in terms of teachers' practice.

(d) Teachers' knowledge and beliefs about pedagogical content knowledge (PCK)

The combination of content knowledge with pedagogical knowledge by teachers is emphasised as essential to teaching (Shulman, 1986). Adler and Reed (2002) also argued that content knowledge on its own is not enough for teaching and learning. Instead, teachers need to acquire and understand knowledge about teaching and learning. In addition, Loughran, Berry and Mulhall (2006) also declare that PCK does not simply involve use of a teaching strategy because it works but it is about integrating knowledge of pedagogy with subject matter knowledge, in a way that the information is better understood by learners.

FINDING KB4: [Knowledge and beliefs about PCK]

"The participant teachers perceive IPW to be an essential, effective and useful means of teaching and learning science. However, their practice revealed a lack of knowledge and deep understanding of its application in classroom".

Evidence for this claim has been constructed by analysing data from the tasks that the participant teachers completed (Figure 6.1, Table 6.9 and Appendix H), as well as from the lessons observed (Appendix I), teacher and learner artefacts and the responses to interview questions (Appendix E). In order to determine teachers' knowledge and beliefs about whether practical work in general and IPW in particular is an essential, useful and effective method for teaching and learning science, the responses to the following questions were analysed:

3. Do you believe that?
3.1 Practical work is important for the effective teaching and learning of science? Explain
3.2 Investigative or inquiry based practical activity is essential for effective teaching and learning of Life Sciences
10. Do you believe that investigative practical work is a useful and effective teaching and learning method? Explain.

All the teacher participants indicated that practical work is an effective and essential strategy for science education. The reasons that they put forth was that it results in meaningful learning, that it also enhances understanding of subject matter, and that it helps to reinforce what has been taught. Furthermore, according to the teachers IPW provides better opportunities for meaningful learning. The following are the teachers' responses in this respect:

"Practical work helps learners to explore and inquire and thereby result in meaningful learning. Filling-in [worksheets] is not much intense and it does not provide learners with more meaningful learning [sic]–but more investigative kind of approach to practical work does allow learners to be good problem solvers". (T1)

T1 also provided a reason as to why IPW is a useful and effective teaching and learning strategy, by suggesting that,

"Because it tries to reinforce, what we have taught in class".

The notion of 'reinforce' implies that the practical work that is conducted is merely for the purposes of verification of established knowledge. This response also alludes to the notion of the confirmatory functions of practical work in general as indicated by the teachers when questioned about their views and importance of practical work in the Life Sciences as noted in section 6.2.1.(i).

T2 maintains that practical work facilitates understanding of subject matter and that IPW,

"Is essential, they don't forget they understand ……So practical work caters for everyone"

In her previous response about the value of practical work T2 also indicated that practical work helps prevent learners forgetting. The comment made by the researcher in (6.2.1) was that it is possible that T2 was conflating two different aspects, that is, 'not forgetting or remembering' with 'understanding'. Not forgetting does not necessarily equate to

understanding because one can learn information by rote and remember it verbatim without understanding it. Her comment about it catering for everyone is perhaps referring to the fact that the design of the activity could be simple so that it could be executed by all learners with equal ease. If this is the case then one could infer that the different abilities of the learners are not taken into account. This therefore provides evidence for a lack of understanding of PCK.

In order to develop PCK, teachers need to explore instructional strategies for various aspects of subject matter during classroom practice. For example, how they relate to everyday life. In addition, they need to gain an understanding of learners' conceptions and learning difficulties concerning these areas (Lederman, Gess-Newsome, & Latz, 1994) so that appropriate support strategies may be employed to enhance the construction of meaningful knowledge and conceptual change. Lacking such knowledge and understanding is further evident in the planning and preparation of their lessons, which was inferred through the lesson observations and through the study of the teacher artefacts.

The response of T4 revealed that the implementation of practical work is of importance for post school studies for those learners wishing to pursue a career in science so that they will possess the necessary skills. He also acknowledged that engaging learners in practical work involves,

"A lot of extra work".

The notion of 'extra work' could be referring to a greater demand on the teachers' time and effort and/or time spent on the curriculum as indicated by T3 when questioned about the value of IPW in school science. This is probably a reason why the teachers find it challenging to pursue IPW in the manner that is required by the curriculum policy.

With respect to IPW being a useful and effective teaching and learning strategy the response of T4 was consistent with the requirements of the curriculum in that:

"It gives the students opportunities to discover for themselves to use the scientific method and to understand the process and come up with their own hypothesis".

In order to determine whether the participant teachers are aware of and/or engage in 'out of the ordinary' practice in IPW, the following questions were posed to them and their responses analysed:

22. Do you encourage your learners to do the following?
(a) Take risks for eg. by making use of an original method to solve a problem / investigate a phenomenon
(b) Express new, original, different and/or unusual ideas
(c) Predict the results of experiments

On the question of 'taking risks' some of the teachers did not understand the concept of 'taking risks within the context of IPW. Whilst the teachers did not seem to understand the phrase, 'take risks', for the next question, that is:
"Express new, original, different and/or unusual ideas", they responded in the affirmative. This therefore supports the assertion that they lack adequate knowledge and understanding of PCK or constructivism within the context of IPW. The affirmative responses by the teachers align with the characteristics of open-ended inquiry such as IPW. However, their responses were inconsistent with the design of their sub-tasks 1.2 and 2.2 (Fig. 6.1 and Appendix H) and therefore also inconsistent with the curriculum. These tasks were supposed to be in the form of open-ended investigative practical work (IPW) for their Grade 12 Life Sciences learners. But all the participant teachers designed lessons which were of the structured and closed-ended type (Wellington, 1994; Bell et al., 2005; Zion & Sadeh, 2007). The design of the lessons for sub-tasks 1.2 and 2.2 were consistent with the design of the lessons observed. For these lessons learners would have to follow a systematic procedure provided by the teacher in order to verify their results with the textbook or teacher's information. There was no opportunity provided for active learner participation for the construction of knowledge. Aspects such as, prior exploration, the generation of conjectures or hypotheses and alternative methods or strategies to conduct the investigations by the learners was lacking.

The response of T1 to the issue of predicting results was, "*hardly*". This supports the finding that T1 has inadequate knowledge with respect to the concept of 'hypotheses.
T2 and T3 were very confident and sure that they encouraged their learners to take risks, express new, original, different and unusual ideas, and to predict the results of experiments (Q22 of Appendix E). T1 and T4 were more cautious in their responses, especially to taking risks and predicting results. They seemed not to understand what is meant by 'taking risks'- even though an example was given.
T4 responded as follows:

"Hmmm….I'm not sure – I haven't had the opportunity yet to have them take risks".

This further suggests that the teacher does not understand what hypothesis testing practical work is and how it ought to be implemented. Moreover, no opportunities were provided for learners to ask questions or challenge the procedures, yet in their interview responses the teachers indicated that questioning by both the teacher and the learners is important for effective teaching and learning. This is an indication, that while the teacher perceives and may have knowledge of the importance of certain strategies in a lesson, they lack a deep understanding and experience of implementing such strategies to support learners. For example, the art of questioning in a lesson involving IPW cannot be ignored for its effective and successful implementation. By posing appropriate questions teachers may be able to guide learners towards the formulation of a relevant hypothesis for instance.

The interview questions, namely, Q20. "*Do you see your role as facilitating the development of learners' thinking and learning skills rather than emphasising the content matter only?"*and Q21. *"Do you think it is important for teachers to often make adjustments to their lessons based on reflection and/or monitoring of their practice and on learner's responses / behaviour? Explain",* is reflective of PCK and constructivism. Hence, it was included in the interview in order to understand teachers' knowledge and beliefs about it.

The teachers revealed limited knowledge and beliefs in this matter. T1 acknowledged that she sees herself as facilitating both the skills as well as emphasising the content. This reflects the content versus process debate in inquiry based science education. Furthermore, her belief in this matter is probably due to the emphasis on the high stakes examinations, which is content orientated.

Her response was as follows:

"It's a bit of both – because at one level you emphasise the content and at another level you emphasise the development of certain skills"

T2 believes that his role is that of developing learners' thinking skills and not just providing them with a lot of information.

Effective teaching requires the teacher to engage in continual monitoring, reflection and adjustment of practice. All the participant teachers indicated that this was very important. However, the participant teachers displayed inadequate knowledge and importance about reflective practice as revealed by their responses below:

> *"It is important for one to actually reflect on the lesson if one really wants learners to achieve success at the end of the day – but even though one cannot be able to do that in every lesson that one presents but in some way or other one really needs to reflect and then try and find out what could be the problem that they may have encountered in the curriculum in the teaching of that particular content.* (T1)

> *"When you are teaching you find the very same topic you have taught this year in following year you change the method because – need to cater for particular learners you have at that particular time".* (T2)

> *"I think the pupils will dictate on how the next lesson will go – based on what they understood and what they did not understand and all the gaps".* (T3)
>
> *"That's something that I'm guilty of not doing often enough. Yes reflecting on the activities is important– to determine for instance, what worked, what didn't work is very important".* (T4)

All the teacher participants believe that reflecting on their practice is important in order to improve on the teaching and learning process. They also believe that reflection helps in taking into account different learners and different learner abilities. Taking these differences into account has the potential to result in meaningful learning. The assumption is that the participant teachers engage in such practices and therefore, there should be an improvement in the implementation of IPW over the years. However, T4 acknowledges that while reflective practice is important, he does not do it often enough. The findings of the classroom practices are discussed later in section 6.3.2.

An attempt to obtain evidence from some of the teacher artefacts such as their lesson plans proved challenging because they did not have such plans. This could be ascribed to the

lack of attention paid to planning and preparation within a school system. It is also possible that teachers perceive their years of teaching experience to be sufficient for classroom practice and therefore there is no need for such planning and preparation. Erdamar and Alpan (2013), cites preparing for lessons as one of the main characteristics of effective teachers. Motlhabane and Dichaba (2013) also observed teachers who were pursuing additional studies at a University, were reluctant to prepare lesson plans for their practical activities. They suggested that this reluctance to prepare lesson plans was due to their lack of confidence in conducting practical work. The intention of studying teacher artefacts for this study was to understand the thinking behind the design of the observed lessons. For instance, it was important to determine the goal/s of the lesson that were being targeted, to determine whether the lesson was planned to occur in any particular sequence and whether there was a set of questions to guide and assist learners in order for meaningful learning to occur. While there was evidence of some preparation in the form of worksheets, which in all cases were very structured with a great deal of information (not necessarily background information) provided. Such detailed guidance made these activities closed-ended, predictable and therefore inconsistent with the requirements of the curriculum on the one hand and also inconsistent with their responses to the questions posed during the interview and in the questionnaire and as indicated in finding KB1, that is, *"All the teacher participants believe that practical work is essential because it makes learning more meaningful, and that investigative practical work (IPW) provides learners opportunities to acquire scientific skills. However, the teachers have limited knowledge and understanding of the different types of practical work and the implementation of IPW as set out in the Life Sciences curriculum"*.

The learner artefacts in the form of the completed and marked worksheets were studied to determine, indirectly the teachers' knowledge in respect of the information provided by the learners and marked by the teachers. Evidence in this regard revealed/verified that teachers do have appropriate content knowledge for the lessons observed.

The average teaching experience among the teacher participants is 17.5 years with the youngest teacher having 11 years of experience and the oldest with 28 years of experience. These teachers therefore do not qualify to be regarded as novices. This therefore implies that the participant teachers would have gained sufficient experience to develop their "own special form of professional understanding" (Shulman, 1987, p.8). Unfortunately, there is a lack of evidence for this 'sophisticated knowledge' (Zohar, 2006) in this study.

(e) Teachers' knowledge and beliefs about pedagogical context knowledge (PCxtK)

The findings about teachers' knowledge and beliefs in respect of PCxtK focused on the classroom environment and more especially on learners. It specifically focused on teachers' knowledge and beliefs about learners' abilities and interests in studying IPW. Learner abilities refer to whether the learners have sufficient background knowledge to learn about IPW. The learners' interests refer to whether IPW activities appeals to them.

Wells (1994) indicated that classrooms are very diverse within a school or across schools, districts and provinces. Hence, individual learners have their own interests, abilities and limitations. Therefore teaching cannot be a simple matter of implementing curriculum packages–a case of 'one size fits all'. Hence, teachers' understanding of PCxtK, for example, teachers' knowledge about the characteristics of the learners is crucial for the implementation of IPW. As indicated in 6.2.1(iv), being knowledgeable and having deep understanding of the characteristics of learners, helps in planning and preparing lessons appropriately.

FINDING KB5: [Knowledge and belief about PCxtK]

"The participant teachers acknowledged the existence of differences among their learners in their abilities and interests to do IPW. However, their practice showed a lack of understanding of how to take these differences into account during the implementation of IPW".

This assertion has been formulated by analysing the responses of the participant teachers to Q7 and Q9 of the interview protocol (Annexure E). To this end, all the participant teachers responded in the affirmative to Q7: *"Do your learners find IPW useful and enjoyable compared to other activities?"*

T1 indicated that,

> *"They do – even though some of them do not because they are lazy to think– and [we] must always provide information for them – but eventually they do".*

This is perhaps an indication that not enough appropriate support and scaffolding or guidance is provided to the learners to think about what they are doing. This therefore may be the cause of frustration and demotivation among the learners, which may be perceived as the learners being lazy. Similar sentiments were expressed by Kirchner et al., (2006). On

the other hand it could be due to other factors such as, the lack of or incomplete integration of new information with existing knowledge as a result of the inability of the teacher to use appropriate teaching and learning strategies like, questioning strategies to establish such relationships and for the purposes of adequate scaffolding.

T2 and T3 maintained that their learners do enjoy IPW but they did not provide any substantiation.

According to T4,

> *"Many of the students like the opportunity – even if it's not hands-on. [They] like an opportunity to discuss things as group work or to problem–solve and get through these activities. I think it is definitely useful".*

This response alludes to the positive outcomes of collaboration and co-operation, which is an essential feature of the constructivist approach.

The teachers responded cautiously to Q9: *"Do you think that your learners are capable of successfully completing hypothesis testing/investigative tasks? How do you know this?*

While T2 and T4 indicated that most of the learners are capable, T1 indicated that her learners still struggle. T3 pointed out time constraints as a factor that challenges the implementation of IPW and therefore the development of capacity among the learners.

According to T1 the learners do experience difficulty with IPW. This difficulty is experienced more in Grades 10 and 11 yet in these grades the IPW activities are not necessarily open-ended. It is possible that less emphasis is placed on the principles of investigations in favour of the specifics through following instructions to complete a highly structured task. However, the teachers are confident that their learners will be capable of engaging in IPW by the end of grade 12.

T1 responded by indicating that,

> *"They still struggle……but by the end of their Grade 12 probably they will master what hypothesis testing is. [In] grades 10 and 11 they [are] still finding it difficult but we [are] getting there".*

T4 acknowledges that the majority of his learners do enjoy practical work and he is of the opinion that they are capable of completing it successfully. His assertion is based on his evaluation of the learner's assessment tasks and their performance in the examinations. His reply to the question was as follows:

"I think the majority of the learners are [enjoying practical work] because later on when I do the evaluation of the assessment–or even assessing hypothesis testing questions in examinations we can see that students do have an understanding of the concepts and the scientific method. They are beginning to think like scientists and not rote–learning everything".

The teachers' assertion needs to be challenged here. The examination is a paper and pencil process and as such some aspects of assessment of IPW are limited under such conditions. Hence, it is therefore not a reliable measure of the abilities of learners to engage in IPW. Johnson et al., (2005a) argue that being told about some topic may be informative but it does not prepare learners to use and do things. The observation of this (T4) teachers' lesson provides evidence that he discusses aspects of IPW theoretically and it shows consistency with the written test and examination outcomes.

According to Barnett and Hodson (2001) the best teachers do not always behave in conventional ways, and how they inspire and motivate their learners is not always immediately obvious. When teachers design and implement lessons they take into account more than subject matter knowledge. Instead it requires knowledge about teaching and learning. Within the context of this study it will be interesting to note whether the participants reacted appropriately to their knowledge of their learners' abilities and interests when they engage with IPW in the classroom. This finding will be discussed in section 6.3.2.

(f) Teachers' knowledge and beliefs about self (teacher)

Knowledge and beliefs about self relates to the teachers' perception about their experiences, role, interests, abilities, confidence and need to change their practice with respect to the implementation of IPW.

The teachers' experiences relate to their experiences in IPW since their school days. Their role refers to their responsibilities in promoting and supporting the implementation of IPW within the classroom. Their interests, abilities and confidence are also related to their classroom practice. The teachers' perception of the need to change is dependent on his/her current practice. This will depend on whether the teacher is satisfied with his/her current practice or whether he/she realises the need to adopt a revised or new approach to implement IPW.

FINDING KB6: [Teachers' knowledge and beliefs about self]

"The participant teachers' perception and knowledge about the implementation of IPW reflects their past experiences with practical work".

This claim has been constructed with evidence from the analysis of teachers' responses to the following questions of the interview protocol (Appendix E).

2.1 When you were in high school did you do practical work in Biology / Life Sciences?
2.2 As a school-based learner of Biology / Life Sciences did you do investigative or inquiry based practical work……
2.3 As a school based Biology / Life Sciences learner the practical work consisted mainly of filling in worksheets while following step by step instructions
2.4 As a college or university student did you do practical work ……
2.5 As a college or university student the practical work consisted mainly of filling in worksheets while following step by step instructions
2.6 As a college or university student how often were you provided with opportunities to engage with investigative practical work?
2.7 As a teacher of Life Sciences do you provide opportunities for investigative or inquiry based practical work to your learners? Why? / Why not?

All four teacher participants remembered that they were exposed to some form of practical work when they were school-based learners or students at tertiary institutions. The nature of the practical work was of a very structured, verification type, similar to those described by Wellington, (1994) and Bell et al., (2005). In this form the practical investigations require learners to follow a set of systematic instructions, and/or fill in worksheets for closed-ended type of activities. For this type of activity a large proportion of the information is provided by the teacher in a worksheet where learners follow instructions in a step-by-step manner to reach predetermined results.

Three out of the four participant teachers were not exposed to IPW which involved open-ended tasks. Some of the participant teachers attempted to justify such a state of affairs by indicating the lack of resources as a challenge. The following are examples of the participant teachers' responses:

> *"Hardly–I suppose because there were not properly equipped laboratories and not enough resources as such. Most of the time ... there was prior knowledge given to [sic] us then we had to conduct the experiment - not actually present us with a problem and then we find a solution to the problem"* (T1).

The teachers' reference to 'prior knowledge' is an inappropriate use of this concept. What she probably meant was theoretical or established knowledge or background information.

The response of T2 also concurs with the lack of experience in IPW and practice with structured, verification type of activities. She suggested that,

> *"It was just 'hands-on' most of the time". "One of the practicals we did it was on starch test in plants – err…..err – we were investigating the requirements … and we had to do a test where we were boiling the leaf – that is the sort of things we did and there were no … like further investigations after that". "Yes…filling in worksheets and following step-by-step instructions. It was more of theoretical stuff".*

Although the teacher makes reference to "investigating the requirements....." this would have been a verification exercise because she refers to 'hands-on most of the time and filling in worksheets and following step-by-step instruction'. These are characteristics of the structured, verification, closed-ended type of tasks/activities.
The reference to "theoretical stuff" by the teacher respondent is with reference to the verification of established textbook knowledge, or it could also refer to 'practical work' being done theoretically. In South African colloquial language, this means without physically conducting the experiments.

With respect to the participant teachers' experiences at tertiary institutions, all indicated having had some exposure to practical work in general, but their exposure to IPW was very limited. T3 and T4 indicated that their exposure to IPW was almost non-existent. The reason forwarded by T3 was that his major was Zoology, and he therefore had minimal exposure to IPW since the courses in Zoology focused on anatomical studies. T4 also indicated that from a Life Sciences subject perspective he was exposed to very little IPW. His response was,

> *"I would say from the Life Sciences point of view very few – in the chemistry that I had to do as a compulsory at the university – there we had to do it probably once or twice a week – we had to gather our own data, come up with our own conclusions and things like that. So chemistry at the university seemed to do a lot more of that".*

T1 seems to be the only participant who had some exposure to IPW at tertiary level. She commented,

> *"At varsity that is where I learned more about what you mean by investigative practical work (IPW), hypothesis testing and it became more meaningful while doing practical work".*

T3 and T4 studied Biological Sciences in the Faculty of Science while T1 studied Science Education in the Faculty of Education. Hence, it seems that the curriculum in the Faculty of Education is aligned with the curriculum of the schooling system, while the science faculty probably focuses on established scientific knowledge at the undergraduate level and less on experimental investigations of the open-ended type.

The teacher participants claimed that they have been implementing IPW to a limited extent prior to the introduction of *NCS.* However, with the introduction of the new curriculum, they have been implementing it with greater rigour and that they do provide opportunities for their learners to engage in IPW. The reason afforded by the teachers for this shift is that, not only is IPW a requirement for school-based assessment (SBA) /continuous assessment (CASS) in the Life Sciences, but also because they believe that practical work helps the learners understand subject better. Furthermore, the teachers revealed that they realised and understood the difference between the different types of practical investigations only after the introduction of the *NCS*. T2 revealed that

> *"Before – I've been doing it but to be clear about the difference between the 'hands-on' and 'hypothesis' – which is during the NCS – it became more clear and involved...".*

T3 indicated,

> *"I think to a limited extent we did it previously – but not err… err... in the manner we are doing it now".*

This is an indication that the teachers are not aware that the requirements for the previous Biology curriculum are very similar to the current Life Sciences curriculum, as established

and elaborated earlier in Chapters Two and Three. This is probably due to the lack of emphasis on the nature of practical work that was required for the purposes of CASS/SBA in the pre-2006 curriculum. The degree to which the teachers understand this difference may be reflected in their confidence or the lack thereof and ability to implement IPW in the classroom.

The response of the teacher participants to the question of whether they design their own IPW task for their learners namely, *"Do you design your own investigative practical activities for your learners or do you often use what is available e.g. from texts or other colleagues? Why?"* (Q8 of interview) revealed that they lack the confidence to do so. This lack of confidence to design and develop their own IPW tasks could be due to their superficial knowledge and understanding of science teaching and learning and the curriculum requirements and its application in practice. Evidence shows that the participants rely on 'outside expertise' such as, text books and other colleagues.
For example, T1 mentions,

> *"To an extent I use what are designed in the text book but I try to be innovative and design my own".*

T2 responded by suggesting that,

> *"We sometimes try to design for them to get used to the method of designing –we normally pick a very simple experiment for the learners to do–then after that for CASS I will just stick to what the subject advisors give us".*

The comment by T2 provides further evidence that what the teacher's claim to know about the curriculum may not be what they really understand and hence, is not consistent with their practice. In the case of T2 she indicated that she designs investigative procedures for the learners, yet the curriculum indicates that at the Grade 12 level it is the learners who ought to design their own investigations. The teacher may provide them with a scenario, or a problem or even the hypothesis and the learners then design procedures to test this. Furthermore, her response also alludes to her lack of confidence in preparing and implementing her own tasks for the purposes of assessment, by stating that she uses what the subject advisors provide.
T4 reveals that,

> *"I think we use …. I use what is available from other colleagues…"*

In response to Q2.7, (Appendix E), *"As a teacher of Life Sciences do you provide opportunities for investigative /inquiry based practical work to your learners"? Why? /Why not?* All the participant teachers answered in the affirmative. According to their responses, they claim to provide the opportunities because they believe that it is an opportunity for exploring, solving problems and making meaningful decisions.

For example, T1 replied as follows:

> *"It provides learners with an opportunity to be problem solvers. Er... make constructive decision making – Explore, make meaning….."*

T3 and T4 declared that they do provide opportunities for learners to engage with IPW activities because it is a mandate of the curriculum and a requirement for CASS/SBA. In addition, T3 maintained that by engaging with IPW learners will be able to understand the nature of science. T4 also indicated that it provides opportunities for learners

> *"To engage with the equipment and with the whole scientific method and gather their own data and things like that".*

The response to the following questions by T4 is significant.

> 18. Do you provide adequate opportunities for your learners to become acquainted with the various aspects of investigative / hypothesis testing activities? Explain.
> 19. In your role as a teacher do you provide adequate help, guidance, and support to your learners for investigative work? How?"

The response of T4 speaks to the practical work and assessment being seen as add-on to the curriculum and thus being regarded as a challenge in completing the tasks appropriately. His response was as follows:

> *"Not as often as we would like – We're using it as a tool for assessment ....but not as a tool for teaching and learning often enough".*

This is a fairly strong conviction by T4. An interpretation of this comment could imply that had it not been for the introduction of IPW as a component of CASS/SBA it probably would not have been attempted at all. This therefore justifies the inclusion of this type of task in the curriculum to serve as a coercive function in order to foster a transformed practice in the teaching of Life Sciences.

The teachers also indicated that certain circumstances and condition do not allow them to provide opportunities as much as they would like to. For example, they pointed out

challenges such as, large classes, the lack of laboratory equipment and resources and time constraints in implementing IPW.

While T2 also indicated that she does provide her learners with a great deal of opportunities to engage in IPW, an interpretation of her comments shows that she lacks adequate knowledge and understanding of the curriculum. She elaborated as follows:

> *"We do … we do but we still do have some problems when it comes to equipment so when we do them we have to improvise most of the time … And then in terms of investigations – we do a lot of investigations – we give them work to research on the internet and to go to the libraries to find out about whatever stuff we are looking for. But even then – because of bigger numbers that we have – sometimes we find that we end up demonstrating instead of letting them do the actual practicals ……."*.

Her reference to the improvisation of equipment, research on the internet and demonstrations, reveals an inaccurate understanding of 'hypothesis testing'/IPW and the requirements of the curriculum in its implementation.

In terms of providing help, guidance and support, T1 responded as follows:

> *"Yes I do provide – because each time I set up investigative practical work you firstly discuss like 'what is the purpose' and actually give clear directions in carrying it out – what is one wanting to actually achieve by engaging them in the practical investigations"*.

The response of T2 also highlights the inadequate knowledge she has about the imperatives of the curriculum as well as about IPW. This, in turn, is manifested in the limited teaching knowledge. She responded in the following manner:

> *"Especially at the beginning. Like I'll also tell them some websites to find out some information and hmm…hmmm yes…in terms of resources where to find information"*.

The response by T4 also highlights an inadequate understanding of the requirements of the curriculum and IPW. He responded as follows:

> *"Yes. I tend to provide a step-by-step help to ensure that they understand where they're coming from, what they're doing … if there is a practical investigation – sometimes we do a practice – run – if you like, a lesson*

before where we do a similar kind of activity before – just to give the kids more of guidance - more of a framework that they can rely on in the next lesson".

As is evident from the responses of the teachers their knowledge base about IPW is inadequate and weak compared to their past experiences which seem to be fairly static and stable. Hence, it is therefore possible that this discrepancy is not strong enough to bring about a change in attitude towards IPW. Thus there is little evidence of the appropriate support and opportunities provided to the learners. This assertion is also supported by the teachers' responses to the questions below:

26. Do you prefer to give your learners tasks where they have to follow a set of instructions or method in a step-by- step manner? Why? 27. Do you think that teachers should ensure that they have control of their lessons and their learners by giving them the method to for all their practical activities? Why? / Why not?

Two out of the four teachers (T1 and T2) responded by indicating that they prefer to provide instructions in a structured way because it serves as a 'guideline' according to T1 and that this format caters for all learners, especially the low gifted ones, according to T2. T3 responded by indicating that the format of the instructions will depend on the task at hand. T4 indicated that although in his current practice he adopts a highly structured format but he prefers the learners to "discover for themselves".

In response to Q27, inferring from the response of T2 shows that she is very much in favour of having control of her lessons. Her response is as follows:

"Yes I think that one is better – especially when it comes to marking. Sometimes when something is too opened they become confused".

This belief held by T2 was played out during her lesson which was observed. Hence, it is consistent with her practice.

T3 indicated that it would depend on the type of activity. If it is investigative then,

"I encourage them to design their own experiments…"

T4 responded by stating that,

"Sometimes we want the learners to develop their own methods – so part of their development will be for them to come up with their own method"

The analysis of the observed lessons of T3 and T4 revealed that their claims to Q27 were not aligned with their practice. Further elaboration in this respect will occur in section 6.3.2 which follows.

6.2.2 The implementation of investigative practical work (IPW)

The findings discussed in this section are an attempt at answering the third critical question, namely, *'How do Life Sciences teachers implement investigative practical work in their classrooms?'* It highlights the findings with respect to teacher's practices and activities when implementing investigative practical work (IPW).

In order to observe the lessons the researcher had made prior arrangements with the teacher participants to observe practical work which are of the 'hypothesis testing' type. The characteristics of such practical work mirror that of IPW. In short, these activities are more learner-centred or learner-directed/learner-driven, open-ended, less structured and with a decrease in teacher-direction. That is, it promotes learner autonomy. From a constructivist perspective it involves active participation on the part of the learners. Active participation in this context is not only confined to the physical execution of the tasks but may also involve having a say in, for example, designing the procedures.

FINDING P1:

'Teachers' practice of the implementation of investigative practical work (IPW) reveals very structured, closed-ended, verification type of activities, which restricts the promotion of learner autonomy'.

This finding has been formulated by analysing teachers' lessons through the lens of the overarching theoretical framework of constructivism. In addition, IPW as an example of inquiry learning has been shown to have similarities with constructivism in Table 4.1. In this regard, the NRC (2000) report, Wellington's 'dimensions of investigational work' (1994), the 'four-level model of inquiry' postulated by Bell et al., (2005), and the steps of the 'scientific method' have also been used to analyse the structure of the observed lessons. Furthermore, evidence was also obtained from the analysis of tasks completed by the teachers as well as the

responses of the teacher participants to the questionnaire (Appendix D) and the interview (Appendix E) to support these findings.

In all the lessons and teacher tasks analysed, the design of the investigations were highly structured, with explicit direction given at all stages by the teacher through worksheets. As indicated in Chapter Three, levels of inquiry may be categorised in terms of the extent of guidance provided by the teacher. To this end, Zion and Sadeh (2007), Wellington (1994) and Bell et al., (2005) presented very similar models.
Accordingly, all the lessons analysed may be categorized as being closed (Wellington,1994), or as partial inquiry at level 1 and level 2 that is, verification and structured, respectively according to the model of Bell et al.,(2005).
The four sub-findings discussed here, when taken together reflect the main finding, P1.

(a) Sub-finding P1.1:

'The general design of the activities lacked the promotion of learner autonomy by virtue of them being highly structured and closed'.

While the *NCS* does not make explicit the theoretical underpinnings of the policy, an analysis of the Life Sciences curriculum shows it to have commonalities with constructivism as well as to inquiry-based teaching and learning. Since it reflects the essential features of constructivism and because IPW is an example of inquiry-based teaching and learning the implementation of IPW should therefore reflect the features of constructivism.

The lessons/activities which were observed lacked active engagement by and with learners. There was not much dialogue or interaction between the teacher and the learners with respect to eliciting and understanding their prior knowledge. It would seem that prior knowledge did not matter in the process of teaching new information. Furthermore, since there was no attempt at understanding learners' prior knowledge it implies that any inaccuracies in their understanding of relevant concepts would not have been identified. These inaccuracies would therefore not have undergone any reorganisation and restructuring to correct it through the process of conceptual change. The implication of this is that such inaccurate conceptions will persist and prevent the meaningful understanding of other related concepts. This state of affairs is probably due to the teacher assuming that

because s/he taught the related concepts to the learners that they all have the appropriate and accurate understanding thereof.

Research Assistant 1 (RA1) commented about the lesson of T4 as follows:

"Teacher stated that they might be familiar with the content to follow. The level of prior knowledge was never established".

RA2 indicated that T1,

"Did not enter into much dialogue with learners regarding their answers – just one liner and did not interrogate their responses…."

Three out of the four 'IPW' lessons observed, lacked evidence to show that opportunities were created for learner exploration before the teacher began the formal presentation of the lesson. In fact, the lessons were designed in such a manner that the aim and method of the experiments were provided and the learners had to execute them by following instructions laid out in the worksheets. Hence, no opportunities were afforded to the learners to discuss or generate conjectures or hypotheses or alternative procedures.

RA1 indicated that the lesson of T1,

"Was built on formal content taught to learners".

The assumption being made by T1 is that all the learners have a common understanding of the content that was previously taught. Hence, she did not attempt to elicit learners' prior knowledge or preconceptions.

RA2 made the following comment with respect to the lesson of T2,

"…learners engaged in same previous work as build-up to practical lesson – no level of abstraction [was] evident – very basic. More like a repeat of the same concepts dealt with in DNA extraction of the previous lesson".

This is supported by what the teacher had to say in the interview, with respect to 'providing adequate opportunities and support'. The previous lesson was a theory lesson where information in terms of established knowledge was presented to the learners. RA2 made the following observation about the lesson of T4,

"Teacher reviewed the scientific method and presented an explanation of how phototropism occurs by providing [computerised] animated versions accompanied by a verbal explanation".

However, it must be emphasised that it was the teacher who did this and not the learners. The learners were passive listeners.

All the lessons attempted to focus on one or more concepts. However, the focus in some instances was on the investigation and in other instances, it was on theoretical aspects and / or peripheral concepts. T4 for example, attempted to emphasise the concepts associated with tropisms. However, this was done theoretically and it was very limited in terms of the principles of investigations.

RA2 noted that T4,

> *"Addresses concepts of hypothesis formulation and phenomenon of phototropism; consideration given to conducting investigations as regards fixed and other variables*".

T4 talks 'about' the process rather than providing opportunities for the learners to experience this process first hand. Since he focuses on the process theoretically it is a possible reason for learners doing well in the assessment of these concepts. The assessment of these concepts is in the form of pencil and paper tests and examinations. Learner performance cannot therefore be attributed to their ability to actually conduct practical investigations.

The lesson of T3 took the form of individual work (similar to a test), where learners had previously set up their investigation on the growth of bread mould. The learners brought in their specimens and were observing and completing their worksheets. Although inclusion of fundamental concepts was not directly observed in the lesson, the instructions and information given to the learners in their practical worksheet revealed that these concepts were addressed. For example, they were to observe their bread mould, first with a hand lens and then under the microscope. They then had to write down a hypothesis based on their observation. From the researcher's perspective, the concept of hypothesis within this context is inappropriate because they had already conducted their investigations. A tentative hypothesis is decided first, then an appropriate investigation is designed before it is eventually conducted. They were now in the process of observing their results. Yip (2007) also claimed that students (and in this case teachers also) have a poor understanding of the concept 'hypothesis'.

Furthermore, RA2 made the following observations:

"Learners were engaged in investigative practical work in which they were making observations of their bread mould…..Furthermore, from looking at the apparatus set up, it seems that the learners had knowledge of how to ensure validity of an investigation as all the containers were identical and[so was] the size of bread used".

From this observation it is possible to infer that the teacher elicited and discussed learners' prior knowledge with respect to the concept validity. Hence, the learners were able to apply this in their investigation design.

T1 presented a lesson that took the form of a verification activity. It involved the practical testing of the theory of phototropism.
RA1 commented about this lesson as follows:

"The lesson was a wrap-up of a practical set-up done earlier in the week. The theory of phototropism was practically tested [a verification exercise] and learners had to make observations, formulate a hypothesis [after setting up the experiment], and make conclusions from their observations."

This is further support for the claim that the teachers do not have a thorough grasp of the concept and/or role of a hypothesis.

T2 spent a great deal of time on the concepts of the structure and components of the nucleus. She did not focus sharply enough on aspects of nucleic acids and more specifically on DNA, which was the focus of the investigation. Instead of trying to ascertain learners' prior knowledge and preconceptions, she spent a great deal of time merely repeating work that was done previously. Unfortunately, this aspect of the lesson was teacher-centred. The learners were not actively engaged and hence, their preconceptions or naive conceptions were not identified and corrected for meaningful understanding. This is perhaps, her idea of eliciting prior knowledge.

With respect to the lesson of T4, the researcher noted that:

"Teacher did all the talking – there was no discussion among the learners or between the teacher and the learners".

Hence, one of the essential features of constructivism, namely, social interactions was not evident in this lesson. There was also a lack of questioning by the teacher in order to identify any naive conceptions on the one hand and also promote divergent thinking among the learners on the other. A great deal of knowledge is socially constructed (Piburn & Sawada, 2000). Therefore, learners' active participation is crucial to accomplish meaningful understanding.

In general, these lessons were highly structured in that learners were not provided with a problem or a hypothesis to investigate, nor were they asked to choose a problem or hypothesis to investigate. Instead, the aim of the activity was presented together with systematic procedures to carry it out. Hence, exploration by learners prior to them executing the given procedure was absent. Moreover, the lessons were designed in a manner that did not allow the learners to engage as members of a learning community. The only engagement amongst learners was in answering the questions on the worksheets as in the case of T1, T2 and T4. Furthermore, from a constructivist perspective, there was no evidence of any attempt at eliciting learners' prior knowledge. The narrowness of the design also failed to promote conceptual understanding, both in terms of the content as well as in terms of the processes or investigative procedures. Due to the lack of engagement between teacher and learner and among learners that is, a lack of social interactions resulted in the lack of opportunities for learners to reflect on their thinking and on their actions. Hence, incorrect understandings or naive conceptions may not have been identified in order to bring about conceptual change for meaningful learning.

(b) Sub-finding P1.2:

'The role of the teachers or their activities was limited to leading the learners towards the 'correct' text book answers and hence, it did not foster intellectual rigour and divergent modes of thinking'.

There was no evidence of any opportunities provided for learners to engage in rigorous debate and discussions with the presentation of a variety of ideas and constructive criticisms. This was perhaps due to them having to follow a structured or step-by-step procedure with the sole intention of arriving at a result that was familiar (to the teacher). In this respect, RA1 made the following observation about the lesson of T2:

"No real debate. Teacher guided learners to the responses she was looking for".

RA2 made the following observation with respect to the lesson of T1:

> *"Learners were given worksheet with questions that had set [predetermined] answers, which served as a recipe for the implementation of the investigation. Lesson was not designed with this purpose in mind. It seemed very much a 'hands-on' practical".*

According to RA2, T4 did encourage to a small extent to,

> *"Provide alternate explanations for stem growth to unilateral light, but was not probing enough…"*

However, there was a greater emphasis by T4 on the content or concept but not adequately on the investigation procedure.

Rigorous debate is a necessary ingredient for scientific endeavours. In a classroom setting this is generally achieved through the presentation of a variety of ideas, which are debated, challenged and negotiated. Following a narrow, step-by-step procedure without the attention to alternative reasoning will result in a limited/narrow view of the nature of science and how science knowledge is enhanced. Providing opportunities for learners to debate and challenge ideas and encouraging them to generate alternative proposals with evidence and logical arguments will result in meaningful understanding.

The nature of the questions that the teachers posed to the learners were also closed-ended and confined to predetermined boundaries. For example, T1 posed questions such as: *What do you call substances that allow plants to respond to stimuli? What are hormones?*
Example of a question posed by T2: *What is the purpose of the dish-washing liquid?*
That is, their questions were not open to foster divergent modes of thinking. Divergent thinking is an important aspect of the scientific enterprise. Unfortunately, none of the teachers actively solicited alternative modes of investigation. In addition, learners were not encouraged to ask questions. Hence, the lack of learner questions and comments prevented the lesson from being directed and focused from the learners' perspective. With respect to the lesson of T1, her questions focused predominantly on the content and not enough on the scientific process. The learners of T3 were confronted with a pre-determined set of questions in a worksheet, which they had to answer individually. Hence, social interaction as an essential feature of constructivism was absent. This would therefore have prevented

the identification of any inaccurate or naive conceptions in order to bring about conceptual change.

With the exception of T3 whose lesson took the form of individual work, in all the other lessons the learners had to follow a fixed procedure in carrying out their 'experiment'. The lessons did not encourage the learners to generate several hypotheses, predictions and alternative methods of testing these and different ways of interpreting their results. Instead, the teachers encouraged learners to follow their (the teachers'/textbook) procedures and interpretation. In other words, it was the teachers and not the learners who determined the focus and direction of the lesson. Shifting the balance of responsibility for scientific thought from the teacher to the learners is encouraged in reformed teaching practice and this change is actively encouraged by the teacher (Piburn & Sawada, 2000).

While active learner participation was encouraged in their lessons, this was however, limited to simply following instructions/directions as laid down by the teacher or in their worksheets and the answering of questions in the worksheets. The learners did not participate in agenda setting or in 'minds-on' and 'hands-on' engagement in order to have a say in what procedures to use in the experiments. They were not given opportunities to engage in thought-provoking activities such as, the critical assessment of procedures. This also implies that the learners did not reflect on their learning, because the lessons did not allow for the re-examination or re-assessment of their thinking. Learners were also not given opportunities to represent phenomena and/or their findings in a different ways. Instead they were instructed to record their results in a specified way in the worksheets.
In an activity involving IPW much of the initiative should come from the learners as indicated in the Life Sciences policy document (DoE, 2005b) and as elucidated in Table 3.2. In order to promote such a situation, it is imperative for the teacher to play the role of a resource person in order to support and guide the learners during the investigations. In this way, the learners could be helped to construct meaning and further understanding from what they already know. However, this type of interaction was distinctly absent and not encouraged in all the lessons observed.
In this regard, RA1 commented about the lesson of T1 as follows:

"Learners were told what to do and how to do it".

The researcher noted that T1,

"Did most of the talking and provided learners with a set methodology".

RA2 indicated that T2,

"Told the learners everything they had to know".

Learner participation for the lesson of T2 was limited to 'hands-on' activities. There was no opportunity provided for 'minds-on' engagement or critiquing of the procedure or of the strategy of recording the results.

RA2 observed the following with respect to the lesson of T1:

"While the investigation was designed for them they were active in conducting the investigation using the worksheet as a tool".

These observations imply that the learners had to follow instructions in an active manner by being allowed to be passive in their actual thinking about why they were doing what they did.

In none of the lessons observed were the learners given any opportunity to determine how the investigation should occur. Instead, learners were provided with a structured set of instructions to follow. This pattern has also been observed in the tasks (Appendix H), to which the teachers responded.

(c) Sub-finding P1.3:

'The lessons promoted 'conformist thinking' amongst the learners by virtue of them being limited to following instructions, making observations and filling in worksheets, which have predetermined solutions to problems'.

All the lessons observed, with the exception of that of T3, were very structured and required learners to follow procedures step–by–step. The teachers–either using procedures designed by themselves or from textbooks, determined this structure. Hence, the design of the lessons did not provide opportunities for learners to seek alternative investigative methods. The lesson did not provide for active engagement with the design, for example, by questioning the teacher. This in turn, therefore did not allow the focus and direction of the lesson to be determined by the learners. Instead, it promoted 'conformist thinking' amongst learners in that it allowed learners to pursue the lesson in a way that a traditional practical lesson would have been conducted, that is, set down by the teacher or the text book – without divergent thinking.

RA1 observed the following about T1 in this regard:

> *"The learners were given a worksheet with a 'recipe' to follow. They were not allowed to design their own investigation. They just had to bring the material to conduct the experiments. The direction of the lesson was determined by the teacher and she steered the activities and discussions in that direction".*

With respect to T2, the researcher and RA2 noted that she mentioned to the learners that there were other methods of doing this particular investigation. However, she did not pursue this further, for instance by asking the learners to suggest alternative methods. She also did not provide any justification for the method chosen by her.

RA2 further indicated that,

> *"The lesson was predictable from the beginning as it was very much teacher-centred in which no space was created for any divergent thinking on the part of the learner".*

The lessons did not create opportunities for learners to generate conjectures and/or hypotheses, predictions, estimations and ways of recording results. Moreover, it did not provide opportunities for learners to devise means of testing these. Due to the closed nature of the activities or lessons, by virtue of the prescribed procedures, learners could not engage in thought-provoking activities such as, the critiquing of the experimental design. Instead, in all the lessons the learners were actively involved in the physical 'doing' and not thinking about the reasons for their actions. The closed nature of the lesson, therefore also did not encourage the learners to engage in metacognition that is, 'thinking about thinking'. Hence, this did not facilitate reflective thinking and learning, which could have resulted in disequilibrium between learners' prior knowledge and the new information, and subsequent intervention by the teacher to bring about assimilation and accommodation or conceptual change. This would have resulted in meaningful learning.

Communication amongst learners was limited to the groups. This mainly involved discussion with respect to the questions in worksheets. There was no discussion with respect to hypotheses, predictions, experimental designs, limitations, results and conclusions. With respect to the lesson of T3, no talking was allowed among the learners. The only time learners were allowed to talk was when they answered a question posed by the teacher.

RA2 recorded the following observation about the lesson of T4:

"Teacher engaged with learners for a large time portion of the lesson with the remainder of the time set aside for learners to engage with each other about phototropism questions in the worksheet. There was a great deal of teacher talk".

All the lessons observed, revealed a very low proportion of learner talk especially among the learners. This also suggests that critical aspects of the lessons were not developed through discussion among learners. In addition, the lack of opportunities for learner questions and comments especially concerning the procedures prevented the flow of the lessons from being influenced and shaped by their (learners') contributions.

(d) Sub-finding P1.4:

'A high proportion of investigative skills were not addressed in the lessons'.

The table below summarises the percentage of skills addressed by each participant teacher in the lesson observed by the researcher. The list of twenty skills was derived from the literature on inquiry based teaching and learning as well as from the curriculum documents (DoE, 2005b).

Table 6.4: Percentage skills addressed in each observed lesson

TEACHERS	T1	T2	T3	T4
Number of skills out of 20 addressed in lesson	7	5	6	6
Percentage of skills addressed in lesson	35	25	30	30

The following skills were not addressed in any of the lessons observed and yet these are important in the execution of IPW:

- Identifying a problem
- Formulating a research question
- Hypothesising
- Generating aim/s
- Identifying variables

- Selecting ways of controlling variables
- Planning an experiment
- Planning ways of recording results
- Understanding the need for replication / verification
- Making and justifying arguments
- Identifying hidden assumptions

The identification of the above skills, which were not addressed during the observed lessons, provides further evidence for sub-findings arrived in P1.1 to P1.3 in this section.

6.3 WHY DO THE TEACHERS IMPLEMENT IPW IN THE WAY THEY DO

The presentation in this section is an attempt to answer the final critical question for this study. That is, *"Why do teachers implement IPW in their classrooms in the way they do"?*
The aim of this study was to determine any relationship between Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW). The findings with regard to the teachers' classroom practice revealed that the participant teachers did not successfully implement IPW in accordance with the requirements of the curriculum as well as in terms of what literature says about the implementation of open-ended investigations (IPW). In order to determine the possible reasons for such an unsatisfactory state, an attempt will be made to link the findings with regard to the different curricula, teachers' knowledge and teachers' beliefs with their classroom practice.

The main finding in terms of the teachers' classroom practice is represented by the assertion below:

'Teachers' practice of the implementation of investigative practical work (IPW) reveals very structured, closed-ended, verification type of activities, which restricts the promotion of learner autonomy'.

This main finding consists of four sub-findings, namely:

Sub-finding P1.1: '*The general design of the activities lacked the promotion of learner autonomy by virtue of them being highly structured and closed'.*

Sub-finding P1.2: *'The role of the teachers or their activities was limited to leading the learners towards the 'correct' text book answers and hence, it did not foster intellectual rigour and divergent modes of thinking'.*

Sub-finding P1.3: *'The lessons promoted 'conformist thinking' amongst the learners by virtue of them being limited to following instructions, making observations and filling in worksheets which have predetermined solutions to problems'.*

Sub-finding P1.4: *'A high proportion of investigative skills were not addressed in the lessons'.*

When taken together, the four sub-findings constitute the main finding. Hence, the focus of the presentation is on the main finding, but inherent in the discussion are the aspects related to the sub-findings. In short, the classroom practice of all the lessons observed as well as the tasks prepared by the teachers may be categorised as being traditional.

The findings of this study have shown that there is no clear-cut relationship between teachers' knowledge, teachers' beliefs and their practice of investigative practical work. As indicated in section 6.2, some aspects of teachers' knowledge and teachers' beliefs are consistent with each other as well as with practice. In other aspects inconsistencies are evident.
In general, the findings show that what the teachers say/perceive/believe and know through their responses to the questionnaire and interview are not always aligned with their actions or practice. This is supported by other studies where some researchers found consistencies between teachers' beliefs and their practices (e.g., Aguirre, 2000; Standen, 2002) while other studies found inconsistencies (e.g., Kynigos & Argyris, 2004; Lefebvre, Deaudelin & Loiselle, 2006; Zembylas, 2005).

The following reasons are postulated as contributing to the way teachers implement IPW in their classrooms:

6.3.1 Teachers' practice is reflective of their experiences

(a) As Learners

The evidence presented for finding KB6: *"The participant teachers' perception and knowledge of the implementation of IPW is consistent with their past experiences which lacked opportunities to practice IPW"* also holds for the reason presented here.

All four participant teachers indicated that they were exposed to some form of practical work as school based learners and tertiary students. However, the nature of the practical work was highly structured, and required them to follow a 'cookbook' approach to verify what was studied in theory. This is in line with what is referred to as the traditional method of doing practical work. Their exposure to IPW was almost non-existent. Almost all the teacher participants indicated that they did not have exposure to IPW. Only one teacher acknowledged having a limited exposure at the university. The traditional method would have been very much like the 'hands-on' type of practical work as described for the Life Sciences.

(b) As Teachers

When the participant teachers entered the teaching arena, there was no 'compulsion' to do practical work in general. As for IPW or open-ended investigations they may not have even thought about it. The reason for such a situation was that, in the old (apartheid) dispensation with a fragmented education system, each Education Department had its own policy regarding science education. In addition, most of the ex-Black schools were poorly resourced, with no laboratory or science equipment. This state of affairs continued from 1994 until 2000 under the new dispensation, while transformation to the education system was being instituted. In a recent study by the South African Institute of Race Relations it was found that only 15% of South African public schools have laboratories (2012). This meant that the Biology/Life Sciences teachers continued to implement practical work in a manner in which they were knowledgeable and comfortable that is, in the 'traditional' way. In addition to this unsatisfactory state of affairs, is the lack of resources at the majority of schools. This includes the lack of proper laboratories and/or the lack of equipment and consumables in the schools.

An analysis of the pre-2006 Biology curriculum and the post-2006 Life Sciences curriculum revealed that the goals of both the curricula are almost identical. Table 2.3 shows the relationship between the LOs of the Life Sciences curriculum and the Aims, objectives and approach of the Biology curriculum. Sixty percent of the aims, objectives and approaches of the Biology curriculum found a home in LO1 of the Life Sciences curriculum. LO1 encompasses investigations and problem solving.

Furthermore, when the inquiry skills required for Biology and Life Sciences were compared (Table 3.1), it differed by only one skill. That is, the Biology curriculum did

not include the skill of 'following instructions'. Another difference is that, even though the Biology curriculum espoused investigative practical work through one of its aims, objectives and approaches namely, *"An ability to analyse and evaluate biological information, to formulate hypotheses and to suggest procedures to test them"*, this was not part of the imperative for practical assessment or CASS. Hence, Biology teachers did not conduct such practicals.

Moreover, the pre-2006 Biology curriculum did not specify the type of practical work for the purposes of CASS. When asked about their understanding of practical work, all the participant teachers responded by referring to it as some form of 'hands-on' activity. This further supports the notion that the nature of practical work involves 'hands-on' activities. The participant teachers did acknowledge, as indicated in section 6.2, that they gained knowledge about IPW / hypothesis testing type of practical work only when the post-2006 Life Sciences curriculum was introduced. Also, the schools chosen for this study achieved an average pass rate of 77% to 87% in the years 2010 to 2012. This implies that the teachers were experiencing success with their learners using the transmission-mode of teaching for a transformed curriculum and therefore did not see the need to change their practice. Hence, it is also possible that it is the teachers' practice which may have fostered the beliefs that they hold about IPW. Studies by Crawford (2007) and Smith and Southerland (2007), have demonstrated that the relationship between teachers' beliefs and practices involves reciprocal influences on each other.

Given the above state of affairs, and taking into account that the training for the implementation of the *NCS* was not substantial, teachers simply continued with what they were comfortable with. That is, preparing tasks and lessons that are very structured, with a great deal of guidance to carry it out, if practical work was ever done. In other words, these tasks are regarded as being traditional or closed-ended and teacher directed verification type.

With all the knowledge and experience gained as a scholar, tertiary student and then as a teacher meant that the teachers became masters in performing practical work in the traditional, highly structured way. Hence, the teachers' knowledge, know-how and experience have become entrenched as part of their beliefs and as such, it has gained a character of being resilient and difficult to change. This assertion is supported by Tsai

(2002), who maintains that the beliefs of many teachers, who have traditional views of teaching science, learning science and the nature of science, may stem from the problem of their own school science experience. Furthermore, it could also be due to the non-assessment of such IPW activities in the pre-2006 Biology curriculum, for the purposes of promotion that teachers continued to engage in such practices.

Teachers' epistemological beliefs are their opinions about the nature of knowledge and about suitable ways to develop or change one's own and others' knowledge (Hofer & Pintrich, 2002; Schommer, 1990). Such beliefs shape individual characteristics which impact on learning activities (Harteis, Gruber & Hertramph, 2010). It is conceivable therefore, that teachers perceive and interpret their teaching and environment that is, the school community as well as the curriculum by applying their individual beliefs.

With the influence of previous experiences, biases, and beliefs on learning and knowledge, it seems that learning, knowledge, and realisation or understanding are individual entities, which establishes a particular world-view which makes sense for the teachers. Thus, bias as the control of an individual's feelings, interpretations, and expectations may be seen as the core of an individual's approaches and abilities (Harteis, Gruber & Hertramph, 2010). From a socio-constructivist view, it may be regarded as a process of making sense of the world (Billett, 2006; Rogoff, 2003).

According to Schommer's (1990, 1993a, 1993b) notion of multidimensional epistemological beliefs the participant teachers' practice within the context of this study, highlights naive or under-developed beliefs. This assertion is based on the analysis of the lessons observed. The lessons manifest as knowledge being absolute (one pathway of arriving at predetermined answers), knowledge is formed by an authority (highly structured and sequenced by the teacher / text book) and transmitted to the learners.

Various studies (e.g. Kuhn & Weinstock, 2002; Schommer, Calvert, Gariglietti, & Bajaj, 1997; King and Kitchener, 1994; Schommer, 1993b) claim that change can occur over time from the so-called naive epistemological beliefs towards sophisticated beliefs.

However, the findings of this study indicate that this is not happening. One of the reasons for this is probably he lack of professional development of teachers. Through such development teachers may be induced into correctly believing that knowledge is

more multifaceted and relativistic, accept the changeability of truth and that knowledge is constructed individually (Kienhues, Bromme, & Stahl, 2008).

6.3.2 Teachers inadequate knowledge and understanding of the prescripts of the curriculum

While the teacher participants acknowledged the importance of practical work in general and IPW in particular, the way they implemented IPW in the classroom indicates that they do not fully understand the imperatives of the curriculum. This assertion is also supported by evidence from the analysis of the tasks completed by the teachers. However, during the interview they claimed to have adequate or requisite knowledge of the LOs and ASs of the *NCS* and SAs of *CAPS* respectively, which are the goals of Life Sciences education. In addition, the teachers were able to provide some differences between 'hands-on' and 'hypothesis-testing' practical work. However, their understanding of IPW was not as per the curriculum. T2 for example, gave a list of the procedures that may be carried out in an investigation such as, aim and method. Her response is reflective of the highly structured, closed-ended, step-by-step, 'cookbook' approach to investigations, which promote the usually one-way transmission of information from teacher to learner or from text book to learner. The tasks as well as the lessons of T2 observed correspond with her desire with respect to having control over learning in the classroom. This alludes to a control-orientated belief system as opposed to a liberal-oriented system (Calderhead, 1996). This therefore manifests as consistent relationship between her knowledge and practice. In fact, all the tasks and lessons analysed reflect one that espouses a closed and control-oriented belief system which emphasises the importance of maintaining order, good discipline, and guiding the activities of the learners.

Instead of the IPW activity being an open-ended one, for both the teacher tasks as well as the lessons observed, these tasks resembled highly structured activities with guidance at all stages. The teachers were unable to distinguish between the nature of IPW activity required for Grades 10 and 11 and that for Grade 12 classes.

The appropriate understanding of the curriculum requirements and its approach is vitally important if lessons are to be well planned and prepared. A well thought out and prepared lesson will enhance its efficiency and effectiveness in order to bring about meaningful learning.

6.3.3 Inadequate understanding of the processes in science or inquiry knowledge and lack of confidence in its application

The motivation for this as a possible reason emanates from the sub-finding KB2.2 namely, *"According to the teachers, having knowledge of the processes that are involved in investigative practical work, helps to guide learners appropriately. However, such guidance was distinctly absent in their plans as well as during their implementation of the observed investigative practical work".*

Inquiry teaching and learning is a complex process, involving both transformative and regulative processes (Njoo & de Jong, 1993). Regulative processes are related to skills such as, planning, monitoring, and evaluating (Maeots & Pedaste, 2014). Transformative processes involve the stages in the 'scientific method' and includes such skills as: identification of a problem, formulation of a question to research, generating and formulating hypotheses, planning and designing the experiment, conducting the experiment, collecting and analysing data and drawing conclusions (Pedaste & Sarapuu, 2006). Unfortunately, evidence for sub-finding P1.4 reveals that a large proportion of the investigative skills were not addressed in the lessons observed. Between 25% and 35% of the skills were addressed in the lessons of the participant teachers. The following skills were not take into account in the design of the activities/lessons: identifying a problem, formulating a research question, hypothesising, generating aims, identifying variables, selecting ways of controlling variables, planning an experiment, planning ways of recording results, understanding the need for replication/verification, making and justifying arguments, and identifying hidden assumptions.

Analysis of the Life Sciences curriculum shows that it has common features with constructivism on the one hand and with inquiry-based teaching and learning on the other (Refer to Table 4.1). Since IPW is an example of inquiry-based teaching and learning, it therefore follows that IPW has commonalities with constructivism. Inquiry learning has been described as learner-centred (Makitalo-Siegl, Kohnle, & Fischer, 2011) and a highly self-directed constructivist way of learning (de Jong & van Joolingen, 1998).

Kolloffel, Eysink and de Jong (2011), maintain that inquiry learning is about learning through experimenting and scientific reasoning and arguments. To engage successfully in such practices require critical and creative thinking and reasoning processes. Critical and creative

thinking and reasoning are regarded as higher order thinking and are also characteristics of scientific endeavours.

The participant teachers' practice in their lessons as well as their tasks lacked the characteristics of inquiry learning as well as constructivism and hence, the restriction of learner autonomy. Instead, the lessons were driven by the teachers, through their highly structured procedures. The learners were not involved in the 5 Es of inquiry, as espoused by the NRC (2000), that is, engagement, exploration, explanation, elaboration and evaluation.

Finding KB1 in section 6.2 asserts, *"All the teacher participants believe that practical work is essential because it makes learning more meaningful, and that investigative practical work (IPW) provides learners opportunities to acquire scientific skills. However, the teachers have limited knowledge and understanding of the different types of practical work and the implementation of IPW as set out in the Life Sciences curriculum"*.

Since the teachers alluded to practical work supporting meaningful learning then it is plausible that they would ensure that their practice will target such meaningful learning. However, their lessons were not conducted with the goals of the curriculum as the focus, or as per what reformation in science education advocates. This is possibly due to the teachers having such strong and resilient beliefs which were developed through their past experiences, that knowledge about open investigations do not feature in their repertoire of teaching and learning strategies. Furthermore, as discussed in finding KB1, the teachers made reference to practical work as helping to concretise and validate what the learners have been taught in theory lessons. Hence, the teachers do not view inquiry learning as focussing on scientific reasoning, which requires critical and creative thinking and reasoning processes.
The teachers' concern or complaint about the lack of resources is eliminated as a valid reason for not effectively implementing IPW on the grounds that all four participating schools being moderately to well resourced, as indicated in Table 5.2. Also, since the observed lessons were based on investigations that do not require any sophisticated resources. These investigations involved, 'extraction of DNA', 'phototropism' and 'growth of bread-mould'.

6.3.4 Limited understanding of aspects of GPK for classroom practice

This postulation is based on finding KB3 which asserts that, '*The teachers are of the view that knowledge and understanding of aspects of GPK is essential for the successful*

implementation of IPW. However, there is a lack of evidence in its translation into effective classroom practice'

The participant teachers professed to having knowledge and beliefs about aspects such as higher-order-thinking skills, prior knowledge, planning and preparation and questioning. In the lessons observed by the researcher this aspect was not evident in the classroom. They all professed that these aspects are important for the teaching and learning of science. But it would seem that their understanding of its value in practice is not clearly grasped and therefore their knowledge of how it may be implemented in the classroom. The teachers were able to give examples of higher-order-thinking, which was associated with IPW, but they did not implement this in the lessons observed. If the teachers were well informed of how to address such aspects in their practice, lessons would have promoted learner autonomy by having unstructured and open-ended tasks.

In addition, more emphasis could have been placed on the planning and preparation of the lessons by taking into account the LOs and/or the SAs of the curriculum and also indicating questions of different levels (cognitive demands) that could be asked during the lessons to promote divergent thinking through intellectual rigour. The teachers' use of questions was very minimal and related to leading the learners towards the 'correct' answer.

The teachers' understanding of the role of determining learners' prior knowledge is a narrow one as discussed under finding KB3. They lack knowledge of the role of prior knowledge in the construction of knowledge by establishing relationships between existing knowledge and new information (Yip, 2004) as well as for the purposes of enhancing conceptual change for meaningful learning (Gunstone, 1995; Posner et al., 1982). In order to facilitate conceptual change for meaningful learning thorough planning is necessary. The teacher first needs to understand the nature of the naive conception and then plan appropriate instructional strategies. Such a practice was not evident from the lessons observed in that, the lessons did not reveal teaching and learning strategies which attempted to elicit learners' prior knowledge or preconceptions (Piburn & Sawada, 2000).

6.3.5 Inadequate pedagogical content knowledge (PCK) base

While PCK was separated for the purposes of categorisation of the various types of knowledge, its application and implementation is a very complex one within the classroom situation. Hence, having an understanding of the related knowledge types and how it facilitates the teaching and learning process results in an increase in PCK. Several scholars

have reformulated the concept of PCK, by mapping out and identifying the constituent parts. Rollnick et al., (2008) regards PCK is an amalgam of other teaching knowledge domains, which is created through their interaction and which are obsereved as 'manifestations' during the lessons. Grossman (1989), developed an extended definition of pedagogical content knowledge namely, knowledge of learners' understanding, curriculum, instructional strategies, and purposes for teaching**.** Silberstein and Tamir (1991), in their expert case study model employed a notion of three areas of teacher expertise interacting during instruction: subject matter knowledge; general pedagogical knowledge; and content-specific pedagogical knowledge. Bennett and Turner-Bisset (1993) found that it was impossible to distinguish between content knowledge and pedagogical content knowledge. According to Bennett and Turner-Bisset (1993) in the act of teaching, all knowledge was presented pedagogically in some way. Cochran et al., (1993) modified the concept of PCK and based it on a constructivist view of learning and its application to teaching. They based it on the combination of the integrated understanding of pedagogy, subject matter, learners and the environmental context.

PCK is concerned with how teachers competently reason about the subject matter through pedagogical and curricular means. In essence teaching is a learned occupation. Hence, this makes a teacher a member of a scholarly community (Deng, 2007). A teacher therefore needs to understand the structures of subject matter and the principles of inquiry.
Understanding the interconnectedness of the facts, ideas, theories, and the processes for teaching makes PCK dynamic since, the teacher needs to relate this to the abilities and interests of the learners for meaningful learning to result. Cochran et al., (1993) emphasise the interrelated nature of these components and the dynamic nature of 'pedagogical content knowing'. Furthermore, the teacher needs to have knowledge and understanding of his/her own role, abilities, interests, confidence, experience and potential to change.
Therefore, the discussion in this section is based on findings KB4 (knowledge and beliefs about PCK), KB5 (knowledge and beliefs about learners), and KB6 (knowledge and beliefs about self). The results of this study point towards deficiencies in the knowledge of skills and knowledge of inquiry in the teaching of IPW in the Life Sciences at the Grade 12 level which has been discussed in section 6.3.3.

While the teachers indicated that their role is that of facilitating learners' thinking rather than transmitting content knowledge only, their practice did not reveal this reformation. In

addition, the lessons did not show any nature of differentiation, for example, to accommodate learners of varying abilities. The lessons of each of the participant teacher were uniform in nature. Also, the lack of appropriate questioning by the teacher as well as the lack of opportunities created for learners' questions made the activities closed-ended.

The fact that the activities followed a structured, 'cookbook' format which is indicative of the traditional approach and what the teachers are experienced with, shows that they probably did not engage in reflective practice. That is, they did not monitor their practice and therefore did not make adjustments to it. Meredith (1995) suggested a constructivist model of pedagogical content knowledge, which highlights teacher reflection. Teachers ought to learn from monitoring and adjustment of good practice, from understanding their learners, schools, curriculum, themselves and instructional methods (Bransford et al., 2000). In addition, teachers need to understand for example, their role, confidence and potential to change.
This is again alluding to either that their belief based on past experience is very resilient and preventing them from incorporating knowledge of reform in science education or it could be due to their belief that IPW requires a lot of 'extra work' and is therefore time-consuming in a crammed programme with the high-stakes examinations on the horizon. Teachers therefore believe that it is much easier to give learners a set of instructions to follow.

According to Harteis, Gruber and Hertramph, (2010) epistemological beliefs shape teacher's characteristics, and this has an influence on the learning activities. It is plausible that the teachers have understood and interpreted their classrooms by relating it to their individual beliefs based on their personal past experiences. Therefore from a socio-constructivist view, the teachers' practices are their way of making sense of the world (Billett, 2006; Rogoff, 2003).

6.4 CONCLUSION

The participant teachers in this study claim to have the knowledge, understanding and commitment to implementing IPW, but evidence shows that they do not, and they are not implementing IPW in their classrooms as per the prescripts of the curriculum. The reason for this state of affairs is their limited understanding of the various domains of teacher knowledge and their epistemologial beliefs about IPW and its implementation in the classroom.
Chapter Seven provides a summary of the main findings and discussion, recommendations and concluding remarks.

CHAPTER SEVEN

SUMMARY OF FINDINGS AND DISCUSSION, RECOMMENDATIONS AND CONCLUSION

7.1 INTRODUCTION

The successful implementation of a transformed curriculum is dependent on numerous factors. The most important of these is the understanding of the knowledge, beliefs and capabilities of the main role players, the teachers. Ignoring such characteristics of teachers could result in an erosion of the reformation process in science education. Understanding the findings of this research could have implications for other role players as well. Other role players such as, the Department of Education, Teacher Educators and Curriculum Developers, require a thorough understanding of the knowledge, beliefs, practices and capabilities of the teachers so as to provide the necessary intervention that will ensure an appropriate implementation of IPW within a transformed Life Sciences curriculum.

This chapter provides a brief overview and discussion of the main findings emanating from the study. It also makes recommendations relating to these findings. The final section provides concluding remarks with respect to the study.

7.2 OVERVIEW OF MAIN FINDINGS

This section presents a summary of the main findings of this research. These findings are presented in accordance with the main research questions and as elaborated in Chapter Six. The four participant teachers in this study claim to have the knowledge and understanding to implement IPW, but in fact they do not, because their observed practice of IPW is not in accord with the prescripts of the curriculum and hence, not in alignment with the principles of constructivism. All four participant teachers' practice of IPW is inconsistent with the requirements of the transformed Life Sciences curriculum in particular and reformation in science education in general. This however is not peculiar to these four teachers since other researchers have highlighted that many teachers lack knowledge and experiences about scientific inquiry and as such they have difficulties in practicing IPW (e.g.,Blanchard, Southerland & Granger, 2008; Lotter, Harwood & Bonner, 2007; Brown & Melear, 2006). Furthermore, the implementation of IPW takes time, and teachers have been struggling year after year to complete the curriculum within the required time. Other factors such as, examination related anxieties, accountability stresses and large class sizes further has an impact on teachers' ability to implement IPW. Moreover, two out of the four participant teachers studied their undergraduate degrees in the Faculty of Science. Open-ended

investigations are not conducted during the undergraduate years, but are only introduced at the Honours level and above. The other two participants studied at the Faculty of Education. The Science courses at the Faculty of Education provides for a very limited experience in practical investigations, about 1,5 hours per week (comment by Dr Dempster).
Nothwithstanding these 'extraneous' factors, for learners to engage in inquiry requires a teacher to have appropriate intellecual or pedagogical tools, knowledge and understanding of science, experiences with scientific inquiry, confidence and positive beliefs which are in agreement with the goals of reform-based science education (Trautmann, Makinster & Avery, 2004).

This study also found that what the participant teachers say, perceive, believe, and know about the transformed Life Sciences curriculum is consistent with the rhetoric about reformation in science education in general. In addition, the teachers' knowledge and understanding of the various categories of teacher knowledge is superficial and therefore inadequate for the application and implementation of IPW.

7.2.1 The participant teachers' practice of IPW is inconsistent with the transformed Life Sciences curriculum but is reflective of their past experiences

The curriculum required Grade 12 learners to implement IPW as open-ended activities with minimum guidance from the teacher. That is, it requires teachers to engage in reformed practices of inquiry based teaching and learning. An analysis of the Life Sciences curriculum and as summarised in Table 4.1, shows that IPW has similarities with inquiry-based teaching and learning and constructivism. Against this background the study found that the practice of IPW occurred through very structured, closed-ended, verification type of activities, which restricted the promotion of learner autonomy. That is, the general design of the activities/lessons did not promote learner independence and hence, constructivist practices.

In all the lessons observed and teacher tasks analysed, the design of the investigations were highly structured, with explicit direction given by the teachers at all stages through worksheets. Hence, the observed lessons and tasks were closed (Wellington, 1994) or as partial inquiry at level 1 / verification or level 2 / structured (Bell et al., 2005). Such lessons are regarded as traditional because it is perceived as involving the transferring of knowledge from the teacher or textbook to the learners and learning science as the acquisition or reproduction of knowledge from credible sources (Howard, McGee, Schwartz and Purcell,

2000; Kang and Keys, 2000; Prawat, 1992). In other words, these lessons were designed to be teacher-centred. Traditionally, practical work in science education involves learners following a highly structured, step-by-step approach, where teachers dominate and control the learning process, while learners play a passive role (Zion & Sadeh, 2007; Bell, Smetana & Binns, 2005; Wellington, 1994).

This state of affairs is reflective of similar trends in other parts of the world. Many international studies have shown that investigative work is distinctly lacking in secondary schools. For example, Haigh (2007) indicated that, whilst the curricula in New Zealand, UK and USA have always emphasised the importance of practical work during the 1980s and 1990s there had been a loss of much of these inquiry and process emphasises and by the end of the 20th century practical work in senior biology classrooms had, largely become a recipe-following practical exercise.

In another study in the US in the year 2000, Smith, Banilower, McMahon and Weiss (2002), found in a survey that, only 12% of teachers asked learners to design or implement their own investigations. The study found that science investigations continue to be done in a 'cookbook' style to verify or confirm information in textbooks (Trumbull et al., 2006 p.1718; Tsai, 2003). Such traditional lessons involve the teacher explaining the processes to be followed before conducting the practical activity. Within the context of this study the teachers provided the learners with worksheets and the relevant equipment and materials as well as explanations about the activity before the learners continued executing their tasks. At the end the teachers provided the expected results without considering the learners' observations and understandings (Peers, Diezman & Watters, 2003; Tsai, 2003; Hofstein & Lunetta, 2004; Windschitl, 2002).

The only purpose of such practical activities seems to be to assist learners in memorising the scientific truths (Tsai, 2003). As such, the learners rigorously follow the tasks which are presented in a form of a worksheet or as listed in a text book like a 'cookbook' (Hofstein & Lunetta, 2004). The prior knowledge of the learners is not taken into account and therefore has little or no relevance to such learning environments (Windschitl, 2002). Helping learners to identify their naive conceptions and helping them to construct knowledge and create new understandings for them is of no consequence (Roehrig & Luft, 2004).

As illustrated in Table 4.1, IPW has commonalities with constructivism. The observed lessons however, lacked many of the essential features of constructivism. Lessons were designed in

ways that did not allow for the active engagement by and with learners. Social interactions among the learners were lacking and therefore did not allow for learners to engage as members of a learning community. This also resulted in a lack of opportunities for the learners to reflect on their thinking and on their actions. Appropriate questioning by the teachers to identify and rectify any alternative or naive conceptions held by the learners was also lacking. Instead, the role of the teachers or their activities and the nature of the questions that they posed was limited to leading the learners towards the 'correct' text book answers and hence, it did not foster intellectual rigour and divergent modes of thinking. The nature of the questions posed by the teachers was closed-ended. In other words there was a lack of deep probing inquiry questions (Feyzioglu, 2012).

Since the observed lessons and activities were highly structured and rigid, it lacked evidence of rigorous debate and discussion and the generation of a variety of ideas and critique of these. There was no attempt at soliciting alternative modes of investigation. Furthermore, the teachers did not encourage the learners to pose questions nor did the teachers encourage their learners to engage in small group discussions. The only group work that was observed was when in three out of the four teachers' lessons, the learners discussed the questions given in the worksheets. That is, as an end result of the investigation.

Such a teaching and learning strategy where the teacher provides detailed guidance enables the teacher to manage his classroom easily (Bryan, 2003; Roehrig & Luft, 2004), at the expense of learner co-operation, and open-endedness of investigation activities (Tsai, 2003). Such a classroom management was evident for the lessons observed in this study. The teachers' lack of confidence is due to the lack of thorough planning and preparation. This lack of planning and preparation is due to their limited or inadequate knowledge about GPK, SMK and especially understanding of procedural knowledge. This therefore, prevented the teachers from entering an 'untested terrain' or 'disorderly' classroom environment to implement IPW in accordance with the curriculum requirements, and according to the principles of constructivism.

Moreover, the lessons being traditional promoted 'conformist thinking' amongst the learners. This 'conformist thinking' was promoted by the teachers by limiting the learners follow instructions, make observations and fill-in worksheets which have predetermined solutions to problems. The design of the activities allowed learners to pursue the tasks in a way that a

traditional practical lesson would have been conducted, that is, by being rigidly set down by the teacher or the text book – without room for divergent thinking. Hence, the design of the lessons did not allow opportunities for learners to seek alternative investigative methods, generation of ideas or conjectures and/or hypotheses, predictions, estimations and a variety of ways of recording results. Further, the lessons did not provide for the active engagement with the design, for example, by questioning the teacher in critiquing of the experimental designs. This in turn, therefore did not allow the focus and direction of the lesson to be determined by the learners.

A comparison of all the lessons observed revealed that only a small proportion, between 25% and 35% of the investigative skills, which were identified in the curricula documents (DoE, 2002b, 2003b; 2005b; DBE, 2011b) and as indicated in Table 2.4 were addessed. This further supports the finding that teachers' knowledge and understanding of science processes or procedural knowledge and/or its application is limited and inadequate for the successful implementation of IPW. This also alludes to the lack of constructivists principles being applied within these lessons.

According to Posner et al., (1982) one's conceptual ecology consists of one's conceptions and ideas which is rooted in one's epistemological beliefs. Such epistemological beliefs tend to greatly influence exchanges with new thoughts and concepts. Prior concepts are very resistant to change in much the same way that beliefs are. It is therefore possible that the four teacher participants in this study experience similar resistance to changing towards a reformed practice in the Life Sciences. The lack of evidence towards a change in their role in response to the curriculum reform also supports this assertion.

7.2.2 All the participant teachers possess superficial knowledge, understanding and beliefs of the various categories of teacher knowledge, which is inadequate for the successful application and implementation of IPW in the Life Sciences.

All the teacher participants believe that practical work is essential because it makes learning more meaningful, and that investigative practical work (IPW) provides learners with opportunities to acquire scientific skills. However, the teachers have a limited understanding of the differences between the two types of practical activities prescribed in the Life Sciences curriculum namely, 'hands-on' and 'hypothesis testing'. The 'hypothesis testing' type of activity resembles open-ended investigations and is therefore referred to as IPW within this

study. In addition, the teachers lacked a thorough understanding of the LOs, ASs, and the SAs of the post-2006 Life Sciences curriculum. The LOs, ASs, and the SAs are the aims and objectives of the Life Sciences curriculum. As such they ought to be used as a compass during the planning, preparation and execution of a lesson and hence, the Life Sciences curriculum. The design of the lessons observed as well as the tasks analysed revealed very structured activities as discussed in section 7.2.1. This is as a result of the teachers' poor understanding of learning outcomes, assessment standards and specific aims of the Life Sciences curriculum.

The teachers were of the belief that practical work is important in Life Sciences education and that IPW is particularly important because it allows for meaningful learning to take place. The teachers' rhetoric of 'the construction of meaningful knowledge' is consistent with the curriculum as well as with the constructivist approach to teaching and learning. In fact, the construction of knowledge is one of the 'essential features' of constructivism as discussed in Chapter Four. Moreover, Justice et al., (2007) and Kahn and O'Rourke (2004), regard the process of constructing knowledge and new understandings as one of the core ingredients of an inquiry-based learning approach.

The teachers also alluded to interest and co-operation as attributes that may be developed by doing practical work. This is also consistent with the prescripts of the curriculum as well as with findings by other researchers. For example, Ramnarain (2010) reported on teacher and learner perceptions about investigations carried out by learners on their own. These teachers and learners perceive such investigations to facilitate the understanding of science concepts and stimulation of interest in the subject. Duggan and Gott (2002) and Haigh (2003) also assert that autonomous investigations by learners improve their learning capabilities. Similar findings were reported by DeBoer (2002) and NRC (2005).

While this study has shown consistency with previous studies in so far as teacher perceptions or beliefs or what they say (rhetoric) is concerned, the teachers' practice is however, inconsistent with such perceptions, beliefs or rhetoric. Possible reasons for such a state will be discussed in the next section.

Subject matter knowledge (SMK) within the context of this study included content/conceptual knowledge and procedural knowledge or knowledge of inquiry. All the teacher participants are of the opinion that possession of good understanding of conceptual knowledge is

important for conveying content to learners. In this regard, the study revealed that the participant teachers do have satisfactory knowledge of the content for the lessons observed. They were adept at transmitting this content knowledge as factual information to the learners but they found it challenging to help learners construct such knowledge for conceptual understanding. This was due to the lessons taking on a teacher-centred approach and the teachers lacking confidence in engaging in a learmer-centred approach. Studies in education report that there are differences between teacher-centred and learner-centred orientations to teaching and learning (e.g. Laksov, Nikkola & Lonka, 2008). Teacher-centred orientations focus on the didactic skills of the teacher, while learner-centred orientations to teaching takes into account how learners learn and are therefore oriented towards facilitating meaning-making, instead of the transmission of knowledge. There is substantial evidence that learner-centred orientations promote meaningful learning in learners (e.g., Laksov, Nikkola & Lonka, 2008).

Some studies have highlighted the importance of beliefs as an indicator of teachers' actions during classroom practice. Some of these studies were more specific in showing that teachers' SMK and their personal beliefs about the teaching and learning of investigations influence their teaching practice (e.g., Saad & BouJaoude, 2012; Woolfolk Hoy, Davis, & Pape, 2006; Lin & Chen, 2002; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001; van Driel, Beijaard, & Verloop, 2001; Hogan, 2000; Thomas, Pederson, & Finson, 2000; Nespor & Barylske, 1999; Richardson, 1996; McDonald, 1993; Carlsen, 1993; Pajares, 1992; Lederman, 1992; Nespor 1987). Engaging in constructivist practices is one way in which learner-centred orientations may be promoted.

All the participant teachers believe that knowledge and understanding of the processes of science or knowledge of inquiry is important to ensure effective teaching and learning of IPW. In addition, all the participant teachers do possess knowledge about science processes and procedures such as, 'the scientific method'. However, they were unable to apply this knowledge and understanding during the implementation of IPW. Perhaps this is due to their lack of practice in this regard. Keke (2014) repoted the lack of procedural knowledge among Life Sciences teachers that impacts greatly on the teaching of practical work in South African schools. A study by Rollnick et al., (2008) on the role of SMK in developing PCK showed that improvement in understanding SMK alone may not be sufficient for teaching but instead

SMK should be developed alongside changes in the assessment regime and enrichment of classroom conditions.

The teaching and learning of IPW at the Grade 12 level reflects a leaner-centered approach, which enhances meaningful learning. Effective teaching and learning implies that it will result in meaningful learning. Due to the teachers' limited knowledge and understanding of the relationship between IPW and constructivism they found it challenging to incorporate the principles of constructivism in their lessons.

The participant teachers also professed their belief in the importance of aspects of GPK such as, 'higher order thinking', 'prior knowledge', 'lesson planning and preparation', and 'questioning' for the successful implementation of IPW. They however, lacked the know-how in translating this into effective classroom practice. For example, when questioned about the concept of 'higher order thinking' the teachers revealed their knowledge by providing examples of the 'higher order' thinking skills such as, the application of knowledge, comprehension, analysis, synthesis, evaluation, making valid deductions, extrapolating and making predictions. They were however, unable to identify aspects of IPW which are regarded as 'higher order thinking'. The processes that are directly linked to IPW include, formulating a research question, controlling variables, making inferences and creating and justifying arguments. These processes are examples of higher order thinking skills. While these processes, as examples of critical thinking skills are regarded as 'higher order' thinking skills they may be viewed within the context of SMK. However, the teaching and learning of such skills will be regarded as GPK since GPK addresses aspects such as, knowledge about how to ask questions on 'higher order' thinking skills or about how to assess inquiry learning. Metacognitive knowledge of specific thinking skills, including generalisations about them is normally part of what constitutes GPK (Brant, 2006; Turner-Bisset, 2001). Since GPK deals with classroom organisation and management, instructional models and strategies, and classroom communication and discourse, understanding the processes involved in IPW as being 'higher order' thinking skills would help teachers prepare and act appropriately for the efficient implementation of IPW. Understanding what is meant by 'higher order' questions could help the teacher in preparing appropriate 'higher order' questions and still maintain appropriate classroom 'order'. Evidence gleaned from the observation of all the lessons showed that these processes were not promoted or addressed by the teachers. Instead this

information was given to the learners. This is most probably as a result of ensuring that order and control is maintained in the classroom by the teachers.

Furthermore, when the definition of GPK by Rollnick et al., (2008) is considered that is, "Understanding what counts as good teaching, the best teaching approaches in a given context, informed by knowledge of applicable learning theories" (p.19), it implies that there ought to be a great deal of planning and preparation for the enactment of a lesson. According to Erdamar and Alpan (2013) one of the characteristics of effective teachers is preparing for lessons. Such evidence of teacher preparation, except for the structured worksheets for the practical lessons, could not be found as part of the teachers' artefacts. Motlhabane and Dichaba (2013) also observed the reluctance of in-service teachers to prepare lesson plans for their practical activities. They suggested that this reluctance to prepare lesson plans was due to their lack of confidence in conducting practical work.

Beliefs about classroom management are a challenge experienced by teachers' that interferes with learning about 'doing' inquiry (Trumbull, Scarano, & Bonney, 2006). According to Everston and Weinstein (2006), classroom management seeks to ensure that the learning environment is orderly and conducive to enable learners to engage meaningfully in academic, social, and moral learning. Also, Marzano and Marzano (2003) argue that learner achievement and learning is dependent on the teachers' management strategies in the classroom. Classroom management strategies are based on two theories, that is, behaviourist or constructivist theories (Brannon, 2010). Behaviourist strategies for classroom management allow the teachers to have greater control and display of authority in the classroom. Hence, in the context of this study, in order to maintain and sustain an orderly classroom environment, teachers engaged in structured lessons so as to ensure that they have control of what goes on in the classroom. The constructivist approaches on the other hand allow for a reduction of control by the teachers (Yasar, 2008). It is therefore evident that the participant teachers still pursue an agenda likened to an 'authoritarian controller' of teaching rather than an 'authoritative facilitator' of learning.

Since IPW is constructivist in its application, it means that lessons will have to be designed in ways that allow for greater learner autonomy and reduced control by the teacher. Changing from a more orderly environment to one that may seem to be disorderly is dependent on the teacher's knowledge and understanding of the variety of teaching and learning knowledge, experience through practice, and confidence to do so. The teacher participants in this study

seemed to lack these attributes because their classroom practice did not allow for learner autonomy, nor learner-centeredness.

The participant teachers believe that IPW is an essential, effective and useful means of teaching and learning science yet their practice did not reveal this. The lack of or limited pedagogical content knowledge by the teachers is due to their limited understanding of the other teaching and learning knowledge domains such as, general pedagogical knowledge, subject matter knowledge, knowledge of the curriculum, pedagogical context knowledge and knowledge of self. According to Rollnick et al., (2008) PCK is an amalgam of other knowledge domains which is created through their interaction and which are obsereved as 'manifestations' during the lessons. When such a model is applied to this study the 'manifestations' observed, reveal a lack of application of other knowledge domains as described in KB1 to KB6 in Chapter Six as well as in this section.

It is necessary for teachers to engage in continual monitoring, reflection and adjustment of practice for effective teaching. While the teachers viewed this to be an important aspect of teaching and learning in general and IPW in particular, they displayed inadequate knowledge and importance about reflective practice. This is an indication of a lack of practice in this regard.

The participant teachers lacked a thorough understanding of how to incorporate knowledge about their classroom environment, particularly knowledge about their learners into their lesson plans and preparations (GPK and PCK) as well as into their classroom practice.
Some researchers maintain that practice-related beliefs occur through interactions between teachers' general teaching-related beliefs and the environmental context in which teaching is practiced (Bingimlas & Hanrahan, 2010). Lacorte and Canabal (2005) maintain that teachers' knowledge and beliefs about the teaching environment is a result of the interplay between the values, goals and assumptions that teachers possess about subject matter knowledge and knowledge about teaching on the one hand and their knowledge and understanding of the social and cultural milieu where teaching takes place. The present study showed that teachers paid little attention to differing contexts of learners and no evidence was found of teachers adapting activities to suit the context and abilities and interests of individual learners. Instead the lessons were designed for a 'one-size-fits-all' programme. Clearly this is an indication that

the teachers do not consider their learners as constructive beings capable of constructing their knowledge and understanding.

According to Bass, Contant and Carin (2009) if teachers perceive science as inquiry, and their learners as constructivist learners, they will therefore want to teach in a manner in which learners can actively construct their ideas and explanations to improve their inquiry abilities. According to Wallace and Kang, (2004) and Wellington, (2000) teachers' beliefs about learners, learning, the nature of science and science education, epistemology, curriculum, expectations of learners and parents and the role of the teacher affect the way that science is taught.

The participant teachers' practice of IPW is reflective of their own experiences as high school learners, tertiary students and as they practiced it during the implementation of the pre-2006 Biology curriculum. Practical investigations during this period predominantly involved learners following a set of systematic instructions in a 'cookbook' fashion and/or filling in worksheets for closed ended type of activities. While the pre-2006 curriculum made provision for IPW, it however, did not prescribe it as a requirement for assessment nor did it indicate how it ought to be implemented in the classroom. Hence, the provision of step-by-step instructions to carry out investigations as evident in the observed lessons and the teacher prepared tasks. It is possible that the teachers' past experiences have now become entrenched and deep seated as part of their resilient belief system. Other studies have also reported similar findings (e.g., Haigh, 2007; Smith et al., 2002; Trumbull et al., 2006).

The findings with respect to the nature of teachers' knowledge and beliefs reveal evidence for a significant shortcoming among the teacher participants in this regard. Lack of confidence in their ability, as a result of knowledge deficiency, deeply rooted epistemological beliefs and lack of experience or practice in IPW as high school learners, tertiary students and teachers are reasons for such a shortcoming. Harwood, Hansen, and Lotter (2006) supports this assertion by stating that, this belief and confidence is formed through observations teachers make and the practices they perform over a long period beginning during their undergraduate years. A recent study in South Africa by Keke (2014) also showed that the need for teachers wanting to improve their personal competence was more distinct than their content needs. Similar findings were reported by others from developing countries (e.g., Osman, Halim, & Meerah, 2006; Rakumako & Laugksch, 2010).

7.3 POSSIBLE REASONS FOR THE MANNER IN WHICH TEACHERS PRACTICED IPW IN THEIR CLASSROOMS

There could be a variety of reasons why teachers are unable or unwilling to design lessons/activities or instructions according to reforms in science education. Some of these reasons may be related to the their changing roles. Such new roles will require teachers to be facilitators of the teaching and learning process instead of being the controller of this situation. As a facilitator the teacher will have to organise the teaching environmnet, guide learners during activities and in the decision making process, encourage learners to share and discuss their ideas and help learners make links between scientific concepts and everyday life. In addition, they will have to advance activity-based, learner-centred, co-opertaive and collaborative activities. Furthermore, teachers will have to be able to manage a wide range of resources and also be able to learn and act according to the constructivist principles of teaching and learning. A brief account of the challenges alluded to above, will be discussed under sections 7.3.1 and 7.3.2 which follows.

7.3.1 The teachers' practice of IPW is reflective of their past experiences

Evidence obtained from the three (T1, T2, and T4) lessons observed as well as the three (T1, T3 and T4) teacher tasks prepared showed that the participant teachers retained their traditional view or practice of science. Three out of the four participant teachers did not have any exposure to IPW previously. They were predominantly exposed to the traditional method of doing practical work. The traditional method is highly structured with sytematic step-by-step instructions provided. This is similar to what the Life Sciences curriculum refers to as 'hands-on' type of practical work. Hence, with the knowledge and experience gained over the years as a scholar, tertiary student and as a teacher meant that the teachers became masters in performing practical work in the traditional, highly structured way. Futhermore, as illustrated in Table 2.4 and discussed in section 2.5, the pre-2006 curriculum has a great deal in common with the post-2006 curriculum. About 60% of the goals are common to both curricula. Given these facts together with the non-sustained and once-off training of teachers for the post-2006 curriculum, teachers continued to practice in the way they felt comfortable and confident. The teachers' past experiences therefore also played a significant role in deciding on the form the IPW activity took. This kowledge and experience has therefore most probably become entrenched as part of their beliefs and is therefore resistant to change. Aikenhead (2006) explained that one of the reasons why teachers retain their traditional view of science is due to their beliefs. Nespor and Barylske (1991) indicate that beliefs shape interpretations and

expectations for future events, and that beliefs can be resistant to change. Tobin (2003) maintains that the most important obstacle in implementing a reformed curriculum is teacher perception. Beliefs and perceptions are appreciated constructs which influences the designs of lessons/activities (Smith & Southerland, 2007).

According to Thompson (1992), some studies support the claim that teachers' beliefs influence classroom practices. For example, Yero (2002) argued that beliefs affect how teachers behave. She contends that if teachers are told to use a programme that is based on a solid foundation, and if such a programme is based on similar beliefs to their own, they will notice ways in which the programme works. If they believe it is not worthy, they will find evidence supporting such a belief. This assertion is supported by Tsai (2002), who maintains that the beliefs of many teachers who have traditional views of teaching science, learning science and the nature of science, may stem from the problem of their own school/college science experience. A study by Mansour (2008) found that teachers' personal religious beliefs and experiences played a significant role in shaping beliefs and practices in science education. The following studies have also shown that beliefs are important indicators of teacher action in the classroom (Woolfolk Hoy, Davis, & Pape, 2006; Tschannen-Moran, Woolfolk Hoy & Hoy, 1998; Pajares, 1992; Bandura, 1986).

7.3.2 Teachers inability to apply the different categories of teacher knowledge in the implementation of IPW

As discussed in the findings for research questions 1 and 2 in Chapter Six, while the teachers claimed to believe that knowledge of the various domains of teacher knowledge are important for the implementation of IPW, their practice revealed that they have a limited understanding of the application of these during the lessons, as well as in the solution to their tasks.

Their limited knowledge and understanding of the curriculum manifested as a highly structured activity for the 'hypothesis testing' (IPW) task. This reflects their inadequate knowledge and understanding of the processes in science inquiry or an attitude of 'taking the easy route' due to 'time constraints'.

Their limited understanding of aspects of general pedagogical knowledge (GPK) and pedagogical content knowledge (PCK) was manifested in their inability to utilise the essential features of constructivism. For instance, there was no attempt by the teachers to elicit

learners' prior knowledge, or to allow for social interactions during the lessons. Questioning by the teachers during the lessons were of the closed-ended type which led the learners to the answer that the teachers were looking for.

While the teachers claimed that not all their learners were capable of completeing IPW tasks, their practice revealed that they did not take into account the differences in the learners interests and abilities when they designed the tasks. All the learners of each teacher were subjected to the same task irrespective of their different abilities and interests. This is an indication that the teachers have a limited understanding of the importance of pedagogical context knowledge (PCxtK) in the teaching process.

Many studies have shown that learners possess naive knowledge and beliefs or views about scientific phenomena when they enter the science classroom. This naive knowledge is often different from the established scientific facts (Cinici, Sozbilir, & Demir, 2011; Alparslan, Tekkaya, & Geban, 2003; Palmer, 2003). If teachers do not approach their teaching in an appropriate manner to identify the naive knowledge then the learners will continue to possess such naive knowledge. Moreover, future learning may be hindered by this naive knowledge. Therefore conceptual change can best be achieved through learner-centred, active learning experiences based on the constructivist approach to learning (Cinici & Demir, 2013). Teaching and learning approaches based on constructivism require that teachers, not only recognise their learners' existing knowledge but also take them into account in planning and preparation for teaching so that the aim of conceptual change is fulfilled (Tsaparlis & Papaphotis, 2009).

7.4 RECOMMENDATIONS

7.4.1 Sustained professional development (PD) courses for teachers in service which should take on an integrated approach

There is an urgent need for PD courses for the teachers in order to target the following aspects:

- Understand the beliefs that they hold about practical work in general and IPW in particular with a view to changing this in the changing landscape of science education
- Understand the reasons for transformation in science education
- Developing thorough knowledge, skills and understanding of the implications and

applications of the different domains of teacher knowledge such as, curriculum knowledge and procedural knowledge.

- Improving content knowledge
- Practical applications of these knowledge domains, for example, planning and preparations of lessons and developing investigative tasks and teaching strategies.
- Assessment of IPW
- Learning to reduce the amount of teacher control in the classroom

These PD courses ought not to be a 'talk-shop' but intensive 'hands-on' application of the underlying theories. Merely learning or being told about the scientific process or about inquiry learning and the efectiveness of questioning in a lesson will not guarantee changes in a teachers' practice (Trumbull, Scarano & Bonney, 2006). It is therefore imperative that teachers are exposed to practical experiences for example, how to use appropriate questioning strategies in order to achieve divergent thinking amongst learners.

The findings of this study indicates that the teachers have strong control of the teaching situation, where they controlled the learning activities that took place in the classroom. Hence, there is a need for teachers to loosen some of this control and share the development of the IPW activities with the learners or exercise less control over the activities. The reduction or releasing of some of the control is said to be constructive in nature (Laksov, Nikkola & Lonka, 2008). Therefore, an important aspect of the PD course is to highlight the relationship among the Life Sciences curriculum, inquiry-based teaching and learning and constructivism. This may be achieved through teachers being assisted to analyse the Life Sciences curriculum policy documents, analysis of literature on inquiry-based teaching and learning and literature on constructivism. One could also use the analysis prepared for this study and as reflected in Table 4.1. This information should then be integrated into the preparation of specific practical lessons. Understanding these aspects will help build confidence in the teachers to carry out such activities as IPW.

An integrated approach implies the following as an example:

The following aspects may be discussed separately first:

- Aspects of teacher knowledge e.g. GPK and specifically strategies, for classroom management should be discussed

- Questioning strategies
- Steps of the 'scientific method'

The above are then integrated into a whole lesson – using a specific IPW example.

7.4.2 Aspects to be considered for pre-service teacher education

If teaching science through inquiry is one of the aims of transformation in science education, then it follows that one of the aims of science teacher education should be to prepare pre-service student teachers for teaching science through inquiry. As indicated in the findings of this study, three out of the four teacher participants did not have exposure to IPW during their years as tertiary students. Brown and Melear (2006) also indicated that many pre-service teachers do not apply inquiry-based instruction in their classes after their undergraduate education. The lack of inquiry-based science in schools could be the result of student teachers not being exposed to science education through the inquiry method (Tatar, 2012).

Since student teachers' beliefs about inquiry-based teaching and learning are related to their previous experiences it is imperative for such beliefs to be identified when these students begin their undergraduate studies. The undergraduate course should be structured in a way to address prior beliefs and experiences.

One of the ways in which this could be accomplished is by integrating the content course with that of the course in pedagogics. The use of inquiry-based, constructivist teaching strategies should be promoted during these sessions. However, this may tend to slow down the coverage of the curriculum. Student teachers should therefore be introduced to, and have opportunities to practice, inquiry-based learning. This must also be accompanied by support from teacher educators with respect to the use of supplementary materials, the design of student-centred activities and experiments including IPW for their future use (Elmas, Demirogen & Geban, 2011).

7.4.3 Prescription of IPW by the curriculum and assessment policies

The findings of this study showed that IPW was executed by the teachers only in response to its prescription for the purposes of CASS/SBA. The curriculum provides many opportuniies for IPW enabling development of the skills of inquiry listed in the curriculum. Learners should be given more IPW tasks than only those required for formal assessment. However, the study revealed that these informal, developmental tasks were non-existent as part of the

teacher and learner artefacts. It is therefore recommended here that more IPW be prescribed for the purposes of CASS/SBA. In addition, a question on experimental design based on an unseen topic should become compulsory in the final written Life Sciences examination. This will serve a coercive function in ensuring that teachers practice inquiry teaching and learning with their learners.

7.4.4 Provision of resources by the Department of Basic Eduaction

The successful implementation of a transformed curriculum requires a well resourced Department of Basic Education. This includes both human resources as well as physical resources. The main human resources to implement IPW are the Life Sciences teachers and the Department of Basic Eduaction officials responsible for the subject that is, the curriculum specialists. In addition to teachers being subjected to PD courses as oulined in 7.3.1 the subject specialists must also engage in these PD courses so that they will be able to provide the necessary support and guidance to the practicing teachers.

The Department of Basic Education needs to ensure that the current state of affairs with respect to the provision of laboratories and related equipment in state schools is turned around. With 83% of state schools without functional laboratories (South African Institute of Race Relations, 2012), this is a tremendous challenge for the teachers and District officials in order to implement the curriculum effectively. It is hoped that with the PD courses alternative ways of accomplishing IPW may be employed in the interim.

The Life Sciences teaching staff needs to be increased so that the challenges of insufficient time and large classes may be addressed. The teachers in this study highlighted the negative impact of insufficient time and large classes in the implementation of IPW. By decreasing the teaching load (duty) of the Life Sciences teacher and increasing the time spent for the subject will help overcome the barrier of time constraints to implement IPW. Also, reducing the class sizes will ensure that learners will be given more individual or small group attention during the IPW activities. Smaller class sizes will ensure that the assessment of learner work becomes less of a burden . It therefore, ought to ensure that learners are given appropriate feedback to improve their performance.

7.4.5 Curriculum development should be a two-way process

Studies on teacher change and curriculum transformation has recommended a bottom-up approach instead of the traditional top-down innovation model (Fincher & Tenenberg, 2007;

Van Driel et al., 2001; Richards, Gallo, & Renandya, 1999). In the traditional top-down curriculum reformation the implementers of these reform policies that is, the teachers, are generally blamed for the failure of the reform. In this respect change is viewed as the transmission of ideas from curriculum developers or researchers to district officials and then to teachers (Fincher & Tenenberg, 2007; Levy and Ben-Ari, 2007). The bottom-up or teacher-oriented approach on the other hand proposes that the role of teachers in curriculum transformation is not only the implementation of the reformed designs of others, as in the case of the South African Life Sciences curriculum, but also involvement in its development.

Currently the curriculum development process is a top-down approach. While the Department of Basic Education would like teachers and other stakeholders to believe that it is an inclusive process, it really is not. A few 'subject experts' design the curriculum and it then goes out for public comment for a relatively short period and these comments may be taken into account in revising aspects of the new curriculum before it is finalised. The majority of teachers do not see this draft.

It is quite possible also that thay may not have the necessary knowledge and skills to participate directly in this curriculum development process. However, their views are generally not captured and taken into account for the development of the curriculum.
For the future, the views and opinions of teachers should be taken into account because these views and opinion are the beliefs of the teachers. Taking their views into account could help to articulate and embellish the curriculum in ways that will ease the implementation of the curriculum.

7.5 CONCLUSION

This study set out to investigate the relationship of Life Sciences teachers' knowledge and beliefs about science education and the teaching and learning of investigative practical work (IPW). The findings of the study shows that all four participant teachers' practice of IPW is inconsistent with the requirements of the transformed Life Sciences curriculum. In addition, this study also revealed that what the participant teachers say, perceive, believe, and know about the transformed Life Sciences curriculum is consistent with the rhetoric about reformation in science education in general. Furthermore, the teachers' knowledge and understanding of the various categories of teacher knowledge is superficial and therefore inadequate for the application and implementation of IPW. For the successful implementation

of the transformed curriculum and particularly IPW, several recommendations have been provided. These recommendations involve strategies to be implemented from a micro (school) level to the macro level (National Department of Basic Education). If teachers' knowledge and beliefs are not taken into account efforts in science education reforms will have difficulty in succeeding.

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APPENDIX : A

kzn education
Department:
Education
KWAZULU-NATAL

Enquiries: Sibusiso Alwar | Tel: 033 341 8610 | Ref.:2/4/8/116

Mr. Peter Preethlall
22 Pienaar Road
Malvern
Durban
4093

Dear Mr. Preethlall

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **The Influence of Teachers' Life Sciences Knowledge and Beliefs about Teaching and Learning on the Implementation of Investigative Practical Work** , in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the intended research and interviews are to be conducted.
6. The Period of investigation is limited to the period from 01 September 2011 to 01September 2012.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please not that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Mr. Alwar at the contact numbers below.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report / dissertation / thesis must be submitted to the research office of the Department. Please address it to The Director-Resources Planning, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to the following Schools and Institutions:
    - 10.1 Umlazi Comprehensive Technical
    - 10.2 Adams College
    - 10.3 Southlands Secondary
    - 10.4 Danville Girls High School
    - 10.5 Northwood Boys High School

Nkosinathi S.P. Sishi, PhD
Head of Department: Education

...dedicated to service and performance
beyond the call of duty.

KWAZULU-NATAL DEPARTMENT OF EDUCATION
POSTAL : Private Bag X9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa
PHYSICAL: Office G 25, 188 Pietermaritz Street, Metropolitan Building, Pietermaritzburg 3201
TEL: Tel: +27 33 341 8610 | Fax: +27 33 3341 8612 | E-mail: sibusiso.alwar@kzndoe.gov.za | Web: www.kzneducation.gov.za

APPENDIX : B

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

Research Office (Govan Mbeki Centre)
Private Bag x54001
DURBAN, 4000
Tel No: +27 31 260 3587
Fax No: +27 31 260 4609
Ximbap@ukzn.ac.za

1 February 2012

Mr Prithum Preethlall (7609478)
School of Education and Develpment

Dear Mr Preethlall

PROTOCOL REFERENCE NUMBER: HSS/0034/012D
PROJECT TITLE: The influence of teacher's Life Sciences knowledge and beliefs about teaching and learning on the implementation of investigative practical work

EXPEDITED APPROVAL

I wish to inform you that your application has been granted Full Approval through an expedited review process:

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

.....

Professor Steven Collings (Chair)
Humanities & Social Sciences Research Ethics Committee

cc Supervisor Supervisor Dr Edith Dempster
cc Mrs S Naicker/Mr N Memela

APPENDIX: C

UNIVERSITY OF KWAZULU-NATAL

UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF EDUCATION AND DEVELOPMENT
DOCTOR OF PHILOSOPHY (PhD) IN EDUCATION
PhD Research

Researcher: Mr P. Preethlall (Cell. No: 0826895458)
Supervisor: Dr E.R. Dempster (Tel. No: 033-2605723)
Research Office: Ms P Ximba 031-2603587

The Principal

_____Secondary School

_____Circuit

Umlazi District

Dear Sir / Madam

Permission to conduct research

I, Prithum Preethlall am a Doctor of Philosophy (PhD) student in the School of Education and Development, in the Faculty of Education at the University of KwaZulu-Natal. My research project is entitled:

The influence of teachers' Life Sciences knowledge and beliefs about teaching and learning on the implementation of investigative practical work.

The aim of this study is to ascertain whether Investigative Practical work is being effectively implemented. This research will help gain insight and understanding into how Grade 12 teachers' subject knowledge and their beliefs about the teaching and learning of investigations, influences their teaching practice. By subject knowledge the researcher means specifically their understanding of biological concepts and the processes in science.

The study will involve gathering data through interviews, questionnaires, observation of lessons and analysis of teacher and learner artefacts. It will involve the participation of one of your Grade 12 teachers and his/her learners.

The initial interview will be conducted outside of teaching time at the convenience of the interviewee. In addition, the questionnaire will be completed in their own/free time and will be returned to me within two days. Additional interviews will be conducted only if there is a need for clarification of any aspect, prior to and immediately after the observed lessons.

A minimum of two and maximum of three practical lessons will be observed. These observations will coincide with the normal teaching programme of the teacher. In this regard, the researcher will obtain all the necessary information, such as, the time-table and work schedule from the teacher concerned early in the year.

Teacher and learner artefacts will be obtained on the day of the observations. These will be copied and returned within a day to the relevant parties.

Consent forms will be issued to the teacher as well as to the selected learners prior to the obtaining of any data.

I wish to assure you of the following:

- Participation will be voluntary;
- The institution will not be identified by name in the research results or discussion;
- No teacher or learner will be identified in the research results or discussion;
- The confidentiality and anonymity of all participants will be respected and ensured;
- A synopsis of the most important findings and recommendations will be forwarded to your school.

Please also find attached, a copy of a letter of approval to conduct research in the Kwazulu-Natal Department of Education.

I trust that my request will be favourably considered.

Thanking you.

Sincerely

Investigator's signature 26 September 2011

Permission granted / refused.

_____

Signature of Principal

APPENDIX: D

PART A: Biographical data

1. Name of teacher: _____
2. Name of School where you are employed: _____
3. Circuit in which your school is located: Indicate by placing a X in the appropriate box.

   Umbumbulu ☐ Phumelela ☐

   Durban Central ☐ Chatsworth ☐
4. Would you regard your school's location as: (choose one of the following by placing an X in the appropriate box.

   Rural ☐ Urban ☐ Township ☐
5. Total number of years teaching Biology/Life Sciences: _____
6. Is your school a State school ☐ ndependent school? ☐
7. How would you describe the provision of human resources at your school?

   Well resourced ☐ Moderately resourced ☐ Poorly resourced ☐
8. How would you describe the provision of physical resources at your school?

   Well resourced ☐ Moderately resourced ☐ Poorly resourced ☐
9. Does your school have a laboratory? Yes ☐ No ☐
10. Do your learners come to your classroom/laboratory for their daily lessons?

    Yes ☐ No ☐
11. What is the duration of each Life Sciences lesson? _____
12. Indicate the subject/s and grades taught in each of the following years:

YEAR	SUBJECT/S	GRADE/S
2006		
2007		
2008		
2009		
2010		
2011		
2012		

13. What is your position at school? Indicate with a X in the appropriate box.

13.1	PL-1 Teacher	☐	13.2	PL-1 Subject co-ordinator/head	☐
13.3	PL-2 HOD	☐			
13.4	Deputy Principal	☐			
13.5	Principal	☐			

14. Post –Matric qualifications:

14.1 Diploma/s / Certificate/s: _____

14.2 Specialisation Subject/s:_____

14.3 Degree/s: _____

14.4 Major Subjects:_____

14.5 Post Graduate Degrees: _____

14.6 Area/s of Specialisation:_____

14.7 Other : _____

15. Total number of years of study in Biology/Life Sciences:_____

PART B:

1. What is your understanding of the following concepts?

1.1 Practical work:_____

_____

_____

_____

1.2 Investigative practical work:_____

_____

_____

1.3 Learner centred activities:_____

_____

_____

1.4 Learner directed activities:_____

_____

_____

2. What you think is the value of practical work in the Life Sciences. List at least FIVE reasons.

_____

_____

_____

_____

_____

_____

3. List / describe the types/kinds of practical work that you engage your learners with.

_____

_____

_____

4. List as many skills and attributes that may be developed through practical work.

_____

_____

_____

_____

_____

5. List as many characteristics of investigative practical work:

_____

_____

_____

_____

_____

6. What is your understanding of the concept *'higher order thinking'* ?

_____

_____

_____

_____

7. List as many examples of 'higher order thinking' skills.

_____

_____

_____

_____

8. Do you believe that the skills named in 6 above can be developed during investigative practical work? Explain fully.

_____

_____

_____

_____

9. What do you understand by learner's 'prior knowledge'?

_____

_____

_____

_____

10. Do you think it is important for teachers to have an understanding of learner's prior knowledge? Why?

_____

_____

_____

_____

11. Did you attend any professional development meeting/workshop/conference where practical investigations in science was the theme/topic?_____

12. If you answered yes to the above question kindly elaborate as follows:

12.1 When did you attend (if more than one indicate all dates?_____

12.2 For each meeting/workshop/conference you participated in indicate the following:

(i) Who was the organiser?_____

_____

_____

(ii) What was the duration of each meeting/workshop/conference?_____

_____

_____

(iii) Who facilitated (not specific name)?_____

_____

_____

(iv) Did it add value to your classroom practice?_____

_____

(v) Please elaborate on (iii) above (How?)?_____

_____

_____

_____

_____

PART C:

List and elaborate on the challenges and/or constraints that you experience in implementing

'investigative ' practical work – under each of the following headings.

(If the space is not sufficient please continue on the reverse side)

(a) Your own knowledge and abilities:

_____

_____

_____

_____

_____

(b) Support from the school management team:

_____

_____

_____

_____

(c) **Support from Curriculum Specialists / Department officials:**

_____

_____

_____

_____

_____

(d) **Administration :** (e.g time-tabling, duration of each period, record keeping, etc.)

_____

_____

_____

_____

(e) **Other:** (e.g resources, etc.)

_____

_____

_____

_____

General comments:

Please feel free to include any comments, which you think has not been covered above:

Thank you

APPENDIX: E

INTERVIEW GUIDE

	Comments
1. What are your views about practical work in general and investigative practical work in particular in the Life Sciences?	
2.1 When you were in high school did you do practical work in Biology / Life Sciences	
2.2. As a school-based learner of Biology / Life Sciences did you do investigative or inquiry based practical work……	
2.3 As a school based Biology / Life Sciences learner the practical work consisted mainly of filling in worksheets while following step by step instructions	
2.4 As a college or university student did you do practical work ……	
2.5 As a college or university student the practical work consisted mainly of filling in worksheets while following step by step instructions	
2.6 As a college or university student how often were you provided with opportunities to engage with investigative practical work?	
2.7 As a teacher of Life Sciences do you provide opportunities for investigative or inquiry based practical work to your learners? Why?/Why not?	

3. Do you believe that:	
3.1. Practical work is important for the effective teaching and learning of science? Explain	
3.2. Investigative or inquiry based practical activity is essential for effective teaching and learning of Life Sciences?	
4. Do you understand the difference between 'hands-on' and 'hypothesis testing' practical activities well? Explain	
5. Since when have you been practicing investigative type of practicals with your learners? Before or only after the introduction of the NCS in 2006.	
6. Do you conduct investigative practical work with your learners only because it is a requirement for CASS? Explain	
7. Do your learners find investigative practical work useful and enjoyable compared to other activities? Explain	
8. Do you design your own investigative practical activities for your learners or do you often use what is available e.g. from texts or other colleagues? Why?	
9. Do you think that your learners are capable of successfully completing hypothesis testing / investigative tasks? How do you know this?	
10. Do you believe that investigative practical work is a useful and effective teaching and learning method? Explain.	
11. Do you believe that a teacher's understanding of learner's prior knowledge is essential for the successful implementation of investigative activities? Explain.	

12. Do you think that teachers need to have good conceptual / content knowledge and understanding about the different topics in order to guide learners when implementing investigative practical work? Why?	
13. Do you think that teachers need to have excellent knowledge and understanding of the processes that are involved in investigative practical activities? Explain	
14. Would you regard planning and detailed preparation by the teacher as being essential for the successful implementation of investigative practical activities? Explain	
15. Is questioning by the teacher during the different phases of the lesson / activity important?	
16. How important is allowing learners to ask questions during the different phases of the lesson / activity? Explain	
17. Should learners be allowed to work in pairs or in groups during investigative activities? Why?/Why not?	
18. Do you provide adequate opportunities for your learners to become acquainted with the various aspects of investigative / hypothesis testing activities? Explain.	
19. In your role as a teacher do you provide adequate help, guidance, and support to your learners for investigative work? How?	
20. Do you see your role as facilitating the development of learners' thinking and learning skills rather than emphasising the content matter only	
21. Do you think it is important for teachers to often make adjustments to their lessons based on reflection and/or monitoring of their practice and on learner's responses / behaviour? Explain	
22. Do you encourage your learners to do the following:	
(a) take risks for eg. by making use of an original method to solve a problem / investigate a phenomenon	
(b) express new, original, different and/or unusual ideas	
(c) Predict the results of experiments	
23. Do you have a good knowledge and understanding of each of the following:	
(a) Principles underlying the *NCS*	
(b) Learning outcomes (LOs) and assessment standards (ASs)for Life Sciences and Specific Aims of *CAPS*	
(c) Skills involved with practical work	
(d) Strategies for investigative activities	
(e) The scientific method for investigative work	
(f) Assessing hypothesis testing activities	
24. Do you believe that the use of investigative activities or inquiry- based learning promotes higher order thinking?	
25. Do you believe that your learners do not have the ability to conduct investigative practical work? Why?	
26. Do you prefer to give your learners tasks where they have to follow a set of instructions or method in a step-by- step manner? Why?	
27. Do you think that teachers should ensure that they have control of their lessons and their learners by giving them the method to for all their practical activities? Why? / Why not?	

APPENDIX: F1

UNIVERSITY OF KWAZULU-NATAL

UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF EDUCATION AND DEVELOPMENT
DOCTOR OF PHILOSOPHY (PhD) IN EDUCATION

PhD Research
Researcher: Mr P. Preethlall (Cell. No: 0826895458)
Supervisor: Dr E.R. Dempster (Tel. No: 033-2605723)
Research Office: Ms P Ximba 031-2603587

Dear Participant,

I, Prithum Preethlall am a Doctor of Philosophy (PhD) student in the School of Education and Development, in the Faculty of Education at the University of KwaZulu-Natal. You are invited to participate in a research project entitled:

The influence of teachers' Life Sciences knowledge and beliefs about teaching and learning on the implementation of investigative practical work.

The aim of this study is to ascertain whether the Investigative Practical work is being effectively implemented. Through your participation I hope to gain insight and understand how Grade 12 teachers' subject knowledge and their beliefs about the teaching and learning of investigations, influences their teaching practice. By subject knowledge I mean specifically their understanding of biological concepts and the processes in science.

The findings of this study lies in its potential to contribute to the literature and to educational practices related to teacher development, with special focus on investigative practical work aimed at promoting higher cognitive processes in the classroom. More specifically it will further contribute to an understanding of the impact of teacher's knowledge and their beliefs on their practice. The results will inform priorities for teacher professional development and pre-service teacher education.

Your participation in this study is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this research project. Confidentiality and anonymity of records identifying you as a participant will be maintained by the School of Education and Development at UKZN.
If you have any questions or concerns about participating in this study, please contact me, or my supervisor at the numbers listed above.

Sincerely

Investigator's signature 26 September 2011

This page is to be retained by participant

APPENDIX: F2

UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF EDUCATION AND DEVELOPMENT
DOCTOR OF PHILOSOPHY (PhD) IN EDUCATION

PhD Research Project
Researcher: Mr P. Preethlall (Cell. No: 0826895458)
Supervisor: Dr E.R. Dempster (Tel No: 033-2605723)
Research Office: Ms P Ximba (031-2603587)

CONSENT FORM 1

I_____(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project. I understand that I am at liberty to withdraw from the project at any time, should I so desire.

_____ _____
Signature of Participant Date

CONSENT FORM 2

Mr Prithum Preethlall is hereby given permission to record interviews with me as part of the process of data collection for the above research project. I understand that transcripts will be made of the interview and that extracts from these may be used in the final report. I have also been assured that my school, my learners and I will have anonymity in the report.

_____ _____
Signature of Participant Date

CONSENT FORM 3

Mr Prithum Preethlall is hereby given permission to video-record my lessons as part of the process of data collection for the above research project. I understand that transcripts will be made of the lessons and that extracts from these may be used in the final report. I have also been assured that my school, my learners and I will have anonymity in the report.

_____ _____
Signature of Participant Date
This page is to be retained by researcher

APPENDIX: G1

UNIVERSITY OF KWAZULU-NATAL

UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF EDUCATION AND DEVELOPMENT
DOCTOR OF PHILOSOPHY (PhD) IN EDUCATION

Dear Grade 12 Learner

PhD Research
Researcher: Mr P. Preethlall (Cell. No: 0826895458)
Supervisor: Dr E.R. Dempster (Tel. No: 033-2605723)
Research Office: Ms P Ximba 031-2603587

I, Prithum Preethlall am a Doctor of Philosophy (PhD) student in the School of Education and Development, in the Faculty of Education at the University of KwaZulu-Natal. You are invited to participate in a research project entitled:

The influence of teachers' Life Sciences knowledge and beliefs about teaching and learning on the implementation of investigative practical work.

The aim of this study is to ascertain whether the Investigative Practical work is being effectively implemented. Through your participation I hope to gain insight and understanding of how certain factors influences the teaching practice of investigations.

To help me in this research, I would like your permission to study some of your written work. No marks or assessment given by your teacher will be interfered with.

All the work that the researcher requires will be copied and the originals returned to you within a day.

Only the researcher will have access to the information that will be collected for this project. This information will be kept in locked storage at the university for a period of five years following the completion of the study. Neither your name, nor the names of your teacher or school will appear in any reports of this research.

Your participation in this study is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this research project.
If you have any questions or concerns about participating in this study, please contact me, or my supervisor at the numbers listed above.

If you agree to participate in this study then kindly complete the attached consent form.

Sincerely

Investigator's signature 08 November 2011

This page is to be retained by participant

APPENDIX: G2

UNIVERSITY OF KWAZULU-NATAL

UNIVERSITY OF KWAZULU-NATAL
SCHOOL OF EDUCATION AND DEVELOPMENT
DOCTOR OF PHILOSOPHY (PhD) IN EDUCATION

PhD Research Project
Researcher: Mr P. Preethlall (Cell. No: 0826895458)
Supervisor: Dr E.R. Dempster (Tel No: 033-2605723)
Research Office: Ms P Ximba (031-2603587)

CONSENT FORM 1

I_____(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project. I understand that I am at liberty to withdraw from the project at any time, should I so desire.

_____ _____

Signature of Participant Date

CONSENT FORM 2

Mr Prithum Preethlall is hereby given permission to study the necessary written work done by me as part of my Grade 12 lessons. I have been assured that I, my school and my teacher will have anonymity in the report.

_____ _____

Signature of Participant Date

This page is to be retained by researcher

APPENDIX: H

Life Sciences - Teacher Tasks

TASK 1:

Information:

Particles given off from vehicle exhausts

Particles in the atmosphere reduce visibility, and so are the most apparent form of air pollution. One can measure and compare the amounts of particles in air and the exhaust fairly easily. For example, one may find dust, ash, soot, smoke, pollen, and other substances suspended in air. Human activity produces a large percentage of these particles every year.

TASK 1.1 :

(i) Design an investigation to compare the nature of the particles in the atmosphere and that which is given off by vehicle exhausts.

(ii) Describe the problem that you investigated.

(iii) State the hypothesis that you tested in this investigation.

TASK 1.2 :

Prepare this task for your class of Life Sciences learners.

TASK 1.3 :

How would you assess your learners' efforts? Prepare the criteria /rubric / memorandum to assess this task.

TASK 2 :

Information:

How long does it take for packaging materials to degrade?

A large part of municipal wastes is dumped into landfills every year. A significant portion of this waste is in the form of packaging materials for foods, clothing, and other household items. As suitable places for waste disposal become increasingly scarce, the waste stream must be slowed down or changed. One way to do this is to be sure that packaging materials can be decomposed or recycled.

TASK 2.1:

(i) Identify a problem to be solved from the above information.
(ii) State a hypothesis related to the problem, which you have identified for investigation.
(iii) Design an investigation to test this hypothesis.

TASK 2.2:

Prepare this task for your class of Life Sciences learners.

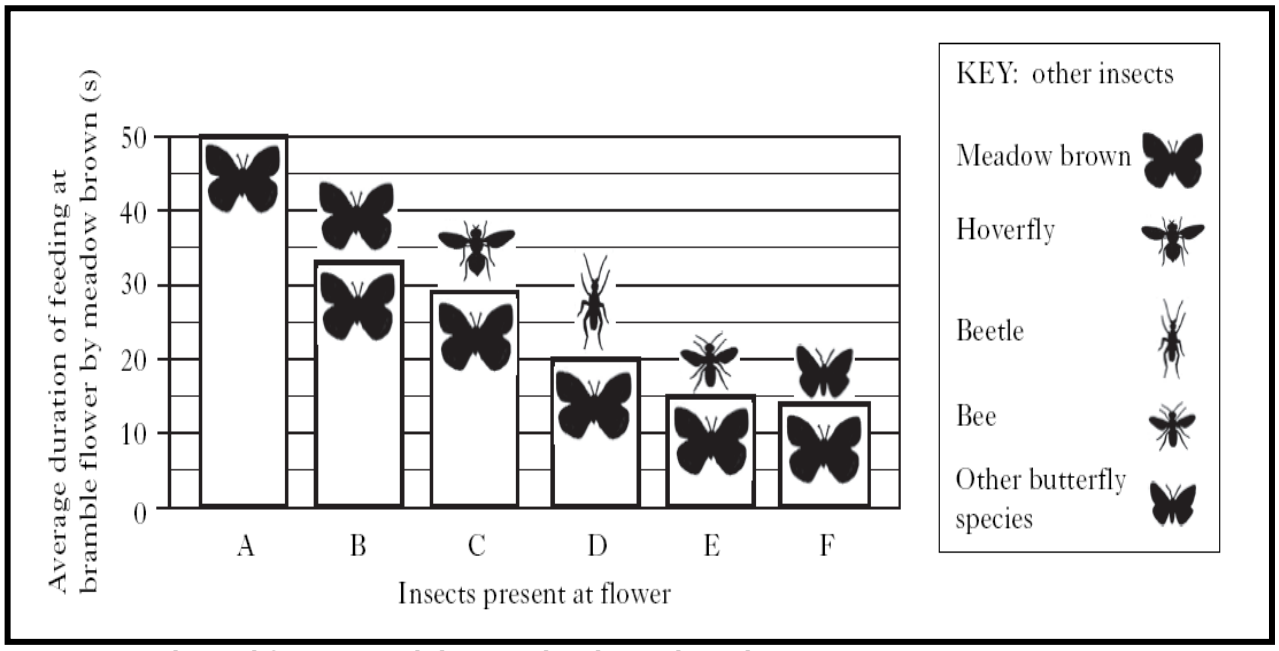
TASK 2.3:

How would you assess your learners' efforts? Prepare the criteria /rubric/ memorandum to assess this task.

TASK 3 :

Bramble plants (*Rubus fruticosus*) are pollinated by a variety of nectar-feeding insects, such as the meadow brown butterfly (*Maniola jurtina*). Bramble flowers are one of many nectar sources for this species.

A study focused on competitive interactions occurring between meadow browns and other insects at bramble flowers. The average time a meadow brown butterfly spent feeding when not disturbed by another insect is shown in the bar graph at A. The other bars show its feeding duration when another insect was also present.



Source: Adapted from Scottish Examinations, (2010)

1. Suggest a hypothesis for this investigation. (4)
2. Name the type of competition occurring at:

   2.3 B
   2.4 E (2)

3. Which bar represents the greatest intensity of competition? (2)
4. Provide an explanation for your answer to Q3. (3)
5. State **one** general conclusion that can be drawn from the above data. (4)
6. Describe **two** shortcomings of the above experimental design. (4)

Task 3.1: Moderate the above question.

Task 3.2: Provide answers to Qs 1 to 6, above.

APPENDIX: I

DATA GATHERING TOOL FOR LESSON OBSERVATION

Teacher:

Title of lesson:

_____

Description of Classroom setting:

Aspects	Descriptions / sketch / drawings
1. Space	
2. Seating arrangement	
3. Resources	
4. Learner details:	
4.1 Number	
4.2 Gender	
4.3 Discipline / behaviour / attitude	
4.4 Any other	
5. Teacher details:	
5.1 Preparedness	
5.2 Relationship with learners	
5.3 Any other	

Each of the items is to be rated as 'YES' or 'NO'. A brief description of the evidence for your judgment may be indicated in the comments column.

ASPECTS OF LESSONS	Occurrence		COMMENTS
1. GENERAL DESIGN OF LESSON	**YES**	**NO**	
1.1 The instructional strategies and activities respected learners' prior knowledge and the preconceptions inherent therein A cornerstone of reformed teaching is taking into consideration the prior knowledge that learners bring with them. The term "respected" is pivotal in this item. It suggests an attitude of curiosity on the teacher's part, an active solicitation of learner ideas, and an understanding that much of what a learner brings to the science classroom is strongly shaped and conditioned by their everyday experiences as well as what they may have learnt in previous grades.			
1.2 In this lesson, learner exploration preceded formal presentation Reformed teaching allows learners to build complex abstract knowledge from simpler, more concrete experience. This suggests that any formal presentation of content should be preceded by learner exploration.			
1.3 The lesson involved fundamental concepts of the subject The emphasis on "fundamental" concepts indicates that there were some significant scientific ideas at the heart of the lesson. That is, an understanding of a range of science concepts and science processes or investigation procedures.			
1.4 The lesson promoted strongly coherent conceptual understanding The word "coherent" is used to emphasise the strong inter-relatedness of scientific thinking. Concepts do not stand in isolation. They are increasingly more meaningful as they become integrally related to and constitutive of other concepts.			
1.5 The lesson was designed to engage learners as members of a learning community Much knowledge is socially constructed. The setting within which this occurs has been called a "learning community." The use of the term community in the phrase "the scientific community" (a "self-governing" body) is similar to the way it is intended in this item. Learners participate actively, their participation is integral to the actions of the community, and knowledge is negotiated within the community.			

ASPECTS OF LESSONS	Occurrence		COMMENTS
2. TEACHER KNOWLEDGE	**YES**	**NO**	
2.1 The teacher had a solid grasp of the subject matter content inherent in the lesson This indicates that a teacher could sense the potential significance of ideas as they occurred in the lesson, even when articulated vaguely by learners. A solid grasp would be indicated by an eagerness to pursue learner's thoughts even if seemingly unrelated at the moment.			
2.2 Connections with other content disciplines and/or real world phenomena were explored and valued Connecting scientific content across the disciplines and with real world applications tends to generalize it and make it more coherent. A physics lesson for example, on electricity might connect with the role of electricity in biological systems, or with the wiring systems of a house.			
3. TEACHER ACTIVITIES			
3.1 Intellectual rigor, constructive criticism, and the challenging of ideas were valued At the heart of scientific endeavours is rigorous debate. In a lesson, this would be achieved by allowing a variety of ideas to be presented, but insisting that challenge and negotiation also occur. Achieving intellectual rigor by following a narrow, often prescribed path of reasoning, to the exclusion of alternatives, would result in a low score on this item. Accepting a variety of proposals without accompanying evidence and argument would also result in a low score.			
3.2 The teacher's questions triggered divergent modes of thinking This item suggests that teacher questions should help to open up conceptual space rather than confining it within predetermined boundaries. In its simplest form, teacher questioning triggers divergent modes of thinking by framing problems for which there may be more than one correct answer or framing phenomena that can have more than one valid interpretation.			
3.3 Learners were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence Reformed teaching shifts the balance of responsibility for scientific thought from the teacher to the learners. A reformed teacher actively encourages this transition. For example, the teacher might encourage learners to find more than one way to solve a problem. This encouragement would be highly rated if the whole lesson was devoted to discussing and critiquing these alternate solution strategies.			

ASPECTS OF LESSONS	YES	NO	
3.4 In general the teacher was patient with learners Patience is not the same thing as tolerating unexpected or unwanted learner behaviour. Rather there is an anticipation that, when given a chance to play itself out, unanticipated behaviour can lead to rich learning opportunities.			
3.5 The teacher acted as a resource person, working to support and enhance learner investigations A reformed teacher is not there to tell learners what to do and how to do it. Much of the initiative is to come from learners, and because learners have different ideas, the teacher's support is carefully crafted to the idiosyncrasies of learner thinking. The metaphor, "guide on the side" is in accord with this item.			
3.6 The metaphor "teacher as listener" was very characteristic of this classroom This metaphor describes a teacher who is often found helping learners use what they know to construct further understanding. The teacher may indeed talk a lot, but such talk is carefully crafted around understandings reached by actively listening to what learners are saying.			
3.7 Active participation of learners was encouraged and valued This implies more than just a classroom full of active learners. It also connotes their having a voice in how that activity is to occur. Simply following directions in an active manner does not meet the intent of this item. Active participation implies agenda-setting as well as "minds-on" and "hands-on".			
4. LEARNER ACTIVITIES	**YES**	**NO**	
4.1 This lesson encouraged learners to seek and value alternative modes of investigation or of problem solving Divergent thinking is an important part of scientific reasoning. A lesson that meets this criterion would not insist on only one method of experimentation or one approach to solving a problem. A teacher who valued alternative modes of thinking would respect and actively solicit a variety of approaches, and understand that there may be more than one answer to a question.			
4.2 The focus and direction of the lesson was often determined by ideas originating with learners If learners are members of a true learning community, and if divergence of thinking is valued, then the direction that a lesson takes cannot always be predicted in advance. Thus, planning and executing a lesson may include contingencies for building upon the unexpected. A lesson that met this criterion might not end up where it appeared to be heading at the beginning.			

ASPECTS OF LESSONS	YES	NO	COMMENTS
4.3 Learners used a variety of means such as, models, drawings, graphs, etc. to represent phenomena Multiple forms of representation allow learners to use a variety of mental processes to articulate their ideas, analyse information and to critique their ideas. A "variety" implies that at least two different means were used. Variety also occurs within a given means. For example, several different kinds of graphs could be used, not just one kind.			
4.4 Learners generated predictions, estimations and/or hypotheses and devised means for testing them This item does not distinguish among predictions, hypotheses and estimations. All three terms are used so that the RTOP can be descriptive of scientific reasoning. Another word that might be used in this context is "conjectures". The idea is that learners explicitly state what they think is going to happen before collecting data.			
4.5 Learners were actively engaged in thought-provoking activity that often involved the critical assessment of procedures This item implies that learners were not only actively doing things, but that they were also actively thinking about how what they were doing could clarify the next steps in their investigation.			
4.6 Learners were reflective about their learning Active reflection is a meta-cognitive activity that facilitates learning. It is sometimes referred to as "thinking about thinking." Teachers can facilitate reflection by providing time and suggesting strategies for learners to evaluate their thoughts throughout a lesson. A review conducted by the teacher may not be reflective if it does not induce learners to *re-examine* or *re-assess* their thinking.			
4.7 Learners were involved in the communication of their ideas to others using a variety of means and media The intent of this item is to reflect the communicative richness of a lesson that encouraged learners to contribute to the discourse and to do so in more than a single mode (making presentations, brainstorming, critiquing, listening, making videos, group work, etc.).			
4.8 There was a high proportion of learner talk and a significant amount of it occurred between and among learners A lesson where a teacher does most of the talking is not reformed. This item reflects the need to increase both the amount of learner talk and of talk among learners. A "high proportion" means that at any point in time it was as likely that a learner would be talking as that the teacher would be. A "significant amount" suggests that critical portions of the lesson were developed through discussion among learners.			

ASPECTS OF LESSONS	YES	NO	COMMENTS
4.9 Learner questions and comments often determined the focus and direction of classroom discourse This item implies not only that the flow of the lesson was often influenced or shaped by learner contributions, but that once a direction was in place, learners were crucial in sustaining and enhancing the momentum.			
4.10 There was a climate of respect for what others had to say Respecting what others have to say is more than listening politely. Respect also indicates that what others had to say was actually heard and carefully considered. A reformed lesson would encourage and allow every member of the community to present their ideas and express their opinions without fear of censure or ridicule.			
5. SKILLS ADDRESSED IN THE LESSON			
5.1 Following instructions			
5.2 Handling equipment / apparatus or materials			
5.3 Making observations			
5.4 Recording information or data			
5.5 Measuring			
5.6 Interpreting information			
5.7 Drawing inferences			
5.8 Identifying a problem			
5.9 Formulating a research question			
5.10 Hypothesising			
5.11 Generating aim/s			
5.12 Selecting apparatus and/or materials			
5.13 Identifying variables			
5.14 Suggesting / selecting ways of controlling variables			
5.15 Planning an experiment			
5.16 Suggesting/planning ways of recording results			
5.17 Understanding the need for replication or verification			
5.18 Making and justifying arguments			
5.19 Identifying hidden assumptions			
5.20 Identifying reliable sources of information			