

**TEACHING PRACTICES FOR THE DEVELOPMENT
OF THE PROBLEM SOLVING SKILLS OF GR 9
NATURAL SCIENCES LEARNERS**

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DECLARATION

I, Ann Elizabeth Vicente declare that **Exploring teaching practices for the development of the problem solving skills of Gr 9 Natural Sciences learners** is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

Signature: _____

Date: _____

Vanderbijlpark

DEDICATION

This thesis is dedicated to my wonderful husband who always believes in me and who is my light and inspiration in everything I do.

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ABSTRACT

A goal of Natural Sciences education is to ensure that learners become scientifically literate. Scientific literacy refers to learners' ability to solve problems that relate to policies and practices that affect the natural world. To achieve this goal, teachers need to ensure that their learners become effective problem solvers.

This study explored the nature of teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners and makes recommendations to support teachers in this regard.

Quantitative, descriptive, survey research was conducted, by means of a structured questionnaire, with Gr 9 Natural Sciences teachers in the Sedibeng West District (D8) of Gauteng, South Africa. The findings of the study show there is a need for improving teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

Scientific Inquiry is a process known to develop the problem solving skills of learners. This process requires that learners employ critical and creative thinking as well as Science process skills as they make observations, pose questions, perform research and support the process with experimental evidence obtained from a Scientific Investigation as they search for solutions to problems.

Although teachers acknowledge that Scientific Inquiry assists in developing the problem solving skills of learners they appear to have a limited view of the implementation thereof. Instead of using Scientific Inquiry to help learners build scientific theories and models when addressing problems, teachers' appear to favour the traditional Scientific Method. This method supports the notion that "doing Science means doing experiments" and problem solving becomes reduced to a sequence of steps performed to reinforce Natural Sciences concept and content objectives.

Other problems associated with the implementation of Scientific Inquiry include limited classroom discussions surrounding Scientific Investigations as well as teachers favouring demonstrations instead of learners performing their own Scientific Investigations. Also, resources for Scientific Investigations appear to be in short supply and teachers experience difficulty in managing large class sizes during Scientific Investigations.

Gr 9 Natural Sciences teachers invest time and effort in their learners' development and show dedication to the task of imparting their Natural Sciences knowledge and skills to their learners. If such teachers were to align their teaching and assessment practices with the process of Scientific Inquiry then a high degree of success would be achieved in developing the problem solving skills of Gr 9 Natural Sciences learners!

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CHAPTER 1

ORIENTATION

1.1 INTRODUCTION AND RATIONALE

In South Africa, outcomes based education (OBE/ Curriculum 2005) was introduced in 1998. This shift in approach to education involved the design and implementation of a new curriculum. The National Curriculum Statement Grades R – 12 (NCS) was introduced and stipulated policy regarding curriculum and assessment in the schooling sector.

In November 2009 the Minister of Basic Education announced that outcomes based education (OBE) was 'dead'. The minister's remarks were based on a report received from the Task Team for the Stated Review of the Implementation of the National Curriculum Statement. The report indicated that teachers were confused, overloaded, stressed and de-motivated, and as a consequence, were underperforming (Department: Basic Education, 2011b:14).

To address the findings of the report, the National Curriculum Statement was amended. The proposed National Curriculum Statement Grades R - 12: Curriculum and Assessment Policy (July 2011) (CAPS) replaces the Revised National Curriculum Statement Grades R - 9 (2002) and the National Curriculum Statement Grades 10 - 12 (2003 & 2005) (Department: Basic Education, 2011b:5, 8,14).

Although the Revised National Curriculum Statement and the National Curriculum Statement have been replaced by the National Curriculum Statement: Curriculum and Assessment Policy, the African National Congress clarified that "...outcomes-based education as a broad framework for education and training in South Africa remains our approach and... the core values of outcomes-based education, such as encouraging critical engagement with knowledge instead of rote learning" (Hofmeyr, 2010). A key change in the curriculum is that it will no longer be framed in terms of Outcomes and Assessment Standards. Outcomes based education (OBE)

policy terminology such as: Critical and Developmental Outcomes, Learning Outcomes and Assessment Standards have been removed. These terms have been absorbed into the General Aims of the South African curriculum and the Specific Aims of each subject document (Department: Basic Education, 2011b:7,14).

Every subject in each grade now has a single, comprehensive, concise Curriculum and Assessment Policy Statement (CAPS). This Statement provides details on what teachers ought to teach and assess. Each subject has clearly delineated topics to be covered per term along with the required number and type of assessments per term (Department: Basic Education, 2011a: 61-79, 86; Department: Basic Education, 2011b:7, 14).

In Natural Sciences, an understanding of the natural world and being able to make informed decisions relating to the policies and practices that affect the natural world, are key characteristics of scientific literacy (Llewellyn, 2005:10). An important reason for teaching Natural Sciences is to develop an inquisitive mind in learners and to empower them to solve problems (Harris & Basson, 2008:6). An important goal in education in general, is to help learners think productively by combining critical and creative thinking (American Scientific Affiliation, 2008). The goal of Natural Sciences education must therefore be to teach learners to solve problems by employing critical and creative thinking skills to ensure that learners become scientifically literate.

The above stated goal of Natural Sciences implies that if learners are to gain an appreciation for Science and compete in the scientific and technically orientated society of the new millennium then they need a curriculum that promotes problem solving (Llewellyn, 2005:10).

With the implementation of outcomes based education (OBE), the Natural Sciences National Curriculum Statement detailed Critical Outcomes that envisaged learners who were:

- able to identify and solve problems and make decisions using critical and creative thinking'; and

- able to collect, analyse, organise and critically evaluate information (Department of Education, 2002:7).

Two of the General Aims of the newly amended Natural Sciences National Curriculum Statement: Curriculum and Assessment Policy (CAPS) are to produce learners who are:

- able to identify and solve problems and make decisions using critical and creative thinking; and
- able to collect analyse, organise and critically evaluate information (Department: Basic Education, 2011a:7)

As can be seen from the above, although the South African curriculum has changed, the idea of solving problems using critical and creative thinking has been acknowledged and addressed in the National Curriculum Statement, Revised National Curriculum Statement and National Curriculum Statement: Curriculum and Assessment Policy, thus highlighting the importance thereof in the education of South African Natural Sciences learners. The purpose thereof is to develop the knowledge and understanding of learners to help them acquire confidence and a measure of intellectual independence that will assist them to participate as informed and responsible citizens in society (Osborne, 2010:67; Department: Basic Education, 2011a:15).

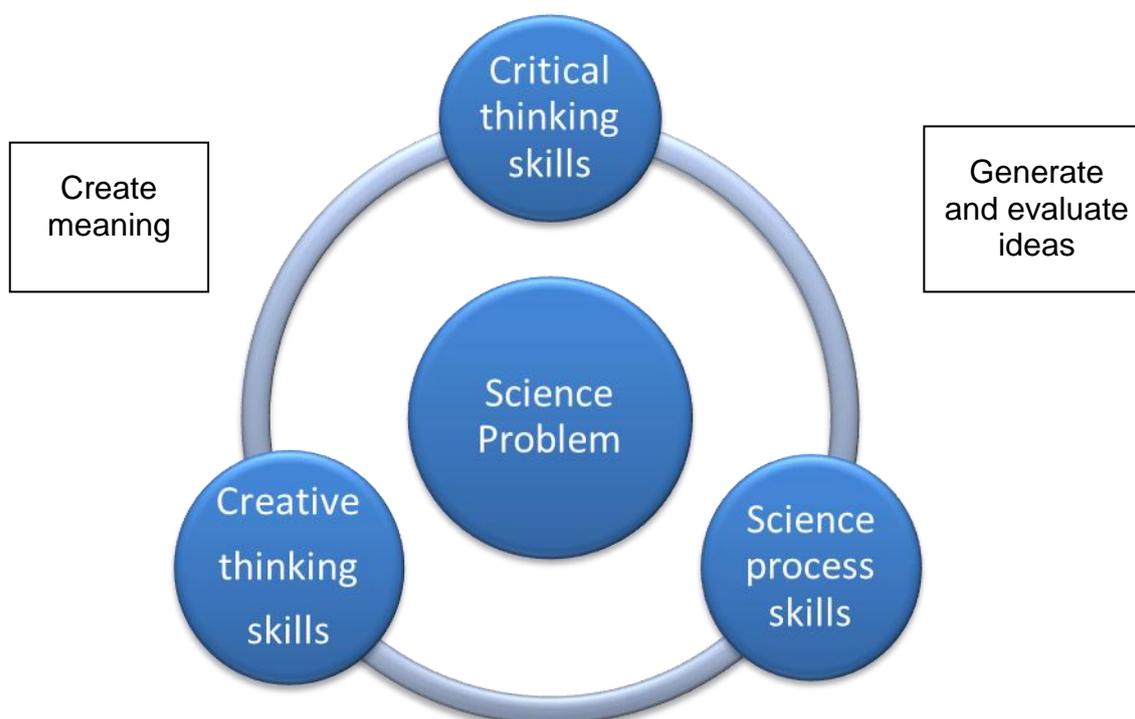
Problem solving involves the process of Scientific Inquiry which involves making observations, posing questions and researching with books and other resources to enhance what is already known. This process is supported with experimental evidence obtained from Scientific Investigations where learners use tools to gather, analyse and interpret data, and subsequently propose a solution to a problem (Chamberlain & Crane, 2009:3; Bybee, 2000:32).

Developing knowledge by means of problem solving begins with observations of the world and asking causal questions. In the case of Natural Sciences this may involve wondering why the temperature of boiling water does not rise even when you continue to heat it; or why tiles feel colder than wooden floors

(Osborne & Dillon, 2010:27). These observations and subsequent questions lead to the formulation of Science problems.

In order for a learner to solve a Science problem, they need to be able to identify the problem, use various skills to gather the necessary information required for solving the problem and then evaluate this information in order to solve the problem successfully.

Figure 1.1: Graphical presentation of approach



In the above diagram:

- A Science problem may be defined as any situation where you have an opportunity to make things better by converting an actual current situation into a desired future situation (American Scientific Affiliation, 2008)
- Critical thinking skills involve the generation and evaluation of ideas aimed at solving a problem through the employment of Science process skills (Foundation for Critical Thinking, 2009; McPeck, 1990:22). Properties of critical thinking include; focused, disciplined, logical, constrained thinking (Barak & Dori, 2009:461; Nickerson, 1999:397).

- Creative thinking skills include the generation and evaluation of creative ideas aimed at solving a problem through the employment of Science process skills (Torrance, 1994:192; American Scientific Affiliation, 2008). Properties of creative thinking include expansive, inventive, unconstrained thinking (Kousoulas & Mega, 2009:210; Nickerson, 1999:397).
- Science process skills are skills used in the process of understanding a new situation and relate to learners' cognitive activity of creating meaning and structure from new information and experiences during problem solving. Examples of Science process skills include observing, making measurements, classifying data, making inferences and formulating questions for investigation (Department: Basic Education, 2011a:15,18,19,20; Chamberlain & Crane, 2009:6).

As can be seen in Figure 1.1, these three skills are in constant interaction with one another. For the purpose of this study, the three skills will not be separated and shall hereafter collectively be referred to as problem solving skills.

The practical implications of teaching problem solving skills are that learners should be given many opportunities to identify Science problems, to apply critical and creative thinking, to make responsible decisions and to solve problems (Nahum *et al.*, 2010:1317; Jacobs *et al.*, 2002:38).

The literature reviewed by the researcher indicates that a number of studies related to problem solving skills have been conducted. Some related studies include:

- Influence of motivation, self-beliefs, and instructional practices on Science achievement of adolescents in Canada (Areepattamannil *et al.*, 2011:233-259).
- Fostering higher-order thinking in Science class: teachers' reflections (Barak & Shakhman, 2008:191-208).

- Exploring teachers' informal formative assessment practices and students' understanding in the context of Scientific Inquiry (Ruiz-Primo & Furtak, 2007:57-184).
- Matching higher-order cognitive skills (HOCS) promotion goals with problem-based laboratory practice in a freshman organic chemistry course (Zoller & Pushkin, 2007: 153-171).
- The status of secondary Science teaching and learning in Lagos state, Nigeria (Ogunmade, 2005).
- Teaching problem solving skills: a reflection on an in-service course for chemistry teachers in Singapore (Lee, 1993:136-145).
- A study of the relationship between conceptual knowledge and problem-solving proficiency (Shaibu, 1992:163-174).
- The state of Science in Australian secondary schools (Hackling *et al.*, 2001:6-17).

The aforementioned studies substantiate the idea that the choice of teaching practices influences the development of the problem solving skills of learners (Chamberlain & Crane, 2009:3; McPeck, 1990:35, 49-53).

In the field of Science, scientists engage in problem solving to learn more about how the natural world operates. Scientific Inquiry is the process through which scientists make their observations, acquire data, support their ideas, modify their beliefs, and ask new questions (Hammerman, 2006:12). When learners become involved with the process of inquiry, they answer questions that challenge their prior knowledge about themselves, the world around them, and the environment. This enables them to grow in scientific literacy and knowledge (Chamberlain & Crane, 2009:3).

Research indicates that although Curriculum Statements generally provide a framework for a Science curriculum focused on developing scientific literacy, the actual curriculum implemented in most schools differs from the intended curriculum. Frustrated high school teachers suggest their subjects are not

producing critical thinkers and that the adoption of the problem solving process in school Science is happening quite slowly (Llewellyn, 2005:99,100; Hackling *et al.*, 2001:16; Watts,1991:134; McPeck, 1990:48). In a study performed by Alazzi (2008:243,244) it was found that most teachers are not familiar with the formal definitions of critical thinking and its associated strategies. Although teachers intend to teach critical thinking, classroom observations show that teachers use little, if any, time teaching strategies that aid the learner in developing critical thinking skills. If learners are not capable of critical thinking then they will be unable to solve problems efficiently and effectively.

Gr 8 Science subject orientation introduces learners to the basic principles of Natural Sciences and familiarises them with skills they need to acquire. As the content and context of each grade shows progression from simple to complex, Gr 8 learners are eventually expected to carry out their own Scientific investigations, expand on introduced concepts and deepen their knowledge (Department: Basic Education, 2011a:6,14). Gr 9 marks the end of the General Education and Training Phase (GET) and by the end of this phase, the aim of the Natural Sciences Curriculum is to ensure that the learners are scientifically literate. This means learners have become problem solvers and should therefore be fully prepared to continue with Science in the Further Education and Training (FET) phase as well as be able to make sense of the world they are venturing into (Department: Basic Education, 2011a:12, 15).

The researcher is of the opinion that without a deliberate effort by teachers, the problem solving skills of Gr 9 Natural Sciences learners will not develop automatically. The focus of this study is to gain quantitative insight into current teaching practices aimed at the development of the problem solving skills of Gr 9 Natural Sciences learners.

This study sought to ascertain if there is a gap between what literature suggests and what teachers actually do to develop the problem solving skills of learners and to make recommendations in this regard that may assist teachers with teaching practices that stimulate the development of the problem solving skills of Gr 9 Natural Sciences learners. The study also

intends to raise awareness amongst Natural Sciences teachers of the importance of teaching learners to solve problems.

The focus of this study is centred on teaching practices for the development of the problem solving skills of Gr 9 Natural Sciences learners. 'Teaching practices' is a broad term that encompasses many 'practices' carried out during the course or teaching. Assessment is a practice critical to the teaching process as effective learning environments support learning through the use of comprehensive feedback methods (Duschl & Grandy, 2008:29). Assessment enables teachers to gather information about learner achievement and to use this information to inform learners about the quality of their work and to monitor learner progress (Department: Basic Education, 2011a:80; Chamberlain & Crane, 2009:4; Mashile, 2003: 60; Champagne *et al.*, 2000:448). Effective assessment practices need to be employed if teachers wish to develop the problem solving skills of Gr 9 Natural Sciences learners. Assessment practices will be discussed in detail in Section 2.7 and for the purpose of this study, the term teaching practices will be extended to include assessment practices.

Also, although this study refers to the subject Natural Sciences most literature consulted referred to the subject Science. The phrase Science has, for the purpose of this study, been extrapolated to the area of Natural Sciences.

1.2 PURPOSE STATEMENT

Based on the above discussion the purpose of this study was formulated as follows:

The purpose of this study was to determine teaching practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

1.3 RESEARCH QUESTIONS

1.3.1 Primary research question

The proposed study was guided by the following primary research question:

What teaching practices do Gr 9 Natural Sciences teachers employ to develop the problem solving skills of their learners?

1.3.2 Secondary research questions

- What is the nature of teaching practices used in the development of the problem solving skills of Gr 9 Natural Sciences learners?
- What is the nature of assessment practices used to evaluate the development of the problem solving skills of Gr 9 Natural Sciences learners?
- What recommendations can be made to support teachers in the development of the problem solving skills of Gr 9 Natural Sciences learners?

1.4 RESEARCH AIM AND OBJECTIVES

The aim of this study was to determine teaching practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

The above aim was operationalised into the following research objectives:

- To determine the nature of teaching practices used in the development of the problem solving skills of Gr 9 Natural Sciences learners.
- To determine the nature of assessment practices used to evaluate the development of the problem solving skills of Gr 9 Natural Sciences learners.
- To develop recommendations to support teachers in the development of the problem solving skills of Gr 9 Natural Sciences learners.

1.5 CONCEPTUAL FRAMEWORK

The researcher's views are based on the constructivist theory of learning. This age old theory was learned by Plato as he followed the teaching practice of Socrates who taught by insightful questioning. This practice helped his

learners to 'reduce to order' their own fragmentary knowledge (Hawkins, 1994:9).

The fundamental principle underlying the constructivist view of learning is that learners construct meaning from experiences. This meaning is dependent on the learners' existing knowledge (Chamberlain & Crane, 2009:8; Fensham *et al.*, 1994:5). Learners create new mental schemas (Hohenstein & Manning, 2010:72) by reflecting on prior experiences as they constantly filter incoming information based on their existing conceptions and thereby construct and reconstruct their own understanding (Llewellyn, 2005:28).

A related theory, called social constructivism, proposes that learners create their own understanding through interaction with their environment. This interaction is often guided by more knowledgeable people in their environment such as teachers (Hohenstein & Manning, 2010:73).

All learning involves the construction of meaning, whether the knowledge is discovered or received by direct transmission. Learners make sense of material based on their active interpretations of ideas they encounter in many sources, including teachers' lessons, books, television and the internet. The learning of Natural Sciences is in its own way an investigative, constructive process (Hohenstein & Manning, 2010:73; Fensham *et al.*, 1994:6; Hawkins, 1994:9).

Teaching based on a constructivist view of learning, is defined as teaching that takes into account learners' thinking. Essentially teachers first create the opportunities to enter into a meaningful dialogue with the learners and then make use of these opportunities to interact with the learners' thinking. Problem solving becomes a viable teaching method to test the 'degree of fit' between one's previously held theories and the scientific explanation of how the world actually seems to be (Llewellyn, 2005:39; Bell & Gilbert, 1996:10, 11).

Problem solving has the potential to facilitate the construction of knowledge and allows for transfer of learning from one context to another, and also encourages the transfer of responsibility for learning from the teacher to the

learner (Littledyke & Manolas, 2010:293; Llewellyn, 2005:40, 45; Watts, 1994:56).

This study will be conceptualised in terms of and based on the following concepts:

- Problem solving
- Critical thinking
- Creative thinking
- Science process skills
- Teaching and assessment practices
- Natural Sciences

1.5.1 Concept clarification

1.5.1.1 Problem solving

Problem solving may be regarded as a process involving the ability to relate conceptual knowledge to a problem in such a way that a reasonable solution is produced at the end (Nahum *et al.*, 2010:1317; Zoller & Pushkin, 2007:156; Shaibu, 1992:164). A simpler explanation includes any situation where you have an opportunity to make things better by converting the current situation into a desired future situation (American Scientific Affiliation, 2008). In Natural Sciences, problem solving would involve the relation of scientific concepts and content to the solving of a scientific problem.

The choice of teaching and assessment practices influences the development of the problem solving skills of learners. Many teachers assume that learners are automatically capable of solving a problem once they have acquired the relevant conceptual knowledge. Teaching and assessment practices are often guided by this assumption (Chamberlain & Crane, 2009:3; Shaibu, 1992:164; McPeck, 1990:35, 49-53).

In this study, the researcher determined teaching and assessment practices used to assist Gr 9 Natural Sciences learners to develop the capability of solving problems effectively.

1.5.1.2 Critical and creative thinking

Research has identified two basic patterns in learning and thinking: one in which the logical, rational mind is dominant (critical thinking) and the other in which the intuitive, creative, non-logical mind is dominant (creative thinking) (Zoller & Pushkin, 2007:157; Torrance, 1994:112).

Critical thinking may be defined as the “intellectually disciplined process of actively and skilfully conceptualising, applying, analysing, synthesising, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Foundation for Critical Thinking, 2009). Or, put very simply, thinking which has an evaluative purpose (Zoller & Pushkin, 2007:157; Jacobs *et al.*, 2002:37). Properties of critical thinking include focused, disciplined, logical constrained thinking. Thinking that is down to earth, realistic, practical, staid, dependable and conservative (Barak & Dori, 2009:461; Nickerson, 1999:397).

Creativity is a process of becoming aware of problems, deficiencies, and gaps in knowledge for which there is no learned solution. This process involves bringing together existing information, identifying missing elements, searching for solutions, making guesses and producing alternatives to solve a problem. These alternatives are then tested and retested until the perfect alternative is found (Zoller & Pushkin, 2007:156, 157; Torrance, 1994:192). The properties of creative thinking differ from those of critical thinking in that creative thinking involves expansive, inventive, unconstrained thinking associated with exploration and idea generation. It is daring, uninhibited, fanciful, imaginative, free spirited, unpredictable and revolutionary (Kousoulas & Mega, 2009:210; Kharkhurin, 2009:60; White & Frederiksen, 2000:334, 397; Nickerson, 1999:397).

Both critical and creative thinking are involved in what has been defined as problem solving (Zoller & Pushkin, 2007:156; Torrance, 1994:112). Research

shows that it is possible to promote both critical and creative thinking in learners and that the choice of teaching and assessment practices influences the promotion and development of this type of thinking (Areepattamannil *et al.*, 2011:236; Chamberlain & Crane, 2009:3; Nickerson, 1999:397; McPeck, 1990:35, 49-53).

The researcher used the widely accepted view that critical and creative thinking lead to problem solving. The researcher determined teaching and assessment practices used by teachers to assist with the development of critical and creative thinking in learners and thereby the problem solving skills of Gr 9 Natural Sciences learners.

1.5.1.3 Science process skills

The purpose of the Natural Sciences Learning Area is to promote scientific literacy in learners by developing the use of Science process skills (Department: Basic Education, 2011a:15; Department of Education, 2002:4).

Science process skills refer to the learner's cognitive activity of creating meaning and structure from new information and experiences. These skills are learning strategies that are used in the process of understanding a new situation. Science process skills are important and necessary as they enable the learner to engage in and gain intellectual control of the world through the formation of concepts (Department: Basic Education, 2011a:15, 16; Department of Education, 2002:13, 88).

Examples of process skills include: observing; comparing; measuring; recording information; sorting and classifying; interpreting information; predicting; hypothesising; raising questions about a situation; planning Scientific Investigations; conducting investigations and communicating Natural Sciences information (Department: Basic Education, 2011a:18-20; Department of Education, 2002:13).

The benefits to the teacher are that these skills may be seen as building blocks from which suitable Natural Sciences tasks may be constructed. Also, the framework of Science process skills assists teachers in designing suitable

assessment activities (Department: Basic Education, 2011a:18, 20; Department of Education, 2002:13).

The researcher will determine if current teaching and assessment practices in the Gr 9 Natural Sciences classroom incorporate the use of Science process skills and therefore contribute to the development of the problem solving skills of learners.

1.5.1.4 Teaching and assessment practices

The practical implications of teaching problem solving skills are that learners should be given many opportunities to identify problems, apply critical and creative thinking, make responsible decisions and solve problems (Nahum *et al.*, 2010:1317, 1318; Jacobs *et al.*, 2002:38). The responsibility of a Natural Sciences teacher becomes to create learning opportunities through which these skills may be developed (Harris & Basson, 2008:7).

Also, assessment is a valuable tool that assists learners to improve their critical and creative thinking skills by helping them to make judgements about their own performance (Department: Basic Education, 2011a:16, 80; Department of Education, 2002:76). Assessment therefore leads to an improvement in learners' problem solving skills.

In this study the researcher determined current teaching and assessment practices aimed at the development of the problem solving skills of Gr 9 Natural Sciences learners.

1.5.1.5 Natural Sciences

Natural Sciences involves the study of objects, phenomena, or laws of nature and the physical world (TAHD, 2009) and includes Biology, Physics, Chemistry, and Geology (CED, 2012).

In the field of Science, in order for a subject to be accepted as a Science, certain methods of inquiry need to be used. These methods include the formulation of hypotheses and the subsequent designing and carrying out of

investigations to test the hypotheses (Department: Basic Education, 2011a:11; Department of Education, 2002:4). This means learners are presented with a problem that requires the use of Science process skills in order to create meaning to the problem. Learners should then relate scientific knowledge or concepts to the situation in order to address and ultimately solve the problem. This entire process is aimed at ensuring meaningful learning in Natural Sciences.

Learners gain these skills in an environment that supports creativity, responsibility and growing confidence. They develop the ability to think objectively as they use a variety of forms of reasoning when they use Science process skills to investigate, reflect, analyse, synthesise and communicate (Department: Basic Education, 2011a:15; Department of Education, 2002:4).

The researcher determined teachers' implementation of Specific Aim 2 of the Natural Sciences Learning area. This Specific Aim relates to investigating phenomena in Natural Sciences. The aim consists of a range of skills related to doing practical work. These skills allow for learners to be able to: follow instructions; handle equipment or apparatus; make observations; record information or data and; measure interpret design or plan investigations or experiments (Department: Basic Education, 2011a:18-20).

1.6 RESEARCH METHODOLOGY

1.6.1 Research paradigm

This study followed a positivist research paradigm with a quantitative approach. Positivism stands for objectivity, measurability, predictability, controllability and constructs laws and rules of human behaviour (Creswell, 2009:7; Dash, 2005). According to Nieuwenhuis (2007:47, 53) positivists believe that researchers need to use observable, objective facts in building a Science base. These facts are then used to discover and confirm a set of probabilistic causal laws that can be used to understand human behaviour. The researcher has little if any impact on the object being observed.

In this study, the researcher's goal was to objectively obtain quantitative statistical results concerning current teaching and assessment practices to better understand how teachers develop the problem solving skills of Gr 9 Natural Sciences learners.

1.6.2 Research design

A literature study and an empirical investigation were conducted.

1.6.2.1 Literature review

Primary and secondary literature sources were examined in order to gather information about the development of the problem solving skills of learners through current teaching and assessment practices in the Gr 9 Natural Sciences classroom in South Africa and other countries. Information gathered from other countries and their success stories of best practices are valuable in providing us with guidelines for improving future teaching and assessment practices.

A variety of electronic databases (NEXUS, EBSCO-Host, ERIC and SA e-Publications), internet websites (<http://www.lch.ch>, <http://www.ei-ei.org>, <http://www.hrw.org>, <http://portal.unesco.org/education>) and internet search engines were used to obtain the relevant literature. Key words included the following: problem solving, critical thinking, creative thinking, Natural Sciences teaching; Gr 9 Natural Sciences; Science problem solving process, Scientific Method, Scientific Inquiry, Science process skills, quality teaching and learning, high-level thinking, higher order thinking skills, inductive and deductive reasoning, experimental inquiry, Scientific Investigation, assessment of Scientific Inquiry.

1.6.2.2 Empirical research

This study utilised quantitative research methods. Descriptive survey research was employed, where structured questionnaires were used to gather the necessary statistical data.

- **Strategy of inquiry**

Quantitative research

Descriptive survey research was employed as this method involves acquiring information about people's characteristics, opinions, attitudes or previous experiences by asking questions and tabulating their answers. In this way, possible correlations between characteristics of phenomena as well as attitudes, opinions and perceptions concerning specific phenomena may be determined (Leedy & Ormrod, 2010:31, 183, 187).

In this study quantitative research questions were used to determine the nature of current teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners. These practices were correlated with practices suggested in literature in order to determine if teachers in South Africa are using effective practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

Answers to quantitative research questions were provided in the form of a structured questionnaire. The choice of a structured questionnaire as the research instrument was based on the fact that it is relatively inexpensive, easy to use and teachers are able to complete the questionnaire in a short space of time with an optimal response rate (Creswell, 2009:146; Maree & Pietersen, 2007:157).

There are however certain limitations surrounding the use of the questionnaire. These limitations include that the researcher will not be able to gain a deep understanding of the participants' characteristics, opinions, attitudes or previous experiences; some participants may not be completely honest and may answer the questionnaire by marking the options given to them without actually reading or thinking about the questions (McMillan & Schumacher, 2006:211; Leedy & Ormrod, 2005:185). These limitations can contribute to the incorporation and use of unreliable information in the study. To avoid such a situation, the researcher made herself available for guidance during the completion of the questionnaire to eliminate any possible problems that occurred. The researcher also supplemented the closed-ended questions

of the questionnaire with open-ended questions so that teachers could not just hazard a guess, but had to think and reason before attempting to answer these open-ended questions. Incongruence's in information were noted by discrepancies in teachers' individual responses to the closed and open-ended questions.

The researcher wishes to highlight that as the literature review showed that the problem solving skills of learners may be developed by means of the process of Scientific Inquiry, the focus of the closed-ended questions was to find detailed evidence of the implementation of Scientific Inquiry. The assessment of the development of the problem solving skills of learners was addressed in the open-ended questions of the questionnaire. The reason for this is that if the process of Scientific Inquiry is not being implemented correctly then teachers will not be able to effectively assess the problem solving skills of learners.

Research population and sample

A research population includes individuals who possess specific attributes that represent all the measurements of interest to the researcher (Strydom, 2005:204). The population for this study comprised of Gr 9 Natural Sciences teachers in South Africa.

For the purpose of this study the method of random sampling was employed as this ensured a representative sample where each member of the population has exactly the same chance of being selected (Creswell, 2009:217; Strydom, 2005:196), this means that all teachers had an equal chance of being selected to participate in this study.

According to Creswell (2009:217) a sample size of 5 to 25 participants should be selected, all of whom have direct experience with the phenomenon being studied (Leedy & Ormrod, 2010:141).The sample for this study consisted of teachers from the Sedibeng West District (D8) of the Gauteng Department of Education. The Sedibeng West District (D8) comprises of 78 (n=78) Natural Sciences teachers. The researcher acknowledges that the sample may be less representative of the population and that the generalisability of the

findings is limited to the participants who took part in the study (McMillan & Schumacher, 2006:125). The group of participants who took part in the study were heterogeneous in terms of the characteristics of the population, namely culture, home language and gender.

1.7 DATA COLLECTION

1.7.1 Data collection instruments

1.7.1.1 Quantitative data collection instruments

Survey research involves acquiring information about people's characteristics, opinions, attitudes or previous experiences by asking questions and tabulating their responses (Leedy & Ormrod, 2005:183). Information from an in-depth literature review was used to develop a self-constructed questionnaire comprising of closed and open-ended questions. The reason for using the questionnaire was to obtain information from teachers concerning teaching and assessment practices used for the development of the problem solving skills of learners in the Grade 9 Natural Sciences classroom.

Closed-ended questions provide for a specific set of responses from respondents (Maree & Pietersen, 2007:161) and may be used to determine a specific objective. These questions are best for obtaining demographic information and data that can be easily categorised (McMillan & Schumacher, 2006:197). The questionnaire used for the purposes of this study comprised of closed-ended questions designed to obtain specific answers from the teachers. A few open-ended questions were also included to qualify and confirm teachers' responses to the closed-ended questions. The open-ended questions also provided teachers with an opportunity to define and explain the teaching and assessment practices they use for the development of the problem solving skills of learners.

A four-point Likert-scale was selected for the closed-ended questions. The scale ranged from 1 to 4, with 1 being "Almost always", 2 "Often", 3 "Sometimes" and 4 "Very seldom". The responses were summarised with percentages and frequency counts.

The researcher took into account the following advantages and limitations of using questionnaires for research purposes:

Advantages of a questionnaire:

- Questionnaires provide a relatively quick way to collect information.
- The responses are gathered objectively and anonymously. This advantage limits researcher bias and complies with ethical principles.
- Participants have time to think about their responses before answering.
- Questionnaires are easy to score.
- Questionnaires are effective in determining frequency and strength of attitude or opinion as envisaged in the research.
- Information may be collected from a large portion of a group (McMillan & Schumacher, 2006:211; Maree & Pietersen, 2007:167; Leedy & Ormrod, 2005:185; Creswell, 2009:146).

Limitations of a questionnaire:

- Questionnaires occur after the event, so participants may forget important issues.
- Participants' may misinterpret questions.
- Questionnaires limit probing and the clarification of answers.
- Participants may answer superficially if a questionnaire takes too long to complete.
- Participants may not be willing to answer the questions (McMillan & Schumacher, 2006:211; Leedy & Ormrod, 2005:185).

In this study the advantages of using a questionnaire outweighed the disadvantages.

1.7.2 Validity and reliability of a questionnaire

To effectively measure the required quantities or attributes of this study, the measurement procedures and instrument pertaining to the study are required to be deemed valid and reliable (Delpont,2005:160).

To ensure that the preliminary questionnaire was free from problems and errors it was pre-tested with a select number of teachers from the target population regarding the quality of its measurement, appropriateness and clarity (Strydom & Delpont, 2005:331). The teachers involved in the pilot study did not form part of the final sample.

1.7.2.1 Validity

The questionnaire was deemed valid in terms of face, content, construct, and criterion validity when the questions that follow, concerning face, content, construct and criterion validity, were answered positively.

Face validity

Does the questionnaire look as if it measures what it is intended to measure? Face validity is concerned with how the questionnaire appears. Does it seem like a reasonable way to gain the information the researcher attempts to obtain; does it seem well designed; and does it seem as though it will work reliably (Delpont, 2005:162; Fink, 1995)?

To ensure face validity the researcher invited the opinion of the supervisor and participants in the pilot study to ascertain whether the questionnaire 'appeared' to measure teaching and assessment practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners.

Content and construct validity

How well does the questionnaire measure what the researcher intends to measure (content validity)? What does the questionnaire mean, what does it measure and how and why does it operate the way it does (construct validity) (Delpont,2005:162)?

Content validity provides evidence about the construct validity of the questionnaire (Delport, 2005:162; Haynes *et al.*, 1995:3). A construct is an attribute, proficiency, ability, or skill that happens in the human brain (Ary *et al.*, 2006:38; Brown, 2000:2).

Content validity represents the degree to which elements of the questionnaire are relevant to and representative of a construct identified for assessment purposes (Creswell, 2009:149; Haynes *et al.*, 1995:2).

Construct validity is defined as the extent to which the questionnaire measures the construct it is supposed to measure (Bell, 2006-2011).

All constructs of the research questions are required to be included and addressed in the questionnaire. The construct for this study was ‘teaching and assessment practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners’. An in depth literature review was performed in order to provide a detailed definition of this construct. This definition ensured that all possible facets of the construct were included in the questionnaire. Scores from the questionnaire reflected whether teachers employ practices that develop the problem solving skills of Gr 9 Natural Sciences learners. The researcher also invited the opinion of the supervisor to evaluate the questionnaire, according to her technical expertise, to ensure that content and construct validities were achieved. The abovementioned factors, combined with a good research design, provided the researcher with sufficient evidence for both content and construct validities.

Criterion validity

How well does the questionnaire compare with one or more external criteria purporting to measure the same thing (Delport, 2005:162)?

To measure the criterion validity of the questionnaire, the researcher had to calibrate it against a known standard or against itself. Comparing the questionnaire with an established questionnaire is referred to as concurrent validity; testing the questionnaire over a period of time is known as predictive

validity. Using at least one of these methods may be regarded as sufficient if the research design is strong (Shuttleworth, 2009).

The researcher performed a literature survey and established that no questionnaire exists that fully meets the specific requirements of this study i.e. to test if teachers employ practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners.

1.7.2.2 Reliability

The questionnaire's measurement may be deemed reliable when there is consistency of measurement, meaning that when the same attribute is measured under the same conditions then an identical measurement will be obtained (Delpont, 2005:163).

The reliability of the questionnaire was developed by employing clearly defined, precise questions with the allocation of more than one question for each attribute measured. The questionnaires were self-administered, i.e. handed to the teachers to complete on their own. The researcher was however available for guidance, should problems be encountered. Teachers were also assured of complete anonymity at all times. Data collection procedures were applied in a standardised manner as all teachers answered the same questions. This ensured that the procedures could be replicated if needed (Fouché & Delpont, 2005:73-75).

1.8 DATA COLLECTION PROCESS

In this study quantitative data was collected by means of a self-constructed questionnaire. The phases in the collection of data were as follows:

- The necessary permission to conduct this study was obtained from the Gauteng Department of Education.
- The necessary permission was obtained from the relevant school principals.

- Teachers were approached to participate in the study. At all times, the researcher worked strictly according ethical considerations (as discussed in section 1.10 of this study) to ensure the voluntary and active participation of teachers.

1.9 DATA ANALYSIS AND INTERPRETATION

The data gathered through the questionnaires was analysed by means of statistical procedures.

1.9.1 Descriptive statistics

Information relating to teaching and assessment practices surrounding the development of the problem solving skills of Gr 9 Natural Sciences learners was gathered by using specific questions posed to teachers that remained constant throughout the entire study.

The Statistical Consultancy Services of the North West University: Vaal Triangle Campus was consulted for assistance with the capturing, analysing and interpretation of all the data collected. Descriptive statistics was used to organise and summarise the data to promote an understanding of the data characteristics (Leedy & Ormrod, 2005:257-267). Various calculations were performed, including frequencies, means and percentages. These calculations were performed to determine teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners. The results are presented in a graphical as well as a tabular format in Chapter 4 of this study.

1.9.2 Inferential statistics

Inferential statistics enable a researcher to reach conclusions that extend beyond the immediate data (Trochim, 2006). Such statistics allow a researcher to make inferences about a population from the sample that was used (Leedy & Ormrod, 2005:267). The population for this study comprised of Gr 9 Natural Sciences teachers in South Africa. As it was not possible to conduct research with all of these teachers, the selected sample may not

represent the entire population; therefore, the findings of this study are limited to the teachers who took part in the study.

1.10 ETHICAL CONSIDERATIONS

Researchers are required to respect the research participants and the sites of research. This means that the researchers need to be cognisant of their impact and therefore minimise disruption of the physical setting (Creswell, 2009:89).

Teachers who participated in this study gave their informed consent to participate which means that they were fully aware of the aim, the process and the benefits of this study (Leedy & Ormrod, 2005:101; Creswell, 2009:89). Some elements of this consent included the following:

- Application for ethical approval for this study was submitted to the North-West University according to protocol. Once approval was obtained, further permission to conduct the study was obtained from the Gauteng Department of Education as well as the relevant principals and teachers.
- Participation in this study was strictly voluntary. Recruitment took place in such a way that teachers did not feel intimidated or bribed to form part of the study.
- No activities exposed teachers to physical, emotional or psychological harm including being subjected to any undue stress or embarrassment (Leedy & Ormrod, 2005: 101).
- No teacher was forced to participate or continue participation in the study. Teachers were made aware that they may withdraw from the study at any time without discrimination and without the necessity of providing reasons.

1.11 POSSIBLE CONTRIBUTIONS OF THE STUDY

It is the intention of the researcher, upon finalising this study, to conduct feedback sessions with teachers regarding the outcomes, findings and recommendations of this study. Teachers may benefit from these sessions in

that they may become sensitised to the importance of developing of the problem solving skills of learners and in so doing, seek ways to adjust their teaching and assessment practices to realise the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

1.12 DELIMITERS OF THE STUDY

Some questionnaires were not completed in entirety even though the researcher tried to combat this by explaining each section of the questionnaire to the teachers before answering to avoid any confusion regarding the questions.

Also, certain teachers did not wish to be a part of the study and therefore did not return their questionnaires.

1.13 PRELIMINARY CHAPTER DIVISION

Chapter 1: Orientation

Chapter 2: The nature of current teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners

Chapter 3: Research design and methodology

Chapter 4: Data analysis and interpretation

Chapter 5: Summary, findings and recommendations

1.14 CONCLUSION

For the purpose of this study, the following ideas and intentions have been outlined:

- Introduction and rationale
- Purpose statement
- Research questions

- Research aim and objectives
- Conceptual framework
- Research methodology
- Data collection
- Data collection process
- Data analysis and interpretation
- Ethical considerations
- Possible contributions of the study
- Delimiters of the study
- Preliminary chapter division

Chapter 2 details the nature of current teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

CHAPTER 2

THE NATURE OF CURRENT TEACHING AND ASSESSMENT PRACTICES FOR THE DEVELOPMENT OF THE PROBLEM SOLVING SKILLS OF GR 9 NATURAL SCIENCES LEARNERS

2.1 INTRODUCTION

In a Chinese war, a learner stands in front of an army tank in order to stop its advance. The learner knows that in so doing, his life is danger. This action may be seen as a display of heroic resistance! Or put another way, a display of critical action by the learner. The action is not blind behaviour, but is informed by knowledge of the political activities of China and is based on an understanding of democracy and freedom. The display of critical action is underpinned with critical thought. The learner is literally saying: “Here I stand. This is the real me. This is what I believe.” The learner has reached this position of brave authenticity through the internal process of critical self-reflection (Barnett, 1997:1).

The above serves as an apt analogy for a learner who is capable of critical and creative thinking. The main purpose of schools is to produce such learners. Learners, who are not taken in by faulty argument, weak evidence or trendy opinions, learners who are informed and who are capable of making intelligent and rational decisions about problems they might face (Department: Basic Education, 2011a:7; Llewellyn, 2005:2; McPeck, 1990:29). In other words, the purpose of schools should be to produce learners who are able to employ critical and creative thinking and can problem solve!

An important reason for teaching Natural Sciences is to develop an inquisitive mind and to empower learners to solve problems (Harris & Basson, 2008:6). Traditional Natural Sciences education placed a high value on learners knowing answers to standard questions. Current Natural Sciences education places more value on learners being able to solve problems (Department: Basic Education, 2011a:7). The reason being is that learners will one day become citizens in society where they will face many problems. Learners will

need to be able to ask questions and seek and evaluate information that will help them answer these questions (Lempinen, 2011). Natural Sciences should provide learners with an understanding of the natural world that will serve as a basis for their personal choices and decisions (Millar, 2011:175).

Understanding the natural world and being able to make informed decisions regarding the policies and practices that affect the natural world are two characteristics of scientific literacy (Lin *et al.*, 2012:27; Llewellyn, 2005:10). Scientific literacy may be defined as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in society, and economic productivity. This type of literacy encompasses the ability to use Natural Sciences knowledge and processes to understand and to participate in decisions that affect Science in life, health, the environment and technology (McConney *et al.*, 2011:2020; OECD, 2003)

If learners are to attain a degree of scientific literacy then they will need a curriculum that promotes problem solving. Teachers, who implement such a curriculum, will play a major role in encouraging learners to use communication, manipulation and problem solving skills to guide them on their way to becoming scientifically literate learners (Nam *et al.*, 2011:1112; Llewellyn, 2005:25).

The goal of Natural Sciences teachers should thus be to help learners make sense of their world and equip them to one day become responsible citizens in society. This translates into employing teaching and assessment practices that assist learners in becoming effective problem solvers.

2.2 PROBLEM SOLVING IN NATURAL SCIENCES

Before looking at problem solving in Natural Sciences, one first needs to define Natural Sciences. In order to do this, one first needs to consider a definition for Science.

According to the Merriam Webster dictionary (MWD, 2011), Science may be defined as knowledge or a system of knowledge covering general truths or the operation of general laws especially as obtained and tested through the

Scientific Method. The average person may define Science as a body of scientific knowledge. Philosophers may regard Science as a means to obtain the truth through questioning. Scientists probably see Science as a means of exploring a hypothesis by following a set of procedures. In the classroom, the teacher may encourage learners to think of Science as problem solving, observation and description of the real world, discovery, seeking the truth, studying nature, turning facts into theories, organising knowledge, using logic, or studying the universe (Department: Basic Education, 2011a:11,12; Chamberlain & Crane, 2009:1).

While all of the above statements have a connection with Science, each one forms only a part of Science. When they are put together they begin to represent Science as a whole. Science, in the broad sense, should thus be regarded as learning about the world (Department: Basic Education, 2011a:11, 12; Chamberlain & Crane, 2009:1).

Natural Sciences may be defined as the study of objects, phenomena, or laws of nature and the physical world (TAHD, 2009) and includes Biology, Physics, Chemistry, and Geology (CED, 2011).

The South African Gr 9 Natural Sciences Curriculum encompasses this definition and consists of four 'Knowledge Strands':

- Life and Living
- Matter and Materials
- Energy and Change
- Earth and Beyond

(Department: Basic Education, 2011a:12)

The purpose of the Natural Sciences Curriculum is to develop the application and understanding of scientific knowledge relating to these knowledge strands and thereby enable learners to make sense of their world. This subject is thus

critical in promoting and developing the scientific literacy of learners (Department: Basic Education, 2011a:12, 15).

Another important aspect regarding the definition of Natural Sciences is that for a subject to be accepted as a Science, certain methods of Scientific Inquiry need to be used. Inquiry methods involve problem solving and include the formulation of hypotheses and the subsequent designing and carrying out of Scientific Investigations to test the hypotheses (Department: Basic Education, 2011a:11).

In the field of Science, scientists engage in problem solving to learn more about how the natural world operates. All scientific disciplines rely on evidence where the observation of phenomena, formulation of hypotheses, search for evidence, development of theories, and use of logic and reasoning are amongst the many methods used to identify, address and to solve a problem (Windschitl *et al.*, 2008:943; Hammerman, 2006:7, 12). This thought has been carried over into education where views of Science show a shift in curriculum position from one that asks, “What do we want learners to know and what do they need to do to know it”, to one that asks, “What do we want learners to be able to do and what do they need to know to do it” (Duschl & Grandy, 2008:5).

Historically, a lot of time in the classroom has been spent on helping learners take in new information, with little attention to helping them learn to apply this information to real-life situations (Chamberlain & Crane, 2009:9). The shift in curriculum position suggests that although learners still need to develop Natural Sciences knowledge, they also need to acquire some of the reasoning and procedural skills of scientists, as well as a clear understanding of the nature of Science as a distinct type of human endeavour (Windschitl *et al.*, 2008:943). Knowledge of Natural Sciences is therefore not enough; learners need to be able to think like scientists and apply their knowledge. It follows then that in order for learners to acquire a degree of scientific literacy they will need to become effective problem solvers.

The development of the problem solving skills of learners in Natural Sciences manifests itself in the process of Scientific Inquiry which involves making observations, posing questions and researching with books and other resources to enhance what the learner already knows. This process is supported with experimental evidence where learners use their current scientific knowledge and understanding to guide a Scientific Investigation in order to arrive at a solution to a problem (Chamberlain & Crane, 2009:3).

A Scientific Investigation involves the action of conducting a search or inquiry; a systematic examination; or research of topics pertaining to Natural Sciences (OED, 2012). This definition of a Scientific Investigation is generally realised in a procedure referred to as the Scientific Method which consists of systematic observation, measurement, experiment, and the formulation, testing, and modification of hypotheses (OED, 2012; Windschitl *et al.*, 2008:942; Llewellyn, 2005:90). Scientific Inquiry and the performing of a Scientific Investigation complement the shift in curriculum position that asks, “What do we want learners to be able to do and what do they need to know to do it”.

Furthermore, in trying to develop an understanding of problem solving in Natural Sciences, one cannot ignore the famous quote of David Ausubel: “... the most important single factor influencing learning is what the learner already knows’ (Bishop & Denley, 2007:66). This quote relates to the constructivist view of learning, where Science is seen as a personal and social exploration that promotes conceptual change (Chamberlain & Crane, 2009:2). Learners are not blank slates, but come to the Natural Sciences classroom with strongly held theories (Brewer, 2008:49). Learning builds upon knowledge from previous experiences, feelings and skills (Chamberlain & Crane, 2009:8) as learners constantly filter incoming information based on their existing conceptions in order to construct and reconstruct their own understanding (Llewellyn, 2005:28).

Constructivists thus perceive learning as a process by which the learners become ‘theory builders’. Knowledge is constantly being assimilated and accommodated in the mind through interpretations of experiences as learners test their ideas, beliefs and models through on-going observations. When

learners' observations and experiences match their presently held theories, the experiences are assimilated and the model is reinforced. When their observations and experiences do not match their presently held theories, either their experience is discounted or the model is accommodated by a conceptual change, to include the new experience (Littledyke & Manolas, 2010:293; Llewellyn, 2005:40, 45). Constructivism emphasises thinking, reasoning, and applying knowledge (Duschl *et al.*, 2007:19; Chamberlain & Crane, 2009:8).

During the process of Scientific Inquiry, learners become involved with a problem where they are required to make observations, perform research and support their ideas with evidence obtained from a Scientific Investigation. During this experience, learners are exposed to a whole lot of information that needs to be assimilated, accommodated or discounted and the process of addressing the problem allows learners to attach meaning to their experience and thereby build their understanding.

Problem solving in Natural Sciences therefore becomes a viable teaching practice to test the 'degree of fit' between what learners know and the 'scientific' explanation of how the world actually seems to be (Areepattamannil *et al.*, 2011:237; Llewellyn, 2005:39).

The practical implications of teaching problem solving in Natural Sciences by means of Scientific Inquiry are that learners be given many opportunities to solve problems. These opportunities involve the employment of problem solving skills.

2.2.1 Problem solving skills

In order for learners to solve a Science problem, they need to be able to identify the problem, use various skills to gather the necessary information required for solving the problem and then evaluate this information in order to solve the problem successfully. This may be regarded by some as 'doing Science'.

In 'doing Science', learners are seen to be inventive, systematic, use tools of Science, reason carefully and hold scientific dialogues. In being inventive, learners are creative and examine many possibilities in their work. In being systematic, learners are careful, organised and logical in planning and carrying out their work. In using tools of Science, learners use laboratory equipment, measuring instruments, diagrams, graphs, charts, calculators and computers appropriately. In reasoning carefully, learners are able to reason appropriately using scientific concepts, theories and models. In holding scientific dialogues, learners are able to use argumentation skills to conceptualise controversies and (mis)conceptions of scientific concepts (Furberg & Ludvigsen, 2008:1776; White & Frederiksen, 2000:334).

As mentioned previously, the development of the problem solving skills of learners in Natural Sciences manifests itself in the process of Scientific Inquiry. During the course of Scientific Inquiry, learners develop the ability to think objectively and to use a variety of forms of reasoning, whilst using skills to enable them to investigate, reflect, analyse, synthesise and communicate. Ultimately, these skills may be carried over for use in everyday life, the community and the future workplace (Department Basic Education, 2011: 7, 15).

The above form the foundation for basic skills learners need to employ for success in solving a Science problem. For the purpose of this study three basic skills, namely critical thinking, creative thinking and Science process skills are identified. Critical and creative thinking are two essential reasoning skills required in the process of solving a problem whereas Science process skills form a necessary part of conducting a Scientific Investigation. A discussion of each of these skills follows.

2.2.1.1 Critical and creative thinking skills

Research has identified two basic patterns in learning and thinking: one in which the logical, rational mind is dominant and which involves consideration of the implications of novel situations (critical thinking); and the other in which the intuitive, creative, non-logical mind is dominant and which involves the

recognition of novel situations (creative thinking) (Zoller & Pushkin, 2007:157; Torrance, 1994:112).

Both critical and creative thinking are involved in effective problem solving (Department: Basic Education, 2011a:7; Zoller & Pushkin, 2007:156; Torrance, 1994:112). The union between the two types of thinking and problem solving forms an 'umbrella' that encompasses thinking, knowledge and cognitive skills (Zoller & Pushkin, 2007:155, 157; Torrance, 1994:112).

According to Barak and Dori (2009:461), critical and creative thinking can be facilitated by implementing a constructivist-oriented pedagogy. Scientific Inquiry based classrooms promote the development of critical and creative thinking skills (Chamberlain & Crane, 2009:4; Barak & Shakhman, 2008:192). This means that when learners are exposed to Scientific Inquiry, their critical and creative thinking skills are developed.

Critical thinking involves the generation and evaluation of ideas once all the necessary data has been obtained through employing Science process skills (Foundation for Critical Thinking, 2009; Barak & Shakhman, 2008:192; McPeck, 1990:22). This type of thinking is often associated with attributing, comparing/ contrasting, classifying, analysing for bias, solving for analogies, and evaluating (Zoller & Pushkin, 2007:157; Foundation for critical thinking, 2009), or, put very simply, a mental process used in the analysis of information gathered by various skills. Critical thinking thus has an evaluative purpose that involves judging ideas, concepts, people etc., and forming an opinion about them (Thomas & Thorne, 2009).

Learners who employ critical thinking are able to raise questions about claims and motives, identify logical flaws in arguments, evaluate the premises from which arguments are launched, search for evidence to support claims, and explore the likely consequences of proposed actions. Such learners are also reflective in that they regularly turn their analyses and questions on their own thinking and methods (Stern & Marcella, 2008:135). Critical thinking learners can think for themselves which means they do not simply believe everything they hear or read including the views of their teacher.

Critical thinking does not come into play on every occasion where rational thought is required but only on occasions when a learner suspects something is amiss. On such occasions the learner begins to question fundamental assumptions or beliefs, and proceeds to try alternatives (Zoller & Pushkin, 2007:156; McPeck, 1990:42). This means that during the solving of a Science problem, when learners come across information that does not match their existing ideas, they will question and evaluate both the new information and their own ideas and look at alternatives such as creative thinking in order to confirm or reject new ideas in their quest to solve the problem. Creative thinking skills include the generation and evaluation of creative ideas aimed at solving a problem (American Scientific Affiliation, 2008; Torrance, 1994:192).

Creative thinking is a process of becoming aware of problems, deficiencies, and gaps in knowledge for which there is no learned solution. This process involves bringing together existing information, identifying missing elements, searching for solutions, making guesses and producing alternatives to solve a problem and then testing and retesting these alternatives until a perfect alternative is found (Zoller & Pushkin, 2007:156, 157; Torrance, 1994:192).

Properties of creative thinking include expansive, inventive, unconstrained thinking. Learners are creative when they examine many possibilities in their work. They show originality and inventiveness in thinking of problems to investigate, in coming up with hypotheses, in designing Scientific Investigations, in creating new laws, theories or models, and in applying these models to new situations (Kharkhurin, 2009:60; White & Frederiksen, 2000:334, 397).

The properties of creative thinking differ from those of critical thinking in that creative thinking involves expansive, inventive, unconstrained thinking associated with exploration and idea generation. It is daring, uninhibited, fanciful, imaginative, free spirited, unpredictable and revolutionary (Kousoulas & Mega, 2009:210; Nickerson, 1999:397). This means that during the solving of a Science problem, when learners come across information that does not match their existing ideas they will employ thinking that is novel or thinking that is 'outside the box' in order to solve the problem.

The choice of teaching and assessment practices influences the promotion and development of critical and creative thinking skills (Areepattamannil *et al.*, 2011:236; Chamberlain & Crane, 2009:3; Nickerson, 1999:397; McPeck, 1990:35, 49-53).

The researcher will use the widely accepted view (Department: Basic Education, 2011a:7; Chamberlain & Crane, 2009:4; American Scientific Affiliation, 2008; Stern & Marcella, 2008:135; Llewellyn, 2005:10; Torrance, 1994:112;) that critical and creative thinking lead to problem solving in order to emphasise the importance of developing critical and creative thinking skills within the problem solving process. The researcher will highlight the development of critical and creative thinking skills and hence the problem solving skills of learners through current teaching and assessment practices in the Gr 9 Natural Sciences classroom where the purpose of Natural Sciences is to produce learners who are able to think objectively and use a variety of forms of reasoning while they use Science process skills to investigate, reflect, synthesise and communicate (Department: Basic Education, 2011a:15).

2.2.1.2 Science process skills

Apart from using critical and creative thinking skills in the problem solving process, learners need to employ Science process skills to effectively solve a problem.

Science process skills refer to the learner's cognitive activity of creating meaning and structure from new information and experiences. These skills are used in the process of understanding a new situation when learners investigate, reflect, synthesise and communicate (Department: Basic Education, 2011a:15).

The problem solving process becomes a general means to an end and skills are an individual's contribution towards the objective. It is not always easy to separate the two in practice and thus problem solving may be used as a strategy to maximise Science process skills training (Nahum *et al.*, 2010:1316; Watts, 1991:40).

Scientists employ Science process skills as they work to gain a deeper understanding of natural phenomena. The characteristics of the knowledge produced by using Science process skills comprise of what we mean by the Nature of Science (Lederman & Stefanich *et al.*, 2006:61). The use of Science process skills helps learners become better problem solvers. Learners should be engaged in skills such as observation, classification, measurement, Mathematic calculations, making predictions, and designing Scientific Investigations (Chamberlain & Crane, 2009:5, 6). By employing the use of Science process skills, learners are able to develop both their critical and creative thinking skills and ultimately their problem solving skills.

Science process skills may be detailed as follows:

<p>Observing</p>	<p>Learners use their senses to gather information about an object or event. All Scientific Investigations begin with observations. Example: Describing a solution as yellow. Observations may be recorded in a variety of ways, such as: drawings, descriptions, counting, and grouping of materials or examples based on observable similarities and / or differences, measurements, comparing materials before and after treatment, observing results of a Scientific Investigation.</p>
<p>Inferring</p>	<p>Learners make an 'educated guess' or provide a tentative explanation about an object or event based on previously gathered data or information. Example: Saying that the person who used a pencil made a lot of mistakes because the eraser was well worn. An inference differs from a conclusion in that inferences are based on observation whereas conclusions are based on logic and reasoning.</p>
<p>Measuring</p>	<p>Learners make quantitative observations by comparing objects, events, or other phenomena to conventional or non-conventional standards. Example: Using a meter ruler to measure the length of a table in centimetres.</p>

	Measurements may include length, volume, temperature, weight or mass, numbers etc. Learners should know what to measure, how to measure and have a sense of the degree of accuracy required for measurement.
Communicating	Learners use words or graphic symbols to describe an action, object or event. Example: Describing the colour change in a Scientific Investigation in writing or by means of a graph.
Classifying	Learners group or order objects or events into categories based on properties or criteria. Example: Placing all rocks with a certain grain size or hardness into one group.
Predicting	Learners state the outcome of a future event based on a pattern of evidence. Predictions allow learners to use what they know and extend this thinking to what they do not know. Example: Predicting the height of a plant in two weeks' time based on a graph of its growth during the previous four weeks.
Controlling variables	Learners identify variables that can affect a Scientific Investigation outcome, keeping most constant while manipulating only the independent variable. The independent (manipulated) variable is the one being tested to determine its effect on the dependent (responding) variable. Example: Realising through past experiences the amount of light and water required to be controlled when testing to see how the addition of organic matter affects the growth of beans.
Defining operationally	Learners name or define objects, events, or phenomena based on their functions and/ or identified characteristics. Example: Stating that spring extension will be measured in centimetres.

<p>Formulating hypotheses</p>	<p>Learners state the expected outcome of a Scientific Investigation. These statements are tentative and testable and suggest the relationship between the independent and dependent variable. Example: The greater the amount of organic matter added to the soil, the greater the bean growth.</p>
<p>Interpreting data</p>	<p>Learners organise data and draw conclusions from data. This involves collecting, storing (through writing, drawing, audio or visual display etc.), and analysing information that has been obtained through the senses. Learners are required to convert information from one form (in which it was recorded) into, for example, an appropriate graph. Learners also perform appropriate, simple calculations, analyse and extract information from tables and graphs, apply knowledge of theory to practical situations, recognise patterns and/or trends, appreciate the limitations of Scientific Investigation procedures, and make deductions based on evidence. Example: Recording data from the Scientific Investigation on bean growth in a data table and forming a conclusion which relates trends in the data to variables.</p>
<p>Investigating/ experimenting</p>	<p>Learners design, plan or conduct a Scientific Investigation, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing a 'fair' Scientific Investigation, conducting the Scientific Investigation, and interpreting the results of the Scientific Investigation. Example: The entire process of conducting the Scientific Investigation of the effect of organic matter on the growth of bean plants.</p>

Formulating models	Learners create a mental or physical model of a process or event by using two- or three-dimensional graphic illustrations or other multisensory representations to communicate ideas or concepts. Example: A model of how the processes of evaporation and condensation interrelate in the water cycle.
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(Department: Basic Education, 2011a:19, 20; Hammerman, 2006:56, 57; Padilla, 1990).

Science process skills need to be developed. Skills such as taking measurements, using scientific equipment, analysing data, tabulating and interpreting graphs may be developed with appropriate exercises. These exercises form an integral part of a larger Scientific Investigation where learners develop the ability to think objectively and use a variety of forms of reasoning as they use Science process skills to investigate, reflect, synthesise and communicate (Department: Basic Education, 2011a:15; Woolnough, 2000:438).

Some researchers suggest that Science process skills, such as planning, hypothesising, observing, analysing, and interpreting can be taught and assessed separately, out of context, and then put together to form the whole process through which a scientist works. Other researchers argue that such processes are dependent on context. Being good at observing scientifically is not the same as being observant. According to Barak and Shakhman, (2008:193) and Woolnough (2000:438) these broad Science process skills can only be properly developed in the context of an authentic scientific activity. The researcher supports the notion that learners gain knowledge and an understanding of 'doing' Natural Sciences when Science process skills are performed in a specific context. Learners make connections between ideas and concepts and are therefore able to apply this knowledge to new and unfamiliar contexts (Department: Basic Education, 2011a:16). These skills may be developed by means of appropriate exercises but for final evaluation of authentic scientific activity they need to be assessed in an authentic

relevant context. In other words learners become better problem solvers when they use Science process skills in the correct context.

2.2.2 Can problem solving skills be taught?

When learners become involved with a Science problem they use critical and creative thinking as well as Science process skills to solve the problem. But, understanding the attributes that are relevant to a certain problem, knowing how to manipulate them, and drawing conclusions that relate back to the world is not a form of thinking that we would expect learners to spontaneously be able to do (Schauble, 2008:54).

This type of thinking is on a higher level than just memorising facts. Higher level or higher order thinking is not content based but relies on skills and understanding (Toplisa *et al.*, 2010:69). These skills are sometimes referred to as higher order thinking skills or higher order cognitive skills and are characterised by cognitive capabilities such as critical thinking, question asking, evaluative thinking, decision making, problem solving and transfer of knowledge (Nahum *et al.*, 2010:1316; Benjamin, 2008:51). Higher order thinking requires that learners understand the facts, connect them together, categorise them, manipulate them, arrange them in new or novel ways, and apply them as they look for solutions to problems (Thomas & Thorne, 2009).

Higher order thinking skills can be taught (Thomas & Thorne, 2009; Barak & Shakhman, 2008:192). To foster learners' higher-level thinking, teachers must possess in-depth Natural Sciences knowledge as well as good pedagogical knowledge on how to develop learners' higher-order thinking (Barak & Shakhman, 2008:191). Such higher order thinking cannot be realised by teaching alone and it is essential that connections be made between theory and practice, so that learners are able to apply higher order thinking during learning (Barak & Dori, 2009:461).

The choice of teaching and assessment practices therefore influences the development of higher order thinking skills and subsequently the problem solving skills of learners (Zoller & Pushkin, 2007:155; Chamberlain & Crane, 2009:3; McPeck, 1990:35, 49-53). Learners can improve their problem solving

skills in an environment that supports creativity, responsibility and growing confidence. Learners' problem solving abilities improve when teachers show faith in learners, have an encouraging attitude and are willing to spend time and effort in teaching higher order thinking skills (Oliveira, 2010a:248,264, 265;Jacobs *et al.*, 2002:26, 37).

Without a deliberate effort by teachers, the problem solving skills of Gr 9 Natural Sciences learners will not develop automatically. It becomes the responsibility of the Natural Sciences teacher to develop the problem solving skills of Gr 9 learners in order to create scientifically literate learners who are able to function in society to the very best of their ability.

This responsibility rests in presenting learners with Science problems that require them to make inferences, connect information and apply this information to new situations. A well designed Science problem focuses attention and helps learners move beyond facts to understanding and application (Chamberlain & Crane, 2009:8) and is a necessary part in effectively developing the problem solving skills of learners.

2.2.2.1 Science problems

In order to develop the problem solving skills of learners a teacher needs to expose learners to Science problems.

The process of developing new knowledge begins with observations of the world and asking causal questions, and in the case of Natural Sciences this may involve wondering why the temperature of boiling water does not rise even when you continue to heat it; or why tiles feel colder than wooden floors (Osborne & Dillon, 2010:27). These observations and subsequent questions lead to the formulation of Science problems.

A Science problem may be defined as “a question raised for Scientific Inquiry, consideration, or solution” (MWD, 2012) or an opportunity to make things better by converting a current situation into a desired future situation (Zoller & Pushkin, 2007:156; American Scientific Affiliation, 2008).

Many Science problems exist and it becomes necessary to distinguish between different types of problems as not all problems lend themselves to a meaningful Scientific Inquiry experience.

Types of Science problems

Science is part of everyday life and Science problems are all around us, for example: In an upright freezer, the freezer door is opened to take something out and then closed again. At the point of closing the door, a gentle hiss is heard and for the next three or four seconds the door is very difficult to re-open. After that point it opens quite easily. Question: What is happening in the freezer to prevent the door from opening (Watts, 1991:2)?

Or: A plastic shower curtain is held by a rail across the entrance to the shower. When a person takes a hot shower, the bottom of the curtain billows inwards and, usually, sticks to a wet leg. Question: Why does the curtain billow inwards (Watts, 1991:3)?

The type of Science problem envisaged in Scientific Inquiry should move learners to higher order thinking where learners are required to compare and contrast their ideas or results. Where teachers ask learners “what if....” or “how could we...” (Chamberlain & Crane, 2009:8). Not all Science problems move learners to higher order thinking and it therefore becomes necessary to distinguish between a Science exercise and a Science problem.

Science exercises may be categorised as questions, exam items, assignments, or tasks which require simple recall of information or a routine application of a known method, theory or knowledge to a familiar situation or context. The goal is specified and while all the steps may not be clear in the Science problem, they are usually clearly defined in the preceding pages of the textbook (Zoller & Pushkin, 2007:156; Watts, 1991:9). An example of a Science exercise would be: Find the density of the block, using the density formula and information provided.

Science problems on the other hand are intellectually and cognitively challenging ‘conceptual’ questions that may require several cycles of

interpreting, representing, planning, deciding, executing, evaluating and re-evaluating. Only general principles are suggested for solving the Science problem. Learners have to choose the best strategies from a wide range of possibilities to achieve this goal. These problems require the higher order thinking skills of reasoning, analysis, synthesis and problem solving, making of connections and critical evaluative thinking, including the application of known theory or knowledge or procedure, to unfamiliar situations (Barak & Dori, 2009:460,461; Zoller & Pushkin, 2007:156; Watts, 1991:11). An example of a Science problem would be: Determine the mass of a liquid based on the liquid's density and measured volume.

Teachers should present their learners with Science problems as opposed to Science exercises during the process of Scientific Inquiry if they wish to effectively develop the problem solving skills of their learners.

2.2.2.2 Solving Science problems

In solving Science problems, the focus is on the engagement of learners to generate and pursue answers to a problem through careful analysis, synthesis and abstraction (De Haan, 2011:1500; Llewellyn, 2005:3). If the Science problems teachers set, require learners to make choices, teachers can be assured that learners are thinking for themselves (Nahum *et al.*, 2010:1317, 1318; Watts, 1991:15).

Mental and physical activities used in solving a Science problem constitute a process involving the ability to relate conceptual knowledge to a problem in such a way that a reasonable solution is produced at the end (Zoller & Pushkin, 2007:156; Shaibu, 1992:164). This process includes the transfer of cognitive content and skills of learning from one context to another context thereby affecting the learning of new material (Department: Basic Education, 2011a:16; Nahum *et al.*, 2010:1317, 1318; Watts, 1991:133). Productive Science problems that guide learners from recitation of facts to being able to apply knowledge to new situations and then making evaluations based upon that knowledge, promotes thinking (Chamberlain & Crane, 2009:5) and therefore problem solving.

In Natural Sciences, problem solving would involve the relation of scientific concepts to the solving of a Science problem. When learners solve a problem, they identify the problem, use various skills to gather the necessary information required for solving the problem and then evaluate this information in order to solve the problem successfully. Furthermore, if the solution works or is at least partially effective, learners gain confidence to tackle further problems (Areepattamannil *et al.*, 2011:237; Watts, 1991:15). Teachers must therefore set problems that stretch the imagination of learners but at the same time lie within their sphere of ability (Department: Basic Education, 2011a:14; Watts, 1991:15).

It follows that the kind of Science problem and how the problem is presented are both critical in creating a productive learning experience. A typical example of a Science problem and the presentation thereof may proceed as follows:

“Calculate the energy consumption of different household appliances, e.g. iron, stove, TV, radio, refrigerator. Use this information to determine how long a prepaid electricity card will last in an average household” (Department: Basic Education, 2011a:73).

At the very least, learners need to identify the problem, use various skills to gather the necessary information required for solving the problem and then evaluate this information in order to solve the problem successfully. This example supports the process of Scientific Inquiry, where learners are encouraged to make observations, pose questions and use their scientific knowledge to guide a Scientific Investigation and support their ideas with experimental evidence.

Although the above Science problem provides for a limited form of true Scientific Inquiry, it is a Science problem one could expect to be solved at Gr 9 level. Progress to a more suitable level of Scientific Inquiry may be made in subsequent grades.

Scientific Inquiry may be introduced into the classroom in a variety of ways. As mentioned previously, constructivists perceive learning as a process by

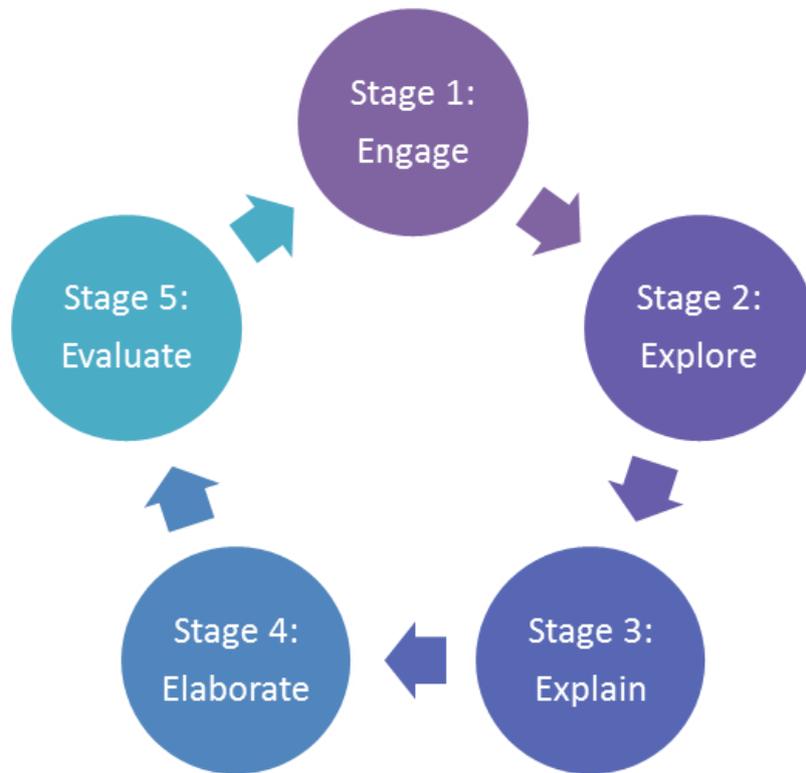
which learners become “theory builders” (Llewellyn, 2005:40). Learners are active constructors of their own understanding and they create this understanding through their experiences. Constructivist teaching models have been developed to help learners make meaningful sense of phenomena (Littledyke & Manolas, 2010:293). Examples of these models include the 5E; 7E and Generative Models (Chamberlain & Crane, 2009:10).

The 5E Model is selected for the purpose of this study as it serves as an appropriate illustration of how Scientific Inquiry based learning and hence problem solving may be introduced into a lesson. Scientific Inquiry based learning is a process used in the development of the problem solving skills of learners that involves making observations, posing questions and researching with books and other resources to enhance what is already known. This process is supported with experimental evidence where learners use current scientific knowledge and understanding to guide a Scientific Investigation (Chamberlain & Crane, 2009:3). The Scientific Investigation includes formulating hypotheses and the subsequent designing and carrying out experiments to test the hypotheses (Department: Basic Education, 2011a:11).

The reason for selecting the 5E Model is that it is a simple, inquiry-orientated teaching and learning model where learners use their prior knowledge and self-constructed concepts to develop explanations for their hands-on experiences of scientific phenomena (Australian Academy of Science, 2011). When learners become involved in hands-on experiences they develop the ability to think objectively and use a variety of forms of reasoning while they use Science process skills to investigate, reflect, synthesise and communicate (Department: Basic Education, 2011a:15). Learners become actively engaged in the learning process and thereby develop their problem solving skills which ultimately leads to an improvement in their scientific literacy.

The 5E Model, illustrated in Fig 2.1, includes five stages consistent with cognitive theories on how learning occurs:

Figure 2.1: 5E MODEL for Constructivist Engagement



(Australian Academy of Science, 2011; Hammerman, 2006:82, 83; Llewellyn, 2005:46).

The five stages of the 5E Model may be explained as follows:

<p>Stage 1: Engage</p> <p>Capture learners interest</p>	<p>A meaningful context is created to motivate learners to investigate and apply Science process skills and concepts. The teacher states the purpose of the lesson and captures the learners' attention and focus. Prior knowledge is assessed as learners share their experiences, current beliefs and understandings concerning the topic.</p> <p><u>Example</u>: The teacher presents the learners with newspaper clippings detailing Eskom power problems. She discusses these clippings with the class and relates them to power calculations in Natural Sciences. She also presents the class with</p>
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	<p>bulbs and other output devices and asks learners to record the voltage rating and power output printed on each device. The teacher asks learners to rate the devices according to which one uses the most power and which one uses the least.</p>
<p>Stage 2: Explore Discovery phase</p>	<p>The teacher presents learners with a Science problem or allows learners to identify their own Science problem. Learners are given the opportunity to design and implement their own Scientific Investigations by working in co-operative groups without direct instruction from the teacher. Learners form hypotheses, collect evidence, record their data, organise their findings, create graphs and other forms of communicating their results and finally share their observations and findings with the class.</p> <p><u>Example:</u> The teacher divides learners into groups and asks each group to calculate the energy consumption of different household appliances, e.g. iron, stove, TV, radio, refrigerator. The teacher also asks the groups to use this information to determine how long a prepaid electricity card will last in an average household. The learners present their findings to the class.</p>
<p>Stage 3: Explain Processing of information for meaning</p>	<p>This stage is teacher directed. The teacher uses data generated by the learners from the exploration stage to support new learning. The teacher designs thought provoking questions that allow learners to explain what they did and reflect on what they learned. Learners work to assimilate or accommodate new information as they make sense of their understanding, constructing new meaning from their</p>

	<p>experience and conceptual change.</p> <p>The teacher may also introduce facts, models, laws, and theories to the learners. These scientific concepts associated with the exploration provide a common scientific language for the class to use. This helps learners articulate their thinking and describe their Scientific Investigations and experiences using scientific terminology.</p> <p>Misconceptions uncovered during the engagement or exploration stage are also addressed during this stage.</p> <p><u>Example:</u> The teacher asks questions and moderates classroom discussions as each group compare their findings. The teacher is careful to emphasise the correct scientific terminology and revisits all electrical calculations, thereby reinforcing the concepts of energy, the National grid and the cost of electricity.</p>
<p>Stage 4: Elaborate Making connections</p>	<p>At this point a transfer of learning from one context to another should take place with learners being able to apply their new knowledge. The teacher helps reinforce scientific concepts by extending and applying evidence to new and real world situations outside the classroom. The lesson becomes meaningful to learners when applications are made to their lives and interests.</p> <p><u>Example:</u> The teacher and learners discuss ways to save energy e.g. by replacing normal bulbs with energy saving bulbs, switching off lights etc. This saving is related to the use of the prepaid card and how to make the card last longer and therefore save</p>

	money.
Stage 5: Evaluate Shaping understanding	<p>The teacher brings closure to the lesson and helps learners summarise the relationship between the variables studied in the lesson and posing higher order questions that help them make judgements, analyses and evaluations about their work.</p> <p>The teacher compares the prior knowledge that was identified during the Engagement stage with newly formed understanding gained from the lesson.</p> <p><u>Example:</u> The teacher encourages learners to reflect on their Scientific Investigations and to comment on what they would do differently.</p>

(Australian Academy of Science, 2011; Chamberlain & Crane, 2009:9; Hammerman, 2006:82,83; Llewellyn, 2005: 47,48; Department: Basic Education, 2011a:72, 73).

Of particular interest to this study is the Exploration stage. This stage engages learners in Scientific Inquiry based Scientific Investigations. A school laboratory Scientific Investigation also referred to as a **lab** (National Science Teachers Association, 2007:1) is defined as an experience in the laboratory, classroom or field that provides learners with the opportunity to interact directly with natural phenomena using scientific apparatus, measuring instruments, materials, data collection techniques and models (Duschl *et al.*, 2007:39; Champagne *et al.*, 2000:452). Within a Scientific Investigation, learners are able to raise questions, develop hypotheses to test, and work without direct instruction from the teacher. Learners collect evidence and data, record and organise information, share observations as they work in their co-operative groups (Duschl *et al.*, 2007:39; Llewellyn, 2005:47). The idea is that when learners are involved in Scientific Investigations they become involved with a certain method for organising their investigation. This method is often referred to as the Scientific Method.

2.3 SCIENTIFIC METHOD

Teachers have always sought ‘something’ to teach learners that would make problem solving easier and critical thinking more precise. A magical intellectual prescription or a way of thinking that is learnable in a finite time with limited resources, and applicable to multiple areas of our lives. Some researchers believe that the Scientific Method is that prescription. The method appears to be simple to understand and simple to teach. There are a few steps to learn, that can be used over and over again, and each step seems to be achievable by learners at various ages and levels of knowledge and skill (Department: Basic Education, 2011a:11; Fazio *et al.*, 2010:666, 667; Finley & Pocovi, 2000:51).

The Scientific Method manifests itself in Specific Aim 2 of the Natural Sciences National Curriculum Statement: Curriculum and Assessment Policy which relates to learners being able to plan and carry out Scientific Investigations. This Specific Aim lists seven skills that are related to performing Scientific Investigations in Natural Sciences. These skills include: following instructions; handling equipment or apparatus; making observations; recording of information or data; measuring; interpreting and designing or planning Scientific Investigations or experiments (Department: Basic Education, 2011a:18, 19, 20).

The Scientific Method represents a sequence of steps in which scientists report information and may be detailed as follows:

- State the problem
- Develop a hypothesis
- Conduct experiments
- Examine the results
- Check the hypothesis
- Adjust the hypothesis

(Harris & Basson, 2008:7; Grandy & Duschl, 2008:308; Verduin, 1996:28)

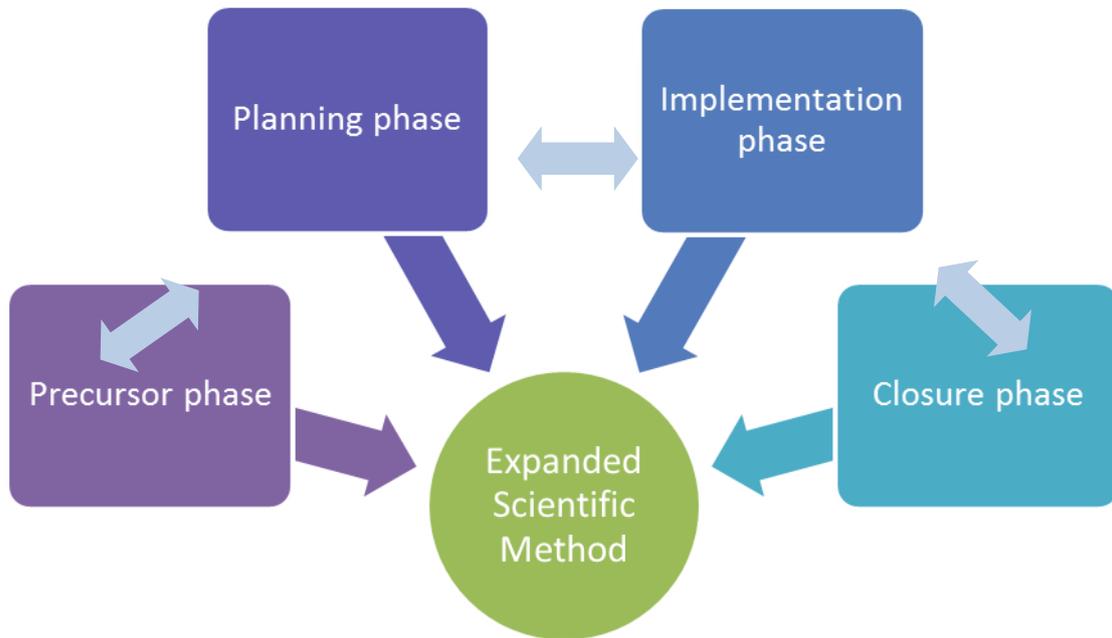
Literature reveals that work in the history and philosophy of Science has provided serious, well-grounded criticisms of the Scientific Method (Gyllenpalm *et al.*, 2010:1154; Finley & Pocovi, 2000:47). This Method supports the view that doing Science means doing experiments. Most Scientific Investigations conducted in school laboratories become reduced to simple experiments that limit a true Scientific Investigation as they act to simply reinforce concept objectives (Duschl & Grandy, 2008:307). The Scientific Method is thus regarded as a procedure and not a way of thinking (Windschitl, 2008:302).

Claims are made that in reality there is no single Scientific Method as scientists may use a variety of approaches, techniques and processes in their work. The notion that a Scientific Investigation may be reduced to a simple step-by-step procedure is misleading and fails to acknowledge the creativity inherent in the scientific process (De Haan, 2011:1500; Duschl *et al.*, 2007:171).

Grandy and Duschl (2008:310) argue that an expanded version of the Scientific Method might be the answer. The expanded version recognises the role of experiment and hypothesis testing but also emphasises the need for the results of the Scientific Investigation to be used to build theories and advance models. Scientific Investigations are “not only about patterns in observable relationships but about how these relationships act as evidence for why a phenomenon happens in a particular way” (Windschitl *et al.*, 2008:947). At the very least, the ‘why’ needs to be associated with a scientific concept, theory or model.

According to Champagne and Kouba (2005:231), all forms of Scientific Investigations proceed in phases that may be defined as precursor, planning, implementation, and closure or extension phase. An expanded version of the Scientific Method, as illustrated in Fig. 2.2, may proceed as follows:

Figure 2.2: Expanded Scientific Method



The four phases of the Expanded Scientific Method may be explained as follows:

<p>Precursor phase</p>	<p>Experiences in the natural world, in reading, in interactions with others, or in response to personal needs make learners aware of something related to Natural Sciences about which they are motivated to learn. Through interactions with others, learners refine a question or hypothesis.</p> <p><u>Example:</u> Hypothesis: Energy saving bulbs save money. This hypothesis is related to the scientific concept that power is the rate at which work is done.</p>
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<p>Planning phase</p>	<p>Learners collect information, refine the hypothesis or question, and select an appropriate method for their Scientific Investigation. Learners then present their plan to others, allow for the criticism thereof, and make the necessary refinements. Some preliminary or pilot laboratory work may be performed as part of the planning process.</p> <p><u>Example:</u> Learners conduct research on power, the types of energy saving bulbs available and how they work, and then learners plan to:</p> <p>collect a range of normal bulbs and energy saving bulbs and compare their power ratings</p> <p>record the price of each bulb</p> <p>perform calculations to determine the cost of electricity associated with each bulb</p> <p>These plans are presented to the class where they are discussed and refined.</p>
<p>Implementation phase</p>	<p>When a satisfactory plan is in place, the Scientific Investigation is conducted. Information and data are collected and analysed. Modifications to the plan may arise during this phase, e.g. the need for additional data may become evident so that new data needs to be collected and analysed.</p> <p><u>Example:</u> Learners implement the plan. They record the differences in power ratings and prices in a table. They then calculate the cost of electricity for each bulb and present this information in a pie chart. The pie chart presents the learners with a conclusion.</p>

<p>Closure or extension phase</p>	<p>During the final phase of the Scientific Investigation, the conclusions are evaluated to determine whether the Scientific Investigation has reached a satisfactory conclusion or further investigation is required.</p> <p><u>Example:</u> Learners evaluate their conclusion and decide whether it supports the hypothesis that energy saving bulbs save money. If it does, the Scientific Investigation has reached a satisfactory conclusion. If the conclusion does not support the hypothesis then the hypothesis may be revisited.</p>
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(Champagne & Kouba, 2005:231; Champagne *et al.*, 2000:453,454)

When using the expanded Scientific Method, the implication is that learners become involved with a specific problem and actively seek solutions in order to solve the problem (Harris & Basson, 2008:6). The expanded Scientific Method becomes an organised and systematic way for learners to accumulate information which learners are able to relate to scientific theories and models in order to solve a problem.

In many instances in Natural Sciences education, Scientific Inquiry is equated or nearly equated with the traditional Scientific Method (Gyllenpalm *et al.*, 2010:1154; Finley & Pocovi, 2000:47). Equating the two presents a problem as true Scientific Inquiry is regarded as more sophisticated than the Scientific Method that is often taught (Duschl *et al.*, 2007:335). Scientific Inquiry incorporates the logic of problem solving that comes from the Scientific Method, but not necessarily the delineated, specific steps or rigid approach of the Scientific Method (Llewellyn, 2005:7). For the purpose of clarity the researcher will provide a detailed definition of Scientific Inquiry in the following section.

2.4 SCIENTIFIC INQUIRY

Problem solving involves the process of Scientific Inquiry. A reconsideration of the role of Scientific Inquiry in school Science began approximately 50 years

ago. Unfortunately this reconsideration led to a proliferation of meanings associated with the term “Scientific Inquiry” (Duschl & Grandy, 2008:5).

One definition is that Scientific Inquiry involves fostering inquisitiveness. Another holds it to be a teaching strategy for motivating learning. Some say Scientific Inquiry means ‘hands-on’. Others say that is too simple, that hands-on is not necessarily minds-on, and that Scientific Inquiry requires mental reflection on experiences. Some teachers add that Scientific Inquiry includes manipulating materials to become acquainted with phenomena and to stimulate questions, as well as using the materials to answer the questions (Fazio *et al.*, 2010:666; Areepattamannil *et al.*, 2011:237; Minstrell, 2000:472).

Llewellyn (2005:24) regards Scientific Inquiry as the process of active exploration by which learners use critical, logical and creative thinking skills to raise and engage in questions of personal interest.

Hammerman (2006:12) sees Scientific Inquiry as the process through which scientists make observations, acquire data, support their ideas, modify their beliefs, and ask new questions. She maintains that Scientific Inquiry is a process that is common to everyday events and problem solving.

The National Science Education Standards document (National Research Council, 1996:23) identifies Scientific Inquiry as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information; planning Scientific Investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Scientific Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. Learners engage in selected aspects of Scientific Inquiry as they learn the scientific way of knowing the natural world (Duschl *et al.*, 2007:39; National Research Council, 1996:23).

As can be seen from the above literature references, there is no single, simple definition. At its core, Scientific Inquiry is about acquiring data and transforming the data first into evidence and then into explanations (Duschl &

Grandy, 2008:305). Whichever definition of Scientific Inquiry a teacher chooses determines their teaching and assessment practices.

What Scientific Inquiry is not is a self-contained procedure, disconnected from scientific theories or models, with orderly steps and much of the epistemological complexity stripped away (Windschitl, 2008:302).

For the purpose of this study Scientific Inquiry will be taken to mean a process used in the development of the problem solving skills of learners which involves making observations, posing questions and researching with books and other resources to enhance what is already known. This process is supported with experimental evidence where learners use current scientific knowledge and understanding to guide a Scientific Investigation (Chamberlain & Crane, 2009:3).

The researcher wishes to affirm that for learners to create meaning and understanding from experiences it is necessary for them to become actively engaged in Scientific Inquiry (Australian Academy of Science, 2011). This is in line with the constructivist view of learning where learners are seen as active constructors of their own understanding resulting from their experiences. This means that when learners are presented with a Science problem they gather the necessary information by employing problem solving skills so that they may find a suitable solution to the problem.

In order for teachers to actively engage learners in the process of Scientific Inquiry they need to understand the respective components associated with Scientific Inquiry.

2.4.1 Components of Scientific Inquiry

According to DeBoer (*in* Chamberlain & Crane, 2009:9), the constructivist model of learning is reflected in Scientific Inquiry based instruction. Learners involved with the process of Scientific Inquiry grow in scientific literacy and knowledge as Scientific Inquiry allows them to answer questions that challenge their prior knowledge about themselves and their environment (Chamberlain & Crane, 2009:3).

Certain components may be identified in the process of Scientific Inquiry. These components include the following:

- Making observations and posing questions to guide a Scientific Investigation
- Accessing and using relevant information
- Formulating a hypothesis or a question to test
- Planning, designing and conducting a Scientific Investigation
- Using tools, technology and Mathematics to collect, record, analyse, and interpret data to draw appropriate conclusions to solve a problem
- Proposing answers, explanations, and predictions; using logic, reasoning and evidence in the revision of scientific concepts, theories and models
- Communicating and defending a scientific argument

(Department: Basic Education, 2011a:11,15,18,19,20; Hammerman, 2006:13; Llewellyn, 2005:24; Bybee, 2000:33)

It is important to reinforce at this stage that the components of Scientific Inquiry are not a linear process of steps to be followed and completed in a specific order to ensure a successful Scientific Inquiry experience.

Scientists understand their world by figuring out how to pose questions to the phenomena at hand. In the same way, learners need to understand their world by learning how to ask the right questions to the phenomena, not the teacher. Research shows that this ability is a powerful tool for learning Natural Sciences (Littledyke & Manolas, 2010:294; Duschl *et al.*, 2007:19; Wheeler, 2000:16). Asking and addressing these questions represents a strategy for solving many of the problems that are encountered in everyday life in society (Duschl *et al.*, 2007:34; Alberts, 2000:4).

Not only should learners be encouraged to struggle with possible answers to questions, but they should also suggest and carry out simple Scientific

Investigations to test some of their ideas. Learners should acquire the ability to explore their natural world effectively by changing one variable at a time, keeping everything else constant (Fazio *et al.*, 2010:666; Alberts, 2000:4).

In order to achieve the above, we need to improve learners' knowledge concerning the process of Scientific Inquiry as well as their ability to do Scientific Inquiry (Gyllenpalm *et al.*, 2010:1153; Minstrell, 2000:473).

A related constructivist theory of learning, social constructivism claims that learners create their own understanding through guided interaction with their environment (Hohenstein & Manning, 2010:73). The teacher acts as a guide during the process of Scientific Inquiry whereby learners are able to perform a Scientific Investigation in order to solve an identified problem.

It follows that as Scientific Inquiry is identified as a viable process for learners to construct meaning and to solve problems in Natural Sciences, teachers will need to know how to introduce the process of Scientific Inquiry into their daily teaching time.

2.4.2 Teaching Scientific Inquiry

Teachers should not be satisfied with learners being passive recipients of Natural Sciences concepts and content. Teachers should orchestrate and sequence activities so that learners actively process the information they are provided with (Bishop & Denley, 2007:76). Teaching and assessment practices should involve sequences of well designed, strategic encounters between learners and Natural Sciences concepts and content where learners are required to manipulate information in order to construct meaning. This involves introducing the process of Scientific Inquiry as a teaching practice. The teacher or learners generate Science problems and learners gain the necessary experience in problem solving by designing methods to answer these problems, conducting data analysis and debating their interpretations of the data (Duschl *et al.*, 2007:4).

This does not mean that all. Natural Sciences lessons need to be taught through the process of Scientific Inquiry. The National Science Education

Standards document (National Research Council, 1996:23) and the Curriculum and Assessment Policy Statement for Gr 9 Natural Sciences (Department: Basic Education, 2011a:7, 14) advocate the use of diverse teaching methods. Teachers should use different methods to develop the knowledge, understanding, and abilities of learners. These methods include traditional lectures, presentations and textbooks (Llewellyn, 2005:8).

When the process of Scientific Inquiry is used as a teaching method and is coupled with suitable Natural Sciences concepts and content in an authentic relevant context, the result is a meaningful learning experience that promotes the effective development of the problem solving skills of learners.

The practical implications of teaching Natural Sciences by Scientific Inquiry are that learners are given many opportunities to identify problems, apply critical and creative thinking, make responsible decisions and solve problems. This process consists of a complex interaction between Natural Sciences theory, data and evidence. The responsibility of a Natural Sciences teacher is to create learning opportunities through which these necessary skills may be developed (Areepattamannil *et al.*, 2011:237; Duschl & Grandy, 2008:34; Harris & Basson, 2008:7).

However, understanding problem solving, applying critical and creative thinking, manipulating information, making responsible decisions and drawing conclusions that relate back to the world is not the type of thinking that teachers can expect learners to spontaneously be able to apply (Gyllenpalm *et al.*, 2010:1153, 1154; Schauble, 2008:54). Quality teaching should promote Natural Sciences as a process of building and improving knowledge and understanding. Constructivists perceive learning as a process by which learners become “theory builders” where knowledge is constantly being assimilated and accommodated in the mind through interpretations of experiences (Littledyke & Manolas, 2010:293; Llewellyn, 2005:40, 45). Learners should have experiences in Natural Sciences where they generate researchable problems, design methods of answering these problems, conduct data analysis, and debate interpretations of their data (Fazio *et al.*, 2010:666; Department: Basic Education, 2011a:11, 15).

In a Natural Sciences constructivist classroom, the teacher's role becomes that of facilitator rather than dispenser of information. The teachers value the points of view that learners bring to the lesson and alter their teaching based on the prior knowledge and preconceptions of the learners. Emphasis is placed on learners working in groups and internalising the information as they develop an understanding of scientific phenomena. By using analogies and having learners raise their own questions, constructivist teachers constantly connect their learners' prior knowledge and experiences to new Natural Sciences concepts and content (Department: Basic Education, 2011a:7,11,12,14, Littledyke & Manolas, 2010:293, 294; Llewellyn, 2005:30).

Specific characteristics of Natural Sciences teachers who portray a constructivist approach in teaching Natural Sciences include the following:

- Encourage learning that opens the doors to problem solving and higher level thinking skills
- Provide challenging activities that stretch the learners thinking and problem solving skills
- Allow learners to work in groups to share and communicate their knowledge and to test their ideas and theories on one another, making learning a personal experience (Llewellyn, 2005:32)

The researcher wishes to argue that a constructivist Natural Sciences teacher recognises that learners are individuals, each with their own ideas. Such a teacher encourages learners to tackle stimulating problems that challenge their existing ideas. When presented with a problem, learners are able to test, evaluate and even modify or change their existing ideas.

Recent developments in the design of learning environments that support learners' acquisition of scientific reasoning, argue for active engagement of learners in the process of reasoning and for activities that make thinking visible (Fazio *et al.*, 2010:667; Duschl & Grandy, 2008:23). In Natural Sciences learners should engage in activities that require them to use the language and reasoning of Science with their peers and teachers. This

engagement would involve the construction and evaluation of scientific arguments and models by examining and explaining evidence obtained from their Scientific Investigations (Department: Basic Education, 2011a:7, 23, Gyllenpalm *et al.*, 2010:1153; Duschl & Grandy, 2008:28).

Following learners' Scientific Investigations, teacher led classroom discussions should focus on learners' experience, data and conclusions related to the Science problem. Although learners are required to make interpretations of their data and experiences, they should be assisted by teachers in this regard as misconceptions may arise. By asking thoughtful questions, teachers can help learners reflect on their experiences; make sense of data; connect learning to prior knowledge; create meaning; apply learning to their lives, technology and society; and determine the next steps for extended learning (Areepattamannil *et al.*, 2011:237; Hammerman, 2006:79). Learners should be able to do this in a safe environment where they receive gentle prompting and guidance from the teacher who introduces relevant Natural Sciences concepts at specific times and who allows learners to test and challenge these concepts.

The researcher is of the opinion that Natural Sciences classes where learners are never encouraged to inquire, explore, induce, or discover logically, represents an example of poor teaching. Learners need to construct and apply their understanding of the natural world by spending some significant time engaging in explicit as well as implicit learning experiences. The exact composition of these integrated, balanced experiences should be determined by informed and experienced Natural Sciences teachers (Gyllenpalm *et al.*, 2010:1153; Holliday, 2006:214).

Teaching and assessment practices that separate the teaching and learning of Natural Sciences concepts and content from the teaching and learning of Scientific Inquiry (cognitive and manipulative) will be ineffective in helping learners develop scientific reasoning skills and an understanding of Science as a way of knowing (Duschl & Grandy, 2008:29). This will lead to the ineffective development of the problem solving skills of Gr 9 Natural Sciences learners.

The following serves as a practical example of a Natural Sciences classroom activity used for the effective development of the problem solving skills of Gr 9 learners. A synopsis of each day and the relevant problem solving skills that are being developed are presented at the end of the example:

The Peanut investigation (Llewellyn, 2005: 155-165):

This Scientific Investigation focuses on decision making and determining the amount of energy stored (caloric content) in a peanut.

The 'peanut investigation' is divided over 4 days; with the odd days, 1 and 3 each comprising of a 90-minute, double period. The even days, 2 and 4, are single 45-minute periods.

Day 1:

Learners review important points of the previous day's lesson concerning the concept of energy:

'The joule is the unit used to express the amount of energy absorbed or released during a chemical reaction; heat flows from hot to cold objects'.

The review is conducted by means of a series of questions eliciting the correct response. Also, as a warm-up exercise, learners use their notes from the previous day's class and Chemistry Reference Tables to apply the appropriate formula and answer the following two questions:

How much heat is needed to melt 50 g of ice?

How much heat is needed to vaporise 10 g of water?

The learners are then introduced to a teacher initiated Scientific Inquiry, the 'peanut investigation'.

The teacher introduces the 'peanut investigation' as follows:

Energy that is produced when plants go through photosynthesis is stored in the leaves, roots and stem; we eat food to get that stored energy; when food

is burned during the process of digestion, the energy is released as heat energy in our bodies; the amount of energy released by the food can be calculated, and the amount of energy stored in the food determined.

The learners are required to determine how much stored energy (in joules) a peanut has. Learners all have regular laboratory equipment available for use as well as peanuts and matches. Their task is to write the equation used to calculate the heat energy released by the peanut as it burns, identify the variables they will need to measure in the Scientific Investigation, and then design and write a safe procedure to determine the amount of heat energy released by the peanut as it burns. Learners are to include a drawing of how their laboratory equipment will be set up.

Learners work in pairs, brainstorm ideas and record all information in their notebooks. After 15 minutes, the teacher asks the groups to share their Scientific Investigation designs with the class. After much discussion and debate the learners agree that the proposal to use a match to ignite the peanut and then use a pin to hold the peanut under a beaker of water (not submerged) to determine how much the temperature of the water rises, is the best proposal. The temperature of the water needs to be taken before and after heating to calculate the change in temperature.

Learners record their Scientific Investigation procedures in their Natural Sciences journals. A typical peanut journal entry would look as follows:

Title/ question: How much energy is in a peanut?

Purpose: To measure the amount of heat energy released by a peanut as it burns.

Materials: Ring stand, ring clamp, and wire mesh pad, graduated cylinder, 500 cm³ beaker, peanut, pin, cork, water, matches, thermometer, electronic balance, and safety glasses.

Procedure:

Assemble a ring stand, ring clamp and wire mesh pad.

Use a graduated cylinder, measure a 100 cm^3 of water and place it in a 500 cm^3 beaker. Place the beaker of water on the ring clamp.

Use a thermometer; determine the temperature of the water in the beaker. Record the temperature.

Assemble a peanut holder by placing a pin, pointed side up, in a small cork stopper. Place a peanut on the pointed end of the pin. Position the peanut and holder under the beaker and ring clamp.

Use a match, light the peanut and allow it to burn completely.

After the peanut burns itself out, determine the temperature of the water. Record the temperature.

Safety procedures: Wear safety glasses, and be careful when using matches.

<i>Data:</i>	Temperature of water before heating	= _____
	Temperature of water after heating	= _____
	Change in temperature	= _____

After conducting the Scientific Investigation, learners calculate the amount of heat energy released by the peanut using the appropriate formula. Learners share their results with the class. The teacher enquires why there is a difference in results. A class discussion ensues and it is decided that not all peanuts are the same size. The teacher supplements this finding by asking learners to compare a regular and a large size energy bar for calorie content. Learners are provided with an opportunity to raise questions and then use their data to provide answers. Learners record their analysis section in their Natural Sciences journal and the teacher has the learners summarise their Scientific Investigation by suggesting ways for improvement.

Day 2:

The teacher solidifies learners' understanding of energy and the joule concept by posing questions and providing examples as she refers to the previous

day's Scientific Investigation. Learners are able to construct knowledge of the heat concept and also calculate joules. Several more problems are presented involving joule calculations. Learners are also required to convert joules to kilojoules and to integrate their graphing skills by drawing a heat curve to show the changes that take place when they heat a 20 g sample of ice at -5°C to water vapour at 110°C . The teacher also reviews the formulas for the heat of vaporisation and the heat of fusion.

Learners use the data and evidence from their previous Scientific Investigation to design their own new Scientific Investigation i.e. learners choose a problem to investigate. The teacher helps initiate problem ideas by placing a can of mixed nuts on the table. Learners brainstorm ideas and suggest the following problems for investigation:

- Which nuts contain the most joules of energy?
- Do regular peanuts produce more heat than dry roasted peanuts?
- What is the amount of joules of energy given off by a small marshmallow?
- Do potato chips or Doritos provide more joules of energy?

Day 3:

Learners conduct their Scientific Investigations and collect and analyse their results. When they have enough information to answer their problem, they plan a 5-minute oral presentation to communicate their results and findings to the class. The presentation is in the form of a poster board or PowerPoint presentation. These presentations are graded according to a rubric which the learners receive before they begin their Scientific Investigations.

Day 4:

On the final day of the Scientific Investigation, each group presents their findings to the class. At the end of each presentation, learners answer the teacher posed question: "If you were to improve your Scientific Investigation,

what would you change?” Learners are then given a short test to assess their understanding of energy, joules, heat and calories.

The researcher summarises the daily activities as follows:

During day 1:

The learners review the previous day’s lesson that focused on the concept energy. The learners have already developed ideas about energy and the joule and the teacher determines these ideas by asking questions to see if the learners have any misconceptions.

The warm-up exercise is regarded as a Science exercise and not a Science problem as it involves the simple recall of relevant information obtainable from the textbook.

They learners are introduced to a teacher-initiated Scientific Inquiry, the ‘peanut investigation’, which involves a teacher initiated Science problem. The problem is considered a Science problem as learners have to choose the best strategy from a wide range of possibilities in order to solve the problem. The chosen strategy involves interpreting, representing, planning, deciding, executing, evaluating and re-evaluating. Learners plan and carry out a Scientific Investigation and record and analyse their results based on a question posed by the teacher.

Specific problem solving skills developed during day 1 include:

Critical and creative thinking skills	
Science process skills	Designing, planning and conducting a Scientific Investigation where learners, control variables, define operationally, observe, measure, communicate, interpret data, infer, classify and predict during classroom discussions.

During day 2:

The teacher briefly reviews the learners understanding of energy and the joule by posing questions and constantly directing the learners to their findings from the previous day's Scientific Investigation thereby reinforcing the concept of energy.

Learners are introduced to extended material relating to energy and the joule, and some Science exercises. The learners are also introduced to an extended learner initiated Scientific Inquiry in which they design a Scientific Investigation based on the identification of their own Science problem.

Specific problem solving skills developed during day 2 include:

Critical and creative thinking skills	
Science process skills	Designing, and planning a Scientific Investigation where learners formulate a hypothesis, decide on variables to be controlled, define operationally and communicate with one another.

During day 3:

The learners carry out their Scientific Investigations, organise their evidence and data, and make graphs and charts to communicate their results. Learners also plan to communicate their findings to the class.

Specific problem solving skills developed during day 3 include:

Critical and creative thinking skills	
Science process skills	Conducting a Scientific Investigation where learners observe, measure, communicate and interpret data, and formulate models to communicate their findings to the class.

During day 4:

Learners communicate the results and conclusions of their Scientific Investigations in a 5-minute oral presentation using either a poster board or a PowerPoint presentation.

Specific problem solving skills developed during day 4 include:

Critical and creative thinking skills	
Science process skills	Communicating, inferring, observing, interpreting of data and predicting during the class presentation and subsequent questioning session.

The Peanut investigation aligns itself with the 5E inquiry-orientated teaching and learning model where learners use their prior knowledge and self-constructed concepts to develop explanations for their hands-on experiences of scientific phenomena (Australian Academy of Science, 2011). During the Peanut investigation the teacher:

- engages the learners to capture their interest and to get them thinking about the subject matter, and then allows learners to;
- **explore** by means of a Scientific Investigation involving Science exercises and Science problems, after which the teacher;
- **explains** concepts by using learner generated data from the exploration stage to support new learning and then;
- **elaborates** to reinforce scientific concepts by extending and applying evidence to new and real world situations outside the classroom; and finally

- **evaluates** learners understanding by summarising the relationship between the variables studied in the lesson and posing higher order questions that help them make judgements, analyses and evaluations about their work.

(Australian Academy of Science, 2011; Chamberlain & Crane, 2009:9; Hammerman, 2006:82, 83; Llewellyn, 2005: 47, 48)

The peanut investigation also aligns itself with the expanded version of the Scientific Method where learners:

- become aware of something related to Natural Sciences about which they are motivated to learn (Precursor phase); learners then
- gather information, refine a hypothesis or question, and select an appropriate method for a Scientific Investigation. Learners also present their plans to others, where they are criticised and learners make refinements (Planning phase); after which they
- conduct a Scientific Investigation, collect and analyse information and data (Implementation phase); and
- evaluate conclusions to determine whether the Scientific Investigation has reached a satisfactory conclusion (Closure or extension phase).

(Champagne & Kouba, 2005:231; Champagne *et al.*, 2000:453,454).

This section has served to illustrate an example of a practical application for the effective development of the problem solving skills of Gr 9 Natural Sciences learners. For this practical application to be successful, the correct classroom climate is necessary. The type of classroom climate conducive to the development of the problem solving skills of learners is discussed in the following section.

2.5 CLASSROOM CLIMATE FOR DEVELOPING PROBLEM SKILLS

Apart from devising suitable activities for the development of the problem solving skills of learners, it is important to create an appropriate classroom

climate. Such a climate is not only dependent on good facilities or resources but is a classroom where learners are encouraged and motivated to be curious about phenomena, to reflect on their learning, to dream, ask questions and not be afraid to express their opinions (Ediger, 2009; Jacobs *et al.*, 2002: 38).

To teach Natural Sciences by Scientific Inquiry requires teachers to carefully reflect on how they guide their learners in the process of Scientific Inquiry (Oliveira, 2010a:265). During the process of Scientific Inquiry, learners construct a scientific argument by weighing evidence from their Scientific Investigations and considering relevant scientific concepts, theories and models in order to form a conclusion to a problem (McNeill & Pimentel 2010:205). Learners then present their conclusions to the class where teachers provide them with feedback, encourage them to evaluate themselves and draw connections and also help them articulate their thoughts and opinions without explicitly evaluating the learners (Tan & Wong, 2012:202; Oliveira, 2010a:265).

This means Natural Sciences classrooms should include many opportunities for learners to engage in classroom discussions where learners are able to practice talking “Science” (McNeill & Pimentel, 2010:204, 206). An important role of the teacher becomes to guide and support learners in playing an active role in such classroom discussions. Positive teacher-learner and learner-learner interaction during these classroom discussions establishes a climate of cooperation and respect (Hammerman, 2006:146).

Learners also adapt to situations in which they find themselves. If learners are in a classroom where scientific thinking is neither needed nor valued, it is highly unlikely to appear. Classroom practices that insist on reasons and evidence, supplemented by teaching ways to structure, represent, and interpret data, make it more likely for learners to spontaneously seek data to support their theories (Schauble, 2008:55, 56).

Learners should not only be encouraged to have a voice in Natural Sciences classrooms, but should extend this voice to the essential scientific practice of

argumentation. Learners need to be able to consider alternative claims as well as critique the claims and justifications provided by other learners in the context of a classroom discussion. This promotes learners' abilities to reason and justify their claims as well as interact with their teacher and peers in terms of both the building and critiquing of ideas (McNeill & Pimentel, 2010: 205, 206).

It follows that a teacher needs to instil confidence in learners that rational disagreement will not be penalised. There is no room for indoctrination and unreflective conformity in a Natural Sciences classroom (Oliveira, 2010a:248; McPeck, 1990:35, 52). Learners may be unfamiliar with critiquing scientific argumentation and the teacher can play an important role in modelling these methods (McNeill & Pimentel, 2010:206).

Learners, who are asked to explain phenomena, and be accountable for constructively critiquing the contributions of their peers, are likely to understand that not everyone interprets the world in the same way (Schauble, 2008:55). These methods help learners' value communication and an audience and thereby assist in improving their communication skills (Schauble, 2008:55; Drinkwater, 2002:97).

Teachers need to bear in mind that Gr 9 learners are often self-conscious about raising questions and are reluctant to give answers and opinions, because in so doing they risk the appearance of 'standing out' in the class (Llewellyn, 2005:65). Teachers should therefore make use of appropriate communication styles to try to convey correct non-verbal messages by listening with empathy and attempting to prevent and/or surmount communication apprehension (Oliveira, 2010a:265; Drinkwater, 2002:97).

The attitude of the teacher, and the learning atmosphere in the class, thus has an important effect on the successful nurturing of scientific thinking (Oliveira, 2010a:247; McPeck, 1990:35).

A classroom climate founded on responsibility, respect, and the desire to learn is thus critical in the development of the problem solving skills of learners (Hammerman, 2006:146). Such a climate will ensure that when classroom

discussions or arguments surrounding Science problems are conducted, learners participate completely, develop their own claims based on evidence and formulate arguments to validate these claims. Learners will also be able to critique the claims made by other learners. This behaviour should lead to the development of higher order thinking skills and thus the development of the learners' problem solving skills.

Another aspect crucial to the development of the problem solving skills of learners is the effective assessment of these skills.

2.6 ASSESSMENT PRACTICES FOR DEVELOPING PROBLEM SOLVING SKILLS

Assessment is the continuous planned process of identifying, gathering and interpreting information about the performance of learners, using various forms of assessment (Department: Basic Education, 2011a:80; Chamberlain & Crane, 2009:4).

Effective learning environments scaffold or support learning through the use of effective assessment practices (Duschl & Grandy, 2008:29). The assessment process enables teachers to gather detailed and reliable information about learner achievement and to use this information to inform learners about the quality of their work, to monitor learner progress, to plan their own lessons, and to inform parents about their children's work (Department: Basic Education, 2011a:80; Chamberlain & Crane, 2009:4; Mashile, 2003: 60; Champagne *et al.*, 2000:448). Effective assessment practices therefore need to be employed if teachers wish to develop the problem solving skills of Gr 9 Natural Sciences learners.

Assessment may include both informal (Assessment for learning) and formal (Assessment of learning) types of assessment (Department: Basic Education, 2011a:80; Chamberlain & Crane, 2009:9).

Informal assessment is the daily monitoring of learners' progress where teachers gather information about learners' developing understanding and act on this information. Teachers step back during teaching, check learner

understanding and plan the next steps they must take to improve learners' understanding (Ruiz-Primo & Furtak, 2007:58,59; Duschl *et al.*, 2007: 280; Department: Basic Education, 2011a:81; Hein & Lee, 2000:99, 101). Informal assessment information may be gathered through observations, classroom discussions, practical demonstrations, learner-teacher conferences and informal classroom interactions and are usually not recorded (Ruiz-Primo & Furtak, 2007:58, 59; Department: Basic Education, 2011a:81).

Learners are also encouraged to perform their own informal assessment. Self-assessment and peer assessment actively involve learners and allow them to learn from and reflect on their own performance (Department: Basic Education, 2011a: 81). A learner comparing his/her work with a memorandum shown by the teacher will make judgements about their performance and make modifications on the basis of reaching the goal made clear in the memorandum (Duschl *et al.*, 2007: 280).

Formal assessment on the other hand, comprises of activities that are specifically designed to indicate how well learners are progressing in a grade and in a particular subject. These assessments take the form of curriculum embedded assessments that focus on some specific aspect of learning. Examples include tests, examinations, Scientific Investigations, projects, oral presentations, demonstrations, performances, etc. These activities are designed in advance and are formally recorded (Ruiz-Primo & Furtak, 2007:58; Department: Basic Education, 2011a:82; Hein & Lee, 2000:99)

Both informal and formal assessment should be interesting, promote learning, motivate learners and form part of daily instruction. Carefully constructed assessments are able to provide:

- opportunities for learners to show what they know and can do in a variety of ways;
- evidence of learners' thinking and problem solving; and

- evidence of skill development and dispositions.

(Department: Basic Education, 2011a:80; Hammerman, 2006:129)

2.6.1 Assessing problem solving skills

Historically education has separated the assessment of the conceptual components from the process, practical and inquiry components of Natural Sciences. Recent developments in assessment call for the active engagement of learners in the process of reasoning and for assessment activities that make thinking visible (Duschl & Grandy, 2008:23, 29). Learners' ideas and experiences in Natural Sciences are essential in helping them make sense of scientific phenomena. Teachers must have access to these ideas, as well as a range of methods they can use to determine what learners understand about a given topic (Duschl *et al.*, 2007:280).

In order to assess learners' problem solving skills, teachers will need to assess learners Scientific Inquiry skills. Scientific Inquiry is a process used for problem solving and is at the heart of knowing and doing Natural Sciences. A fundamental aspect of Scientific Inquiry is the design, conducting, and interpretation of a Scientific Investigation to answer a question or to test a hypothesis (United States Department of Education, 2008:117).

2.6.2 Assessing the Scientific Inquiry skills of learners

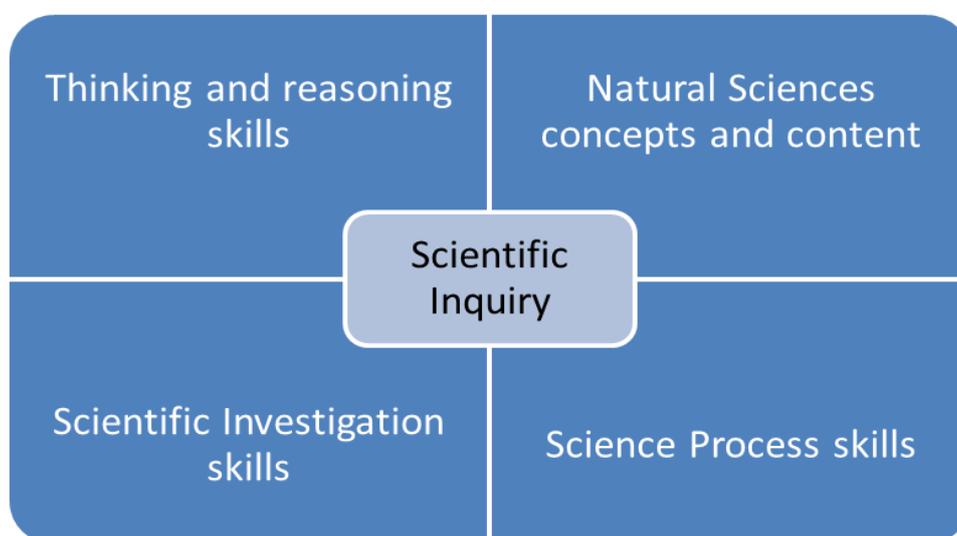
Problem solving in Natural Sciences rests in the development of learners' Scientific Inquiry capabilities. Inquiry capabilities are practiced by scientifically literate learners and involve learners being able to access Natural Sciences knowledge necessary to make reasoned decisions and to help them understand the natural world. Scientific Inquiry capabilities have traditionally been conceptualised by terms such as: problem solving skills, critical thinking, reflexive thinking, conceptual understanding, the Scientific Method and Science process skills and have important consequences for the kinds of inferences that can be made about Natural Sciences achievement (United States Department of Education, 2008:10; Champagne *et al.*, 2000:450; Duschl & Grandy, 2008:31; Zachos *et al.*, 2000:940).

Scientific inquiry includes hands-on interaction with the natural world and ensures that learners are involved in doing as well as thinking and reasoning. Scientific Inquiry thus involves both physical and mental activity as it engages learners in conducting Scientific Investigations; sharing ideas with peers; specialised ways of talking and writing; mechanical, Mathematical, and computer-based modelling; and developing representations of phenomena (Duschl *et al.*, 2007:251; Hein & Lee, 2000:99, 100).

Natural Sciences teachers should develop assessments that reveal and measure a learner's Scientific Inquiry skills (National Science Teachers Association, 2007:4). Firstly, these assessments should address how well learners are able to carry out physical processes (Scientific Investigation skills and Science process skills) such as measurement, observation, investigation, design, problem solving, etc. Secondly, the level of learners' thinking and reasoning skills should be assessed, meaning whether learners are able to draw valid conclusions, choose appropriate methods, recognise regularities in nature, etc. Finally, it is important to assess learners' knowledge of Natural Sciences concepts and content (United States Department of Education, 2008:8, 9, 73; Hein & Lee, 2000:100).

All of these skills are required to be assessed in the process of Scientific Inquiry as illustrated in the following figure:

Figure 2.3: Skills required to be assessed in Scientific Inquiry



It is not advisable to try to assess each of these skills separately, nor is it possible to report on the individual skills separately (Department: Basic Education, 2011a:23).

To assess Scientific Inquiry skills, teachers may make use of performance assessments which can help to assess content and higher order thinking skills as well as allow learners to demonstrate creativity, problem solving and decision making. These assessments involve Scientific Investigations that are similar to tasks that learners will encounter outside the classroom and are also similar to the activities of scientists (United States Department of Education, 2008:106; Duschl & Grandy, 2008:29; Llewellyn, 2005:115).

Performance assessments consist of multistep activities requiring equipment or materials. They may be formal or informal in nature and:

- assess important goals and standards;
- are rooted in interesting and meaningful contexts;
- provide opportunities for learners to show Natural Sciences concept and content understanding and use of skills in a single task; and
- provide opportunities for learners to show higher levels of thinking and problem solving.

(Department: Basic Education, 2011a:18, 23, 80; Hammerman, 2006:132)

An example of a performance assessment would be when learners are presented with a selection of objects that they are required to find the density of. Learners make use of a variety of available equipment to determine the density and then sort the materials according to their differing densities.

The findings of these performance assessments enable a teacher to inform learners where their weaknesses and strengths lie with regard to their Scientific Inquiry skills. These weaknesses and strengths are an indication of a learner's ability to conduct a Scientific Investigation in order to solve a problem. Teachers may use this information to provide learners with feedback

to assist them in developing their problem solving skills. The assessment of each of these skills will be discussed in detail in the following sections.

2.6.2.1 Assessing thinking and reasoning skills

When learners are required to solve a problem, they have to use the process of Scientific Inquiry. This process allows learners to develop the ability to think objectively and use a variety of forms of reasoning while they use Science process skills to investigate, reflect, synthesise and communicate (Department: Basic Education, 2011a:15).

As mentioned previously performance assessments in the form of Scientific Investigations may be used to assess learners' Scientific Inquiry skills. During the Scientific Investigation the level of learners' thinking and reasoning skills are required to be assessed. Teachers assess whether learners are able to draw valid conclusions, choose appropriate methods, recognise regularities in nature, etc. (Department: Basic Education, 2011a:15, 18-20; Hein & Lee, 2000:100). This means that teachers need to continuously elicit learners' thinking and reasoning to help learners consider their developing conceptions on the basis of scientific evidence (Duschl *et al.*, 2007:281).

During the assessment of thinking and reasoning skills the teacher should specifically assess learners' abilities to:

- construct a coherent argument in support of a question;
- judge the scientific quality of a question;
- develop a plan for a Scientific Investigation (including the selection of appropriate scientific apparatus);
- develop a well-structured argument leading from the original question through the data collection and analysis to the solution;
- devise a well-structured argument in the application of conclusions from the Scientific Investigation to a social, or personal context; and

- consider alternative ways to which conclusions from the Scientific Investigation might be applied in a particular context.

(Department: Basic Education, 2011a:7,15,18-20; Champagne *et al.*, 2000:456-461)

Teachers can assess learners' thinking and reasoning ideas through writing, drawing, and sharing orally. Teachers may also recognise learners' thinking and reasoning through open classroom discussions (Duschl *et al.*, 2007:283). Classroom discussions not only engage learners with conceptual and epistemic goals but can also make scientific thinking and reasoning visible for the purposes of informal assessment by teachers (Duschl & Grandy, 2008:32).

Learners need encouragement and guidance during classroom assessment discussions in order to articulate their ideas and to understand that explanation rather than fact is the goal of Science (Duschl *et al.*, 2007:251). Such classroom assessment discussions take place in any learner-teacher interaction and help the teacher acquire assessment information on a continuing basis. Teachers elicit a response from learners, recognise if the response is a scientifically accepted idea and then use the information to guide learning. Eliciting responses may involve asking learners to formulate explanations or to provide evidence. Recognising may be when the teacher repeats or re-voices learners' responses. Using occurs when a teacher asks learners to elaborate on their response, or when a teacher explains learning goals or promotes argumentation (Ruiz-Primo & Furtak, 2007:59, 60, 62).

When planned deliberately, classroom assessment discussions become an example of planned-for assessment that permits teachers to recognise learners' conceptions, mental models, strategies, language use, or communication skills and allows teachers to use this information to guide instruction (Duschl *et al.*, 2007:281). Classroom assessment discussions require teachers to be facilitators of learning rather than providers or evaluators of correct or acceptable answers (Ruiz-Primo & Furtak, 2007:59, 60, 62).

Assessment of thinking and reasoning skills involves the assessment of Scientific Inquiry skills. Scientific Inquiry promotes thinking and reasoning by prompting learners to design Scientific Investigations and relate the evidence obtained from their Scientific Investigations to Natural Sciences concepts, theories or models in order to reach suitable conclusions to an identified problem. The learners are encouraged to defend their scientifically acceptable conclusions during open classroom discussions. Without knowledge of Natural Sciences concepts or content, learners will be unable to reason and think appropriately during the process of Scientific Inquiry and will therefore not be able to solve the problem under investigation. It is therefore also important to assess learners' knowledge of Natural Sciences concepts and content.

2.6.2.2 Assessing Natural Sciences concepts and content

Scientific Inquiry requires knowledge of Natural Sciences concepts and content that learners use in an effective manner in appropriate situations (Ruiz-Primo & Furtak, 2007:62).

Knowledge of Natural Sciences concepts and content includes a deep understanding of Natural Sciences processes, phenomena, mechanisms, principles, theories, laws, and models as parts of the larger Natural Sciences conceptual schemes. This knowledge involves knowing, understanding, and making meaning of Natural Sciences in a way that enables learners to make many connections between the ideas and concepts in their minds. Making such connections enables learners to apply their knowledge to new and unfamiliar contexts. The process of acquiring a deep understanding of Natural Sciences is about more than just knowing a lot of facts (Department: Basic Education, 2011a:16).

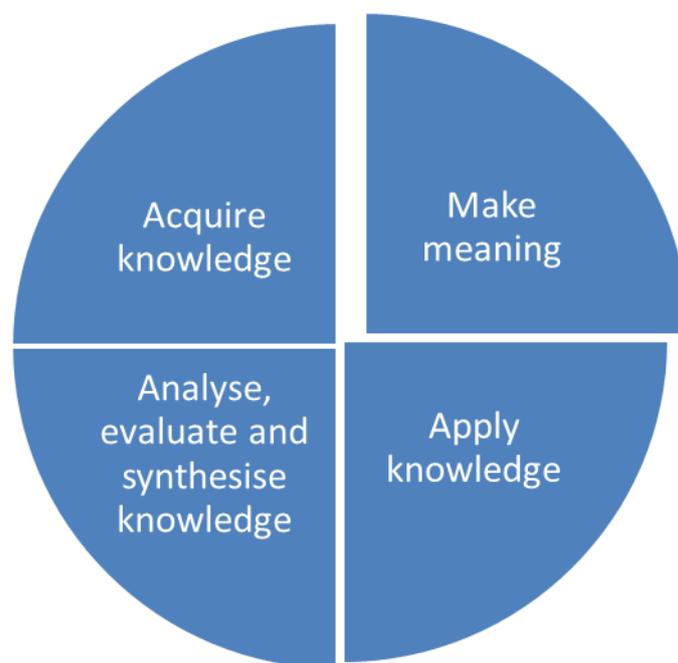
An expectation of being able to perform a Scientific Inquiry is that learners should be able to identify patterns in data obtained from Scientific Investigations and relate these patterns to Natural Sciences concepts, theories or models (United States Department of Education, 2008:73). When assessing Scientific Inquiry, Scientific Investigations should be content rich in

that they require knowledge of Natural Sciences principles to carry them out. These Scientific Investigations if carefully designed can probe learners' abilities to combine their Natural Sciences knowledge with their investigative skills that reflect the nature of Scientific Inquiry (United States Department of Education, 2008:106, 107)

The process of knowledge development involves acquiring knowledge; understanding, comprehending and making connections between ideas to make meaning of the knowledge; applying the knowledge to new and unfamiliar contexts and analysing, evaluating and synthesising scientific knowledge, concepts and ideas (Department: Basic Education, 2011a:16; Hein & Lee, 2000:100).

This process is an integrated process and is represented in the following figure:

Figure 2.4: Knowledge Development Process



Teachers should design assessment activities that assess all four integrated aspects of knowledge development.

During the assessment of knowledge acquisition the teacher should specifically assess learners' abilities to:

- access information from a variety of sources;
- select key ideas;
- recall facts; and
- describe concepts, processes, phenomena, mechanisms, principles, theories, laws, models.

During the assessment of making meaning and achieving understanding the teacher should specifically assess learners' abilities to:

- build a conceptual framework of Natural Sciences ideas;
- organise or reorganise knowledge to derive new meaning;
- write summaries;
- develop flow charts, diagrams and mind maps; and
- recognise patterns and trends.

During the assessment of applying knowledge the teacher should specifically assess learners' abilities to:

- use information in a new way; and
- apply knowledge to new and unfamiliar contexts.

During the assessment of analysing, evaluating and synthesising knowledge the teacher should specifically assess learners' abilities to:

- analyse information/data;
- recognise relationships between existing knowledge and new ideas;
- relate patterns in data to Natural Sciences concepts, theories or models;

- critically evaluate scientific information;
- identify assumptions; and
- categorise information.

(Department: Basic Education, 2011a:16-18; United States Department of Education, 2008:80; Ruiz-Primo & Furtak, 2007:63; Champagne *et al.*, 2000:456-461)

Assessment of the knowledge of Natural Sciences concepts and content provides learners with the means to assess their learning and make connections from prior understandings to new situations that encourage the application of concepts and problem solving skills (Llewellyn, 2005:48).

During performance assessment learners also require knowledge and skills to perform an actual Scientific Investigation.

2.6.2.3 Assessing Scientific Investigation skills

Scientific Inquiry is at the heart of knowing and doing Natural Sciences. A fundamental aspect of inquiry is the design, conduct, and interpretation of empirical Scientific Investigations to answer a question or test a hypothesis. Although a full assessment of Scientific Inquiry is not possible, hands-on Scientific Investigations attempt to approximate this aspect of inquiry under time, space, cost and logistical constraints (United States Department of Education, 2008:107).

Performance assessments require learners to complete or perform complex Scientific Investigations (Duschl & Grandy, 2008:31). Such Scientific Investigations, also referred to as a lab (*cf.* 2.2.2.2), are defined as: “...an experience in the laboratory, classroom, or the field that provides learners with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques, and models” (Singer *et al.*, 2005:3). Learners manipulate selected physical objects and try to solve a Science problem involving the objects (United States Department of Education, 2008:106, 107).

The performance assessment should provide learners with a challenging problem that draws on Natural Sciences concepts and content and leaves learners free to design and carry out a Scientific Investigation to arrive at a solution (United States Department of Education, 2008:107). Within these performance assessments, learners develop an understanding of Scientific Inquiry as well as the ability to do Scientific Inquiry (Black & Harrison, 2010:194; National Science Teachers Association, 2007:2, 4; Champagne *et al.*, 2000:451)

Specific skills related to a performing a Scientific Investigation include:

- identifying a problem;
- hypothesising;
- selecting apparatus or equipment and/or materials;
- planning an investigation;
- recording results; and
- understanding the need for replication or verification.

(Department: Basic Education, 2011a:18-20)

The abovementioned skills would all be required in one form or another to carry out a Scientific Investigation (Department: Basic Education, 2011a:20). These skills provide a valuable framework for teachers to design rating scales, memos and instruments to record the participation of learners (Department of Education, 2002:13). As learners engage in the Scientific Investigation, the teacher is able to collect a variety of information (Champagne *et al.*, 2000:459) thereby gathering evidence of learning.

During the Scientific Investigation the teacher should specifically assess learners' abilities to:

- formulate questions or a hypothesis appropriate to the Scientific Investigation;

- develop a suitable plan for the Scientific Investigation (including selecting appropriate scientific apparatus);
- conduct the Scientific Investigation using appropriate tools and techniques;
- understand laboratory procedures, including health, safety and scientific methods;
- control Scientific Investigation variables;
- collect data; and
- develop a complete description of the Scientific Investigation.

(Department: Basic Education, 2011a:18-20; United States Department of Education, 2008:80; National Science Teachers Association, 2007:4; UNSW, 2011:1; Achieve, 2010:63; Champagne *et al.*, 2000:456-461)

Apart from the ability of learners to conduct the Scientific Investigation they should also be able to employ the necessary Science process skills required in conducting the Scientific Investigation.

2.6.2.4 Assessing Science process skills

A performance expectation of Scientific Inquiry is that learners conduct Scientific Investigations using appropriate tools and techniques (e.g. selecting an instrument that measures the desired quantity: length, volume, weight, time interval and temperature with the appropriate level of precision). Performance assessments should address how well learners are able to carry out these physical processes (United States Department of Education, 2008:73; Hein & Lee, 2000:100).

During the assessment of Science process skills the teacher should specifically assess learners' abilities to:

- follow instructions;

- handle laboratory equipment or apparatus and measurement devices safely and appropriately;
- make accurate measurements;
- make observations; and
- record and report information or data in properly formatted tables and graphs.

(Department: Basic Education, 2011a:18,19; Champagne *et al.*, 2000:456-461)

As can be seen from the abovementioned sections, assessment of Scientific Inquiry involves performance assessments in the form of thinking and reasoning skills, knowledge of Natural Sciences concepts and content, the ability to perform Scientific Investigations and the use of Science process skills. The aforementioned sections covered the specifics of what to assess. The following section will cover the specifics of how to assess.

2.6.3 How to assess the Scientific Inquiry skills of learners

On-going assessment is an integral part of teaching that can foster learning when appropriately designed and used regularly (Duschl *et al.*, 2007:251). Assessment involves four steps namely: generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand and assist the learner's development in order to improve the process of learning and teaching (Department: Basic Education, 2011a:80).

As mentioned previously assessment tasks may be either informal or formal in nature. All assessment tasks should be mapped against the content and intended aims specified for Natural Sciences (Department: Basic Education, 2011a:80). For this to happen, teachers' need to specifically identify what skills and knowledge learners need to achieve by the end of each learning experience. Clear and measurable criteria should be developed to determine if learners have met the identified skills and knowledge. Once the criteria have

been determined the levels of success a teacher may expect to see regarding the identified skills and knowledge should be defined. This may be achieved by describing what an exemplary set of skills and level of knowledge would look like and then describing what an unacceptable set of skills and level of knowledge would look like (Chamberlain & Crane, 2009:80).

It is important to ensure that during the course of a school year a variety of different forms of assessment are used (Department: Basic Education, 2011a:80). Formats for authentic assessment include:

- Scientific Investigations
- Rubrics
- Application questions
- Teacher observation (checklists)
- Verbal explanations; learner-learner or learner-teacher discussions; informal questions
- Interviews with learners
- Data tables, charts, and graphs
- Journals containing written responses; essays; research reports; reflections
- Concept maps
- Projects and products
- Drawings, posters, graphic organisers, and mind maps
- Self-evaluations
- Portfolios

(Chamberlain & Crane, 2009:13, 14; Hammerman, 2006:129; Llewellyn, 2005:115-127)

Teaching and assessment practices should always be aligned so that all assessments are meaningful and can be used to determine what learners have learned (National Science Teachers Association, 2007:4). It is also a known fact that Scientific Investigations and the solving of problems remain a tricky area in assessment. If learners develop the ability to say: "... this is my solution to the problem and here are the assumptions I have made...", how do teachers fully assess learners' solutions and assumptions? There is no perfect instrument. A solution might be for teachers to present learners with a rubric that asks the following questions:

- Did you draw a picture?
- Did you list your assumptions?
- Did you think about how your assumptions will affect the results of your Scientific Investigation?
- Did you try to minimise uncertainties?
- Where do uncertainties come from?

When presented with this rubric, learners should be able to conduct self-assessment to see the way they need to think. In this way, teachers are not telling them what to do, but rather what to worry about (Etkina, 2008:276).

Finally, recording of assessment is a process in which the teacher documents the level of learners' performance in a specific assessment task and indicates learner progress towards the achievement of the knowledge as prescribed in the Natural Sciences Curriculum and Assessment Policy Statement (Department: Basic Education, 2011a:82). Evidence obtained from the assessment of Scientific Inquiry skills will indicate how well the learner has progressed in the development of their problem solving skills.

In the next section, the researcher intends to highlight some of the problems experienced by teachers in teaching by means of Scientific Inquiry. Problems experienced with the implementation of Scientific Inquiry will contribute to the partial or incomplete development of the problem solving skills of learners.

2.7 PROBLEMS WITH IMPLEMENTING SCIENTIFIC INQUIRY

Problem solving in Natural Sciences involves the process of Scientific Inquiry which involves making observations, posing questions and researching with books and other resources to enhance what is already known. This process is supported with experimental evidence where the learner uses current scientific knowledge and understanding to guide a Scientific Investigation (Chamberlain & Crane, 2009:3).

The researcher discovered a wealth of evidence to support the use of the process of Scientific Inquiry in developing the problem solving skills of learners as indicated in the preceding sections. Scientists understand their world by figuring out how to pose questions to the phenomena at hand. This provides a powerful tool for learning Natural Sciences when learners understand their world by asking the right questions to phenomena and not the teacher (Littledyke & Manolas, 2010:294; Duschl *et al.*, 2007:19; Wheeler, 2000:16). This method of learning involves the process of Scientific Inquiry and helps learners to solve many of the problems they will one day encounter in society (Duschl *et al.*, 2007:34; Alberts, 2000:4).

Upon closer examination, however, it was discovered that although this process is a favoured approach, it does not often translate itself in teaching and assessment practices. The researcher will attempt to highlight some of the problems experienced with the implementation of teaching and assessment practices involving Scientific Inquiry.

Scientific Inquiry involving problem solving that engages learners in planning and conducting Scientific Investigations that are both hands-on and minds-on and that involves learning skills that are at the heart of scientific literacy, has not penetrated the implemented Natural Sciences curricula of many schools (Muzah, 2011:196; OECD, 2008:80, 81; Hackling *et al.*, 2001:9). This hampers learners' achievement in the area of developing their problem solving skills

Learner achievement is highly dependent on four major factors:

- a knowledgeable and capable teacher;
- high quality instructional materials, equipment, and resources;
- pedagogical content knowledge; and
- a safe rich environment for learning.

(Department: Basic Education, 2011a:7, 24; Hammerman, 2006:xix)

When problems occur in any of the above areas; it may be safe to assume that problems will occur with the implementation of Scientific Inquiry. Problems experienced with the implementation of Scientific Inquiry will inevitably hamper the development of the problem solving skills of learners.

In reference to the above, Llewellyn (2005:99,100) lists the following specific top ten reasons as to why teachers do not teach through Scientific Inquiry:

- 1) Teachers don't have enough time to do Scientific Inquiry
- 2) Learners are accustomed to getting the answer from their teacher
- 3) Teachers have a final exam they need to teach to
- 4) Learners don't have the skills to do Scientific Inquiry
- 5) Teachers don't have enough supplies and equipment to perform Scientific Inquiry
- 6) Learners need to be told how to do a Science Investigation
- 7) Scientific Inquiry is not a focus of the textbook teachers use
- 8) Scientific Inquiry is not an emphasis in Natural Sciences teaching/ teachers have not had any professional development in teaching by means of Scientific inquiry
- 9) When teachers teach through Scientific Inquiry, they lose control

- 10) Teachers feel more comfortable teaching the traditional experiments as that's the way they were taught

In South Africa research findings relate to and support some of the abovementioned reasons. A short discussion of relevant points follows in which the researcher underpins and supports Llewellyn's claims with current research findings in South Africa.

2.7.1 Reasons why South African teachers do not implement Scientific Inquiry

Teachers who implement Scientific Inquiry during lessons help learners develop their problem solving skills. Unfortunately, due to the following reasons, many teachers do not support the implementation of Scientific Inquiry during teaching:

2.7.1.1 Teachers don't have enough time to do Scientific Inquiry

Time has been described as a major constraint for many teachers (Stern & Marcella, 2008: 268).

In a study performed by Hackling, Goodrum and Rennie (2001:10) involving focus group meetings and telephonic interviews with teachers, Australian schools show that variations in Science teaching time range from a high 4 hours to a low 2 hours and 30 minutes per week. High school teachers indicated that on average Science is taught for 3 hours and 20 minutes per week. In comparison with South Africa, Gr 9 Natural Sciences teachers have a 3 hour weekly teaching time allocation (Department: Basic Education, 2011a:9).

The process of Scientific Inquiry demands time for learners to perform their research, plan and conduct Scientific Investigations and report on their findings. If time allocation for Natural Sciences is slightly limited, as appears to be the case in South Africa when compared with the average time of teaching Natural Sciences in Australia, then the time allowed for a practice such as

Scientific Inquiry will be limited. This may result in teachers sacrificing the practice of Scientific Inquiry in favour of completing the curriculum.

On the opposite side of the coin, even though a slightly limited number of hours have been allocated for Natural Sciences teaching, it has been shown that some teachers are not using their time effectively. A study by Taylor (2008:21) involving national surveys and small descriptive studies shows that the majority of South African schools exhibit a culture which tolerates a very loosely bounded timetable where teachers come and go as they please and teaching happens desultorily. Teachers should be prepared to actively teach for the minimum number of hours a day, every day as specified by policy. This would assist the teacher in ensuring sufficient time for curriculum coverage (Department: Basic Education, 2009:57) and also sufficient time for implementing Scientific Inquiry.

A heavy content and administrative load also adds to the problem of insufficient time. With the introduction of the National Curriculum Statement, controversy was raised almost immediately as the implementation thereof depended on overworked teachers (OECD, 2008:80). In a national investigation conducted in South Africa involving hearings and submissions from teachers to determine the nature of the challenges and problems experienced with the implementation of the National Curriculum Statement it was reported that teachers across the country complained about onerous administration requirements (Department: Basic Education, 2009:8). This curriculum and administrative overload was further confirmed in a statement released by the Minister of Basic Education on the progress of the review of the National Curriculum Statement (Department: Basic Education, 2010).

According to an exploratory study by Muzah (2011:195,196) involving school related factors that cause high matriculation failure rates in public high schools in the Alexandra township in South Africa, it was found that 90% of Science teachers teach 31 lessons or more per week. These teachers are left with few or no free periods to perform administrative duties and other activities such as preparing or changing apparatus for Scientific Investigations. If Gr 9 Natural Sciences teachers are exposed to such a heavy teaching load they will be left

with insufficient time to implement the process of Scientific Inquiry effectively as this process requires time for the development of suitable problems as well as preparation time for the associated Scientific Investigations.

Taylor (2008:24,25) further reports that with the curriculum overload, teaching in most South African schools is moving too slowly to cover anywhere near the demands of the curriculum. Pacing the curriculum so as to achieve the required learning over the year is an art which few South African teachers manage satisfactorily. Teachers who adapt to learners' needs by slowing down the pace of their teaching run out of time and some topics are not taught at all (Stern & Marcella, 2008: 268).

Unfortunately, when there is a heavy content burden or teachers have run out of time to cover the curriculum, expository instruction becomes the only way for teachers to get through the information needed to prepare their learners for the exams. This means that no time is left to deal with critical thinking (Alazzi, 2008:246, 247). Lack of time also causes teachers to modify the curriculum. Teachers make judgments about what may be omitted and teach the more difficult or important topics first (Stern & Marcella, 2008: 268).

The researcher is of the opinion that when teachers are faced with limited time for implementing the curriculum and an increased administrative and curriculum workload, teaching and assessment practices aimed at the development of problem solving skills may be sacrificed in favour of expository teaching. This will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

2.7.1.2 Teachers have a final exam they have to teach to

Increased emphases on standardised tests and the pressure teachers' face to have their learners perform at high levels of achievement have resulted in the phrase "teaching to the test" (Llewellyn, 2005:51).

In an exploratory study by Muzah (2011:192,193, 196) involving public high schools in Alexandra Township in South Africa, Science teachers confirmed that they teach to the test. His findings lead him to conclude that teachers lay

more emphasis on aspects of the Science Curriculum that will be tested at matriculation level and therefore leave out practical work as this is not examinable and is also time consuming. This means that most teachers apply teaching and assessment practices that do not allow learners to take ownership of learning and in so doing reduce teaching to exam spotting and training learners to do well in exams only, rather than developing scientific knowledge and skills through Scientific Inquiry.

The above may also be the scenario in the Gr 9 Natural Sciences classroom. Gr 9 learners also write an end-of-year examination where practical work is not examinable. Some Natural Sciences teachers may focus more on preparing their learners to do well during this exam and neglect the implementation of Scientific Inquiry in the process. Neglecting Scientific Inquiry will lead to the incomplete development of the problem solving skills of learners.

2.7.1.3 Learners don't have the skills to do Scientific Inquiry

According to a report by Taylor (2008:24) involving national surveys and small descriptive studies, evidence is strong that teaching in most South African schools is happening at too low a cognitive level to cover anywhere near the demands of the curriculum.

Often, a lot of time in Natural Sciences classrooms is spent on helping learners take in new information, but with little attention to helping them learn to apply this information to real-life situations (Chamberlain & Crane, 2009:9). A reason for this may be that some teachers have fixed ideas about their learners' cognitive abilities and attitudes. Wallace and Bentley (2002:3) summarised these fixed ideas as follows:

- Intelligence is a fixed commodity, only the brightest learners will ever be able to think logically.
- Some children inherit the capacity to think and solve problems, it is in their genes and they thrive on the challenge.

- Most learners are lazy and don't want to think for themselves.

In an exploratory study that included interviews with teachers from seven schools in South Africa in Tshwane North, teachers made comments such as: "Our children don't want to learn....teachers try their best but they....they never even want to try" and "If our students could be serious about their studies everything would be well" (Mji & Makgato, 2006:260).

Sadly, with this kind of thinking, teachers are known to modify the curriculum according to their learners' characteristics. One Science teacher reported removing the difficult Mathematics to ensure that the learners' lack of Mathematics skills did not hinder the learning of Science concepts (Stern & Marcella, 2008: 268).

It is possible then that the failure of learners to develop the ability to solve problems is not because they are unable to do so, but because teachers don't expose their learners to problem solving activities as they feel their learners are not interested or they may not be able to cope with these activities.

Setting high expectations of learners, including engaging learners at high levels of cognitive demand in the classroom, is associated with improved learning. Teachers should thus demand a high level of cognitive engagement in order to improve learning (Taylor, 2008:17) and thereby develop the problem solving skills of Gr 9 Natural Sciences learners.

2.7.1.4 Teachers don't have enough supplies and equipment to perform Scientific Inquiry

Scientific Inquiry and the advantage of using the laboratory helps learners' improve their higher order thinking skills such as analysis, problem solving and evaluating (*cf.* 2.2.2.2). Mji and Makgato (2006:260, 261, 262) conducted a study in South Africa to establish what factors contribute to the poor performance of learners in Mathematics and Science. Their exploratory study included interviews with teachers and learners from seven schools in Tshwane North. One identified factor was a lack of resources. Both learners and teachers complained specifically about a lack of laboratory equipment.

In another research study conducted by Muzah (2011:192) involving public high schools in Alexandra Township in South Africa, it was shown that these schools are under-resourced in terms of facilities such as laboratories, chairs, tables, chemicals, equipment and a variety of learner-teacher support materials necessary for learners to perform Scientific Inquiry.

These local research findings are supported by international research findings. In a study conducted by Ogunmade (2005:101, 135) in Lagos, Nigeria, involving the status of secondary school Science teaching, teachers indicated that one of the most important factors inhibiting teaching and learning of Science was insufficient resources. Schools lacked laboratories and resources such as chemicals, reagents and equipment.

Many Science teachers believe that Science teaching and learning can be improved with the provision of resources and equipment (Ogunmade, 2005:112). Teacher demonstrations and learners being able to conduct their own Scientific Investigations supplement what is in textbooks and as a result, learning is enhanced (Mji & Makgato, 2006:260, 261, 262). Limited resources, however, encourage teachers to modify the curriculum by omitting hands-on experiences (Stern & Marcella, 2008: 268) resulting in limited or no exposure to the process of Scientific Inquiry.

Taylor (2008:24) brings the argument back to the teacher. Based on a study involving national surveys and small descriptive studies with schools, he argues that a starting point for improved teaching in South Africa will be when teachers take responsibility for the learning outcomes of their learners. This needs to involve a change in attitude on the part of the teachers, from one that blames their situation on forces outside themselves such as a lack of resources to one in which they feel they can improve their own situation by exercising enterprise and energy.

This implies that although teachers have limited resources, they will need to exercise creativity to source alternative resources in order to implement Scientific Inquiry if they wish to develop the problem solving skills of their Gr 9 Natural Sciences learners.

2.7.1.5 Scientific Inquiry is not a focus of the textbook teachers use

Controversy was raised almost immediately after the introduction of the National Curriculum Statement in South African education as the curriculum was heavily reliant on textbooks. Many schools at the introductory stage were already struggling with few and outdated textbooks (OECD, 2008:80).

Textbooks aid curriculum coverage and make available the conceptual logic of the subject in question as the content progresses through the set field of knowledge to be taught and learnt. Textbooks also offer a crucial resource for teachers in their planning and in gaining access to the appropriate knowledge and skills to teach, at an appropriate level (Department: Basic Education, 2009:25).

In South Africa in a national review of the Implementation of the National Curriculum Statement involving hearings and submissions from teachers, it was stated that learners had not been provided with sufficient textbooks and that some textbooks were of dubious quality (Department: Basic Education, 2009:9).

Also, many times, teachers do not have much choice in the textbooks they use. If the material is outdated or the material is not appropriate for learners' abilities and needs, the teacher just has to make do (Chamberlain & Crane, 2009:22). The problem is compounded when teacher manuals do not include strategies to aid the teachers in critical thinking activities. These manuals often include information about the curriculum, with some statements that imply the need for critical thinking teaching strategies, but specific explanations of how critical thinking is to be taught are not included (Alazzi, 2008:246, 247).

In a report issued by the Catholic Institute of Education (CIE, 2010:15) documenting critical insights into the proposed National Curriculum Statement changes and involving consultations with schools around the country, it was said that textbooks will need updating to include all recommended content and teachers will need to be guided with regards to suitable material to be used.

Dubious quality books will hamper the adequate implementation of Scientific Inquiry.

According to a study by Taylor, involving national surveys and small descriptive studies, the use of good textbooks will greatly assist teachers in providing an accessible source for teaching their subject (Taylor, 2008:24). Such books would include suitable Scientific Inquiry activities involving effective problem solving opportunities. The challenge then becomes for Natural Sciences teachers to carefully consider the textbooks they choose (Chamberlain & Crane, 2009:22).

Sadly, another area in need is that even when teachers do have access to a variety of textbooks, they have developed an aversion for these textbooks. This aversion has led them to adopt a single text and allow this text to serve as their year plan, the source of their activities and their interpretation of the curriculum (Taylor, 2008:24, 25). Although many teachers use a single textbook as a basic staple for learning, in a move towards a constructivist teaching culture, teachers need to consider a multi-text approach whilst using primary sources of relevant information as Scientific Inquiry advocates the use of a variety of textbooks during a Scientific Investigation (Chamberlain & Crane, 2009:22; Llewellyn, 2005:52).

A recommendation from a review of the Implementation of the National Curriculum Statement is that the useful role of textbooks and other learning and teaching support materials needs to be communicated to teachers. Teachers should be encouraged to use nationally approved textbooks and Teacher Guides, for both planning and classroom teaching (Department: Basic Education, 2009:54).

According to a statement released by the Minister of Basic Education on the progress of the review of the National Curriculum Statement with regards to the increased and improved use of textbooks and learners support and teaching material, a national catalogue of learning and teaching support materials will hopefully address the above issues (Department: Basic Education, 2010). Natural Sciences textbooks that include comprehensive

Scientific Inquiry and problem solving activities aimed at developing the problem solving skills of Gr 9 Natural Sciences learners will need to be selected for inclusion in this catalogue.

2.7.1.6 Scientific Inquiry is not an emphasis in Natural Sciences teaching/ teachers have not had any professional development in teaching by means of Scientific Inquiry

In many Natural Sciences classrooms, problem solving has not yet achieved primacy over traditional teaching and assessment practices. Bentley and Alouf (*in* Chamberlain & Crane, 2009:3) state that although leaders in the field of Science education continue to promote problem solving (through Scientific Inquiry), traditional didactic expository instructional practices such as teacher-centred whole class lectures and textbook-based read-about-science activities still make up much of the instruction in Natural Sciences classrooms.

A study performed by Hendricks (2008:65) focused on teachers' perceptions of their ability to implement the National Curriculum Statement in the GET-Band in three schools in Somerset East in South Africa. It was found that only 39.7% of teachers *always* implement the National Curriculum Statement effectively, while 44.3% teachers *often* implement the National Curriculum Statement effectively and 15.6 % only *sometimes* implement the National Curriculum Statement effectively. Hendricks' concern is that after such a lengthy period since the introduction of the National Curriculum Statement he would expect that all teachers or at least 90% of teachers would always be able to implement and use the National Curriculum Statement effectively in the classroom.

The above implies that the principle of encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths is not being fully implemented and therefore learners are not being developed to identify and solve problems, collect, analyse, organise and critically evaluate information and make decisions using critical and creative thinking. Thus the problem solving skills of learners are not being developed.

Edelson (2008:177) suggests that teachers have difficulty implementing Scientific Inquiry based elements because they do not fully understand the rationale, they lack the knowledge and skills necessary for implementation, and they do not have prior experiences to draw upon.

In a review of the Implementation of the National Curriculum Statement in South Africa it was reported that many teachers have deficiencies in respect of their subject specialisations and it would appear they have often not been adequately prepared in respect of the appropriate teaching and assessment practices related to their subjects. Teachers also complained that most tertiary institutions did not cover the National Curriculum Statement thoroughly enough and that many newly trained teachers were not competent to teach the curriculum (Department: Basic Education, 2009:10, 55).

An exploratory study by Muzah (2011:191) involving public high schools in Alexandra in South Africa revealed a lack of declarative and procedural knowledge of Science teachers, particularly in terms of steps, methods, strategies and processes to follow in teaching.

Teachers cannot teach learners what they themselves do not understand. A lack of declarative and procedural knowledge hampers the unfolding of Natural Sciences knowledge and content and the development of the problem solving skills of learners.

A study by Taylor (2008:12, 24, 25) involving national surveys and small descriptive studies confirmed there is an urgent need to improve the knowledge of many teachers. The subject knowledge of many teachers does not meet the curriculum standards set for the learners they are teaching. He suggests that intensive in-service training is required to equip teachers with the knowledge they need to teach effectively.

A recommendation from a review of the Implementation of the National Curriculum Statement suggests that teachers should be given guidance and support in the curriculum documents on how to teach specific content, concepts and skills (Department: Basic Education, 2009:27). This means that although the Natural Sciences Curriculum Statement advocates Scientific

Inquiry in developing the problem solving skills of learners, teachers are not fully trained to implement Scientific Inquiry. In other words they are not trained to impart the knowledge and skills necessary for the development of the problem solving skills of learners.

Apart from the lack of training and professional development of teachers, Muzah (2011:198) also highlights the lack of available support for teachers within Science departments. Taylor (2008:23) confirms the need for curriculum support for teachers. Heads of Department should be appointed on the strength of their subject expertise, and they should provide opportunities for teachers to improve their subject and pedagogic knowledge through individual and small group mentoring, establishing peer support groups, and commissioning in-service training for teachers within the school, from external service providers or from district level subject advisors.

The review of the Implementation of the National Curriculum Statement indicates that there are too few subject advisors nationwide to do justice to thorough and qualitative support for teachers. Many subject advisors do not have sufficient knowledge and skills to offer teachers the support they require to improve learners' performance (Department: Basic Education, 2009:8). This means that even if teachers wish to improve their ability to implement Scientific Inquiry they may not have the available support structures to help them do so.

In addition, poor planning skills of Science Department heads result in teachers being appointed as Science teachers for which they have no tertiary training (Muzah, 2011:198). A number of teachers are teaching outside their area of specialisation due to a shortage of teachers in certain subjects (Department: Basic Education, 2009:59).

The South African Education system has experienced constant change and this has resulted in teachers becoming change weary. In order to re-establish the teachers' authority in the classroom, they need to receive comprehensive training in their subject (Department: Basic Education, 2009:57). This means that in order for a teacher to become proficient in developing the problem

solving skills of learners they need to be comprehensively trained in both Natural Sciences content and Scientific Inquiry methodology. Many teachers lack the necessary support at school and local government level. This will result in the Natural Sciences Curriculum and Policy Statement not being implemented effectively leading to the partial or incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

2.7.1.7 When teachers teach through Scientific Inquiry, they lose control

In a review of the South African education policy, large class sizes were highlighted as a problem area experienced by both teachers and learners (OECD, 2008:58, 59). This was confirmed in a report documenting the implementation of the National Curriculum Statement where an overwhelming number of comments referred to overcrowding coupled with the difficulty of implementing the curriculum in large classes. In particular, large class sizes are said to make informal assessment difficult and formal assessment extremely onerous for teachers (Department: Basic Education, 2009:59).

A class size of 40 learners is too large to effectively teach critical thinking skills (Alazzi, 2008: 246, 247). According to an exploratory study by Muzah (2011:193, 194, 195) involving public high schools in Alexandria, large numbers of learners are common in Science classes. Most teachers involved in the study indicated that they teach 46 or more learners in their classes. Such large numbers make practical work more difficult to conduct as these sessions involve preparation of equipment, individual assistance to learners and interactions between learners. With large numbers of learners, noise levels increase and control and discipline may become adversely affected. Teachers have indicated they cannot cope with the teaching of such large classes.

There are however specific methods and approaches to teaching large classes effectively, particularly in the area of classroom management principles (Department: Basic Education, 2009:59). Effective management becomes the key to a Scientific Inquiry-based classroom (Llewellyn,

2005:100, 102). Muzah (2011:196) confirms in his study that deficiencies in effective classroom management skills are common amongst Science teachers.

Although there are difficulties to be found with implementing Scientific Inquiry in overcrowded classrooms, effective classroom management may help the teacher alleviate some of these difficulties.

2.7.1.8 Teachers feel more comfortable teaching the traditional experiments as that's the way they were taught

In the past, teacher training emphasised rote learning, authoritarian teaching and assessment practices and behaviourist pedagogy, leaving most of the profession unprepared for the constructivist teaching approaches of the new curriculum (OECD, 2008:80, 81; Pitsoe, 2007:201).

Constructivist teaching and assessment practices urge teachers to help learners construct their own understanding, reality and knowledge of the natural world through reflection on their own experiences and through interactions with the environment (Pitsoe, 2007:210). In Natural Sciences this involves discovery through Scientific Inquiry which is a process that involves making observations, posing questions and researching with books and other resources to enhance what is already known. This process is supported with experimental evidence where learners use their current scientific knowledge and understanding to guide a Scientific Investigation (Chamberlain & Crane, 2009:3). These practices are effective in developing the problem solving skills of Gr 9 Natural Sciences learners.

According to an exploratory study by Muzah (2011:196) involving public high schools in Alexandra, it appears that the teaching and assessment practices applied by most Science teachers do not allow learners to take ownership of their learning. Teachers see learners as passive recipients of information where teaching is reduced to exam spotting and exam performance rather than the development of scientific knowledge and skills through Scientific Inquiry. Lack of opportunities for learners to explore ideas through Scientific

Investigations implies that Science teaching in these schools still encourages rote learning.

Edelson (2008:180) claims that middle and high school learners are not adequately prepared to engage in Scientific Inquiry, nor are teachers prepared to assist learners in Scientific Inquiry. In South Africa, although teachers received training in the implementation of the National Curriculum Statement, concerns were raised that this training was watered down and inadequate (OECD, 2008:80, 81) therefore leaving teachers unprepared for the implementation of Scientific Inquiry.

There is also a notion that “teachers teach as they have been taught” (Llewellyn, 2005:51). This notion suggests that teachers who were educated in an incompetent manner would have learnt bad practice and are likely to employ the same bad practice when teaching their learners. It is therefore critical that teachers become involved in in-service training courses, which are conducted by a variety of different people. This will hopefully result in changes to teachers’ outdated teaching practices (Mji & Makgato, 2006:262, 263).

While much of non-implementation of the National Curriculum Statement and the Revised National Curriculum Statement may be attributed to insufficient training or even a lack of training, there may be other factors involved with non-implementation.

According to Chang and Green (*in* Alazzi, 2008:247), the job security of lifetime employment has caused teachers to believe that a good teacher teaches the same as the teacher next door. This sense of security has caused teachers to fall into a pattern of teaching that does not foster change and intellectual growth. Teachers may also lack both the practical skills and practical knowledge of how to use certain equipment and therefore choose to avoid practical work completely (Muzah, 2011:193).

Another issue compounding the problem is that according to a report documenting the implementation of the National Curriculum Statement, teachers are change weary and their confidence in teaching has been compromised. Teachers have lost confidence in their practice, and authority

as subject specialists (Department: Basic Education, 2009:16). This may leave the teacher with feelings of “let me rather stick to what I know as things may change again soon”.

Factors such as poor teaching habits or feelings of apathy may lead to the adoption of non-constructivist or poor quality teaching and assessment practices which in turn will inhibit the development of the problem solving skills of Gr 9 Natural Sciences learners.

2.8 SUMMARY

Natural Sciences education seeks to create scientifically literate learners who are able to function as responsible citizens in society. To do this, learners need to become effective problem solvers. The choice of teaching and assessment practices influences the development of the problem solving skills of learners. Problem solving skills may be developed by means of the process of Scientific Inquiry. During this process, learners employ skills used by scientists as they perform a Scientific Investigation to solve a problem. These skills include critical and creative thinking as well as Science process skills. Learners are able to apply scientific knowledge and understanding as they identify a problem, form hypotheses, collect evidence, record their data, organise their findings, create graphs and other forms of communicating their results in addressing the problem and then finally share and justify their observations and findings with the class.

Successful Scientific Inquiry occurs in a classroom environment that ensures learners have a voice, where scientific thinking is valued and needed, where rational disagreement is not penalised and the attitude of the teacher and learners is founded on respect and responsibility.

Not all Science problems lend themselves to the effective development of the problem solving skills of learners. Teachers who present their learners with Science exercises that involve the recall of information or routine application of knowledge to familiar situations and contexts instead of Science problems that employ the use of higher order thinking skills and include the application

of knowledge to unfamiliar situations will contribute to the partial or incomplete development of problem solving skills of learners.

Unfortunately the traditional Scientific Method is often equated with the process of Scientific Inquiry. This is not a positive equation as Scientific Inquiry is regarded as more sophisticated in the sense that Inquiry incorporates the logic of problem solving that comes from the Scientific method, but not necessarily the delineated, specific steps of the Scientific Method.

To successfully assess the development of the problem solving skills of learners means to assess the learners' ability to perform Scientific Inquiry. This requires that learners be engaged in performance assessments where teachers assess learners' engagement in a Scientific Investigation. Such engagement involves the application of critical and creative thinking as well as Science process skills to solving problems similar to those which the learner will encounter in the natural world outside the classroom (Department of Education, 2003: 25). Assessments address learners' ability to carry out physical processes (Scientific Investigation skills and Science process skills) such as measurement, observation, experimental design, problem solving etc; the level of learners' thinking and reasoning skills such as whether learners draw valid conclusions, choose appropriate methods, recognise regularities in nature; as well as learners' knowledge of Natural Sciences concepts and content. If the process of Scientific Inquiry is not implemented correctly then effective assessment of the development of the problem solving skills of learners cannot take place.

Poor implementation of the process of Scientific Inquiry will lead to the poor development of the problem solving skills of learners. Reasons for the ineffective implementation of the process of Scientific Inquiry by teachers may be attributed to poor teaching and assessment practices where under-qualified or unqualified teachers see their learners as possessing limited capabilities; time constraints due to a heavy curriculum content; and administrative load. Further reasons for poor implementation of the process of

Scientific Inquiry may be attributed to teachers who are required to teach in overcrowded and ill-equipped classrooms, with severely limited resources.

Teachers who do not employ comprehensive teaching and assessment practices contribute to the partial or incomplete development of the problem solving skills of Gr 9 Natural Sciences learners. These skills are essential in achieving the goal of Natural Sciences education which is to develop learners who are able to solve problems effectively and efficiently and who ultimately becomes people who can function to the very best of their ability in society.

In the next chapter the research design and methodology of this study will be presented.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

In the previous chapter, an in depth literature study was conducted with regards to defining teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners in South Africa.

The purpose of this chapter is to outline the design and methodology used for this study in order to ascertain if Gr 9 Natural Sciences teachers in South Africa are using suitable teaching and assessment practices for the development of the problem solving skills of learners.

The literature study in chapter two formed a basis for the empirical research design.

In Chapter 1 the objectives of this study were detailed as follows:

- To determine the nature of teaching practices used in the development of the problem solving skills of Gr 9 Natural Sciences learners
- To determine the nature of assessment practices used to evaluate the development of the problem solving skills of Gr 9 Natural Sciences learners
- To develop recommendations to support teachers in the development of the problem solving skills of Gr 9 Natural Sciences learners.

3.2 METHOD OF RESEARCH

3.2.1 Research paradigm

The study followed a positivist research paradigm with a quantitative approach.

Positivism stands for objectivity, measurability, predictability, controllability and constructs laws and rules of human behaviour (Creswell, 2009:7; Dash, 2005).

According to Nieuwenhuis (2007:47, 53) positivists believe that researchers need to use observable, objective facts in building a Science base. These facts are used to discover and confirm a set of probabilistic causal laws that can be used to understand human behaviour. Positivist researchers postulate that there is one objective reality that is observable by a researcher who has little if any impact on the object being observed.

The goal of this study was to obtain quantitative statistical data concerning practices employed by teachers in developing the problem solving skills of Gr 9 Natural Sciences learners.

3.2.2 Research design

A literature review and an empirical investigation were conducted.

3.2.2.1 Literature review

Primary and secondary literature sources were examined in order to gather information concerning the development of the problem solving skills of learners through current teaching and assessment practices in Gr 9 Natural Sciences classrooms in South Africa and other countries.

A variety of electronic databases (NEXUS, EBSCO-Host, ERIC and SA e-Publications), internet websites (<http://www.lch.ch>, <http://www.ei-ei.org>, <http://www.hrw.org>, <http://portal.unesco.org/education>) and internet search engines were used to obtain relevant literature. Key words included the following: problem solving, critical thinking, creative thinking, Natural Sciences teaching; Gr 9 Natural Sciences; Science problem solving process, Scientific Method, Scientific Inquiry, Science process skills, quality teaching and learning, high-level thinking, inductive and deductive reasoning, experimental inquiry, Scientific Investigation, assessment of Scientific Inquiry.

The information gathered through the literature review was used to construct a questionnaire to gather information concerning current teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

3.2.2.2 Empirical research

This study utilised a quantitative research method. Descriptive survey research was conducted by means of a structured questionnaire in order to gather statistical data.

Descriptive survey research was the method of choice as this method involves acquiring information about people's characteristics, opinions, attitudes or previous experiences by asking questions and tabulating their answers. In this way possible correlation between characteristics of phenomena as well as attitudes, opinions and perceptions concerning specific phenomena may be determined (Leedy & Ormrod, 2010:31, 183, 187).

In this study quantitative research questions were used to determine the nature of current teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners. These teaching and assessment practices were correlated with teaching and assessment practices suggested in literature to determine if teachers in South Africa are using effective teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

The questionnaire as measuring instrument

A questionnaire consists of a set of questions for obtaining statistically useful information from individuals (MWD, 2012). The basic objective of a questionnaire is to obtain facts and opinions about a phenomenon from people who are informed on a particular issue (Creswell, 2009:146; Delport, 2005:166)

Questionnaires usually consist of closed or open-ended style questions. Both types of questions may be used to determine a specific objective, and are

best for obtaining demographic information and data that may be categorised easily (McMillan & Schumacher 2006:197). Closed-ended questions are used when all possible, relevant responses to a question can be specified, and the number of possible responses is limited (Maree & Pietersen, 2007:161; Ary *et al.*, 2006: 421). Open-ended questions on the other hand are used when there are a great number of possible answers or when the researcher cannot predict all the possible answers (Ary *et al.*, 2006:421).

Information from an in-depth literature review was used to develop a self-structured questionnaire comprising of closed- and open-ended questions. The role of the questionnaire was to obtain information from teachers concerning teaching and assessment practices used in the development of the problem solving skills of learners in the Grade 9 Natural Sciences classroom in South Africa. Closed-ended questions were used to obtain specific answers from teachers whereas a few open-ended questions were included to qualify and confirm teacher responses to the closed-ended questions. The open-ended questions also provided teachers with an opportunity to define and explain their teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

The choice of a structured questionnaire as the research instrument was based largely on the fact that it is relatively inexpensive, easy to use and teachers were able to complete the questionnaire in a short space of time with their response rate being optimal (Creswell, 2009:146; Maree & Pietersen, 2007:157).

According to McMillan and Schumacher (2006:211), Maree and Pietersen (2007:167), Leedy and Ormrod (2005:185); and Creswell (2009:146) further advantages to the use of a structured questionnaire include that:

- Responses can be gathered objectively and anonymously. This advantage limits researcher bias and complies with ethical principles.
- Information is collected relatively quickly.

- They are easy to score.
- They are effective in determining the frequency and strength of attitude or opinion as envisaged in the study.
- Participants have time to think about their responses before answering.
- Information can be collected from a large portion of a group, i.e. 42 teachers in the Sedibeng West District (D8) of the Gauteng Department of Education.

There are however limitations to the use of a questionnaire. In the context of this research, limitations included that the researcher was not able to gain a deep understanding of the teaching and assessment practices used in the development of the problem solving skills of learners as questionnaires limit probing and clarification of answers and also some respondents might not be completely honest in terms of the use of teaching and assessment practices for problem solving (McMillan & Schumacher, 2006:211; Leedy & Ormrod, 2005:185).

Further limitations in the use of a structured questionnaire include that:

- Some participants may misinterpret certain questions.
- Participants may answer superficially.
- Participants may answer the questionnaire by simply marking the options given to them without reading the questions (McMillan & Schumacher, 2006:211; Leedy & Ormrod, 2005:185).

The researcher took into account all of the above advantages and limitations of using a questionnaire for research purposes. In an attempt to prevent these limitations from causing a major setback in the study in terms of the incorporation and use of unreliable information, the researcher incorporated both closed and open-ended questions in the questionnaire. In the open-ended questions teachers could not hazard a guess, but had to think and reason before attempting to answer these questions. Incongruence's in

information were noted by discrepancies in teachers' responses to the closed and open-ended questions.

The design of the questionnaire

The format and layout of the questionnaire are as important as the nature and wording of the questions asked (Delpont, 2005:170). A well-constructed questionnaire is an important factor in influencing the response rate (Maree & Pietersen, 2007:159; Ary *et al.*, 2006:428).

Questionnaires should be clear, neat and easy to follow (Maree & Pietersen, 2007:159; Delpont, 2005:170). Questions with similar content should be grouped together (Maree & Pietersen, 2007:160; Ary *et al.*, 2006:428) with each question containing only one thought (Delpont, 2005:171). Once the questions are written, apart from being grouped according to similar content, they must be arranged in an appropriate order. The order is important as this can influence the respondents' interest in completing the questionnaire (Maree & Pietersen, 2007:160). The first question should be especially interesting and easy enough for all respondents to interpret and answer. If respondents are motivated to answer the first question, they are more likely to continue with the questionnaire. Researchers further recommend that the first few questions should be closed-ended questions (Ary *et al.*, 2006:428).

With the above in mind, a carefully self-structured questionnaire containing clearly defined questions and presented in a neatly laid out, user friendly format was compiled for the purpose of this study. The questionnaire consisted of 36 closed-ended questions and 9 open-ended questions. An easy first question i.e. 'I make use of the Scientific Method', was followed by questions containing a single thought which were grouped together and ordered according to a SWOT analysis (strengths, weaknesses, opportunities and threats) of teaching and assessment practices for developing the problem solving skills of Gr 9 Natural Sciences learners. The SWOT analysis was performed by the researcher using information obtained from the in-depth literature review.

Closed-ended questions were used to obtain specific answers from teachers regarding the implementation of Scientific Inquiry for the development of the problem solving skills of learners. Although teaching practices encompass assessment practices, the intention of the researcher was to find detailed evidence of the implementation of Scientific Inquiry for the development of the problem solving skills of learners. If little or no evidence was found then this would mean the teacher would be unable to effectively assess the development of the learners' problem solving skills. Open-ended questions were included in the questionnaire to qualify and confirm teacher responses to the closed-ended questions as well as to provide them with an opportunity to define and explain their assessment practices.

Once questions are formatted, a scale needs to be assigned to each closed-ended question. A scale is used to measure attitudes, values, opinions and other characteristics and consists of a set of numeric values assigned to individuals, objects or behaviour for the purpose of measuring variables. Scales are used to measure the degree to which an individual exhibits the characteristic of interest (Ary *et al.*, 2006:226). For the purpose of this study, a four-point Likert-scale was used for the closed-ended questions. The scale ranged from 1 to 4, with 1 being "Almost always", 2 "Often", 3 "Sometimes" and 4 "Very seldom". The teachers' responses were summarised with percentages and frequency counts.

Questionnaires need to be kept as short as possible (Ary *et al.*, 2006:431) with adults being able to complete a questionnaire in less than 20 minutes (Maree & Pietersen, 2007:159). On average, teachers were able to complete the questionnaire designed for this study within 20 minutes.

After careful consideration of the design of the questionnaire, it is important that all respondents be provided with clear and precise instructions on how to answer the questionnaire (Delport, 2005:171). The questionnaire was accompanied with a research information sheet specifically designed to outline the purpose of the study for teachers as well as provide them with detailed instructions on how to complete the questionnaire.

The validity of the questionnaire

A questionnaire's measurement may be deemed valid when the following questions in terms of face, content, construct, and criterion validity are answered positively by the researcher and the supervisor:

Face validity is concerned with how the questionnaire appears. Does it seem like a reasonable way to gain the information the researcher is attempting to obtain; does it seem well designed; does it seem as though it will work reliably (Delpont, 2005:162; Fink, 1995)?

To ensure the face validity of the questionnaire, the researcher invited the opinion of the supervisor to ascertain whether it 'appeared' valid in terms of measuring teaching and assessment practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners in South Africa.

Content validity provides evidence about the construct validity of the questionnaire (Delpont, 2005:162; Haynes *et al.*, 1995:3). A construct may be any attribute, proficiency, ability, or skill that is defined by established theories (Ary *et al.*, 2006:38; Brown, 2000:2). Content validity represents the degree to which elements of the questionnaire are relevant to and representative of a construct identified for assessment purposes. In other words do the elements in the questionnaire measure the content they were intended to measure (Creswell, 2009:149; Haynes *et al.*, 1995:2)?

Construct validity is defined as the extent to which the questionnaire measures the construct it is supposed to measure (Bell, 2006-2011).

To ensure content and construct validity of the questionnaire any construct emanating from the research questions was required to be included and addressed. The identified construct was 'teaching and assessment practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners'. A thorough literature review was performed to provide a detailed definition of this construct. This definition ensured all possible facets of the construct were included and scores from the questionnaire reflected whether a teacher employs teaching and assessment practices aimed at developing

the problem solving skills of Gr 9 Natural Sciences learners. The researcher also invited the opinion of the supervisor of this study who evaluated the questionnaire according to her technical expertise in order to ensure content and construct validity had been achieved.

To measure the criterion validity of a questionnaire a researcher must calibrate it against a known standard or against itself. Comparing the questionnaire with an established questionnaire is referred to as concurrent validity; testing the questionnaire over a period of time is known as predictive validity. Using any one of these methods may be regarded as sufficient if the research design is strong (Shuttleworth, 2009).

The researcher performed a literature survey to establish if a questionnaire existed that tests if teachers employ practices aimed at developing the problem solving skills of Gr 9 Natural Sciences learners in South Africa. No suitable questionnaire was found that fully meets the requirements of this study. The researcher therefore constructed a new questionnaire.

A questionnaire's measurement may be deemed reliable when there is consistency of measurement, meaning that if the same attribute is measured under the same conditions then an identical measurement will be obtained (Creswell, 2009:149; Delport, 2005:163). The reliability of the questionnaire for this study was found to be acceptable as clearly defined and precise questions and criteria addressed the construct with the added measure of the allocation of more than one question/ criteria for each attribute being measured.

Questionnaire distribution

The questionnaire was self-administered (personally handed to the teachers to complete). The researcher was available for guidance either directly or via e-mail, where problems were encountered.

3.2.3 Research population and sample

A research population includes individuals who possess specific attributes that represent all the measurements of interest to the researcher (Strydom, 2005:204). The population for this study comprised of Gr 9 Natural Sciences teachers in South Africa.

For the purpose of this study the method of random sampling was employed as this ensured a representative sample where each member of the population had exactly the same chance of being selected (Creswell, 2009:217; Strydom, 2005:196).

According to Creswell (2009:217) a typical sample size of 5 to 25 participants should be selected, all of whom have direct experience with the phenomenon being studied (Leedy & Ormrod, 2010:141). The sample for this study consisted of teachers from the Sedibeng West District (D8) of the Gauteng Department of Education. The Sedibeng West District (D8) comprises of 78 (n=78) Natural Sciences teachers. A total of 42 questionnaires were completed. The reason for all 78 Natural Sciences teachers not completing questionnaires may be attributed to some teachers being included in the pilot study and some teachers not having sufficient time or not wanting to participate in the study.

The researcher acknowledges that the sample might be less representative of the population and that the generalising of the findings is limited to the teachers who took part in the study (McMillan & Schumacher, 2006:125). Teachers who participated in this study were heterogeneous in terms of the characteristics of the population, namely culture, home language and gender.

3.2.4 Data collection process

In this study, quantitative data was collected by means of a self-constructed questionnaire. The phases in the collection of data were as follows:

- The necessary permission to conduct this study was obtained from the Gauteng Department of Education.

- The necessary permission was obtained from the relevant school principals.
- Once teachers were approached to participate in the study and their permission was obtained, the researcher worked strictly according to ethical considerations in order to ensure the voluntary and active participation of all teachers in the study.

3.2.4.1 Data analysis and interpretation

The data gathered through questionnaire responses was analysed through statistical procedures.

Descriptive statistics

Descriptive research outlines specific details of a situation and focuses on 'how' and 'why' questions (Fouché & de Vos, 2005: 106). Information gathered relating to teaching and assessment practices surrounding the development of the problem solving skills of Gr 9 Natural Sciences learners, was focused on specific questions posed to teachers that remained constant throughout the entire study.

The Statistical Consultancy Services of the North West University: Vaal Triangle Campus was consulted for assistance with the capturing, analysis and interpretation of the collected data. Descriptive statistics was used to organise and summarise the data in order to promote an understanding of the data characteristics (Leedy & Ormrod, 2005:257-267). Various calculations performed included frequencies, means and percentages. This enabled the researcher to determine how teachers develop the problem solving skills of learners in the Gr 9 Natural Sciences classroom. All of the results are presented in graphical and tabular format in chapter 4.

Inferential statistics

Inferential statistics enables the researcher to reach conclusions that extend beyond the immediate data (Trochim, 2006). These statistics allow the researcher to make inferences about the population from the sample used

(Leedy & Ormrod, 2005:267). The population for this study comprised of Gr 9 Natural Sciences teachers in South Africa. It was not possible to conduct research with all of these teachers. A total of 42 out of a possible 78 teachers in the Sedibeng West District (D8) completed questionnaires. The teachers who responded may not be representative of the entire population; therefore, the findings of this study will be limited to the teachers who took part in the study.

3.2.5 Ethical considerations

As researchers anticipate data collection, they need to respect the participants and the sites of research (Creswell, 2009:89). This requires that researchers, be cognisant of their impact and therefore minimise disruption of the physical setting. Teachers in this study gave their informed consent to participate which means that all teachers were completely informed about the aim, the process and the benefits of the research (Leedy & Ormrod, 2005:101; Creswell, 2009:89).

Some elements of this consent included the following:

- Application for ethical approval for this study was submitted to the North-West University according to protocol. Once approval was obtained, further permission to conduct the study was obtained from the Gauteng Department of Education as well as the relevant principals and teachers.
- Participation in this study was strictly voluntary. Recruitment took place in such a way that the teachers did not feel intimidated or bribed to form part of the study.
- No activities exposed teachers to physical, emotional or psychological harm including being subjected to any undue stress or embarrassment (Leedy & Ormrod, 2005: 101).
- No teacher was forced by the researcher to participate or continue participation in the study. Teachers were made aware that they may

withdraw from the study at any time without discrimination and without the necessity of providing reasons.

The above information was verified by means of the inclusion of a consent form and research information sheet for teachers and principals. All consent forms were signed by the teacher and relevant principal.

3.3 CONCLUSION

In this chapter the research design was briefly presented with the research method and development being outlined.

The researcher wishes to emphasise that caution needs to be applied when any inferences are made concerning this study as survey research captures a brief moment in time. This study relies on data where teachers told the researcher what they believe to be true or even perhaps what they thought the researcher wanted to hear. Furthermore as teachers' answers were constructed on the spot, when answering the questionnaire, their responses may have been influenced by recent events or contexts in their lives (Leedy & Ormrod, 2005:184,185). This implies that teachers' responses are only as good as the moment in which they were made.

The following chapter will present the data analysis and interpretation.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

The aim of this research was to determine teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners with the objective of developing recommendations to support teachers in this regard (*cf.* 1.4).

The target population of the empirical survey included Gr 9 Natural Sciences teachers in South Africa. The sample for this research consisted of teachers from the Sedibeng West District (D8) of the Gauteng Department of Education and comprised of 78 Natural Sciences teachers (*cf.* 1.6.2.2).

One of the advantages of employing questionnaires as a research instrument in a study is that it is a relatively quick process and information may be collected from a large number of teachers (*cf.* 1.7.1.1). To ensure a high return rate, 78 questionnaires were hand distributed to teachers in the Sedibeng West District (D8). Of the 78 questionnaires, 42 were returned. The reason for all questionnaires not being returned may be attributed to some teachers being included in the pilot study and some teachers not having sufficient time or not wanting to participate in the study. This return rate is acceptable according to the required sample size as specified by Creswell (*cf.* 1.6.2.2).

4.2 SECTION A: SURVEY DETAILS

This section of the research was for office use only. The researcher completed these items.

4.2.1 Record number

Out of a possible 78 teachers in the Sedibeng West District (D8), a total of 42 questionnaires were completed.

4.2.2 Name of researcher

The name of the researcher, A.E. Vicente, was printed on the questionnaire for the responding teachers' attention.

4.2.3 Date of retrieval of the questionnaires

The teachers filled in the date when they completed the questionnaire.

4.3 SECTION B: GENERAL BACKGROUND INFORMATION

4.3.1 Teaching district

All respondents were Gr 9 Natural Sciences teachers, who taught in the Sedibeng West District (D8) of Gauteng Province.

4.4 SECTION C: PERCEPTIONS OF TEACHING PRACTICES–CLOSED-ENDED QUESTIONS

Developing the problem solving skills of Gr 9 Natural Sciences learners requires that teachers employ certain teaching practices. A teaching practice, identified in literature that assists in developing the problem solving skills of Natural Sciences learners, is Scientific Inquiry. Scientific Inquiry is a process whereby learners make observations, pose questions and research with books and other resources to enhance what they already know. This process is supported with experimental evidence where learners use their current scientific knowledge and understanding to guide a Scientific Investigation as they search for solutions to problems (*cf.* 2.4).

The researcher explored current teaching practices employed for the development of the problem solving skills of Gr 9 Natural Sciences learners. The information gathered was used to compile a questionnaire to assist the researcher in determining what teaching practices are currently used in the Gr 9 Natural Sciences classroom for developing the problem solving skills of learners. The questionnaire detailed closed-ended questions relating to teaching practices surrounding the process of Scientific Inquiry and Scientific Investigations.

'Teaching practices' is a broad term that encompasses many practices carried out during the course or teaching. Assessment is a practice critical to the process of teaching as this practice supports learning through the use of good feedback methods (Duschl & Grandy, 2008:29). Effective assessment practices need to be employed if teachers wish to develop the problem solving skills of Gr 9 Natural Sciences learners. The focus of the closed-ended questions was centred on obtaining detailed evidence regarding the implementation of Scientific Inquiry. The assessment of the Scientific Inquiry capabilities of learners was addressed in the open-ended questions of the questionnaire. The researcher is of the opinion that if the process of Scientific Inquiry is not being implemented correctly, teachers will not be able to effectively assess the development of the problem solving skills of learners.

A discussion of current teaching practices employed for the development of the problem solving skills of Gr 9 Natural Sciences learners follows.

Table 4.1 depicts data on whether teachers employ the Scientific Method during teaching:

Table 4.1: I make use of the Scientific Method

	Frequency/ f	Valid Percent/ %
Almost always	17	40.5
Often	15	35.7
Sometimes	7	16.7
Very seldom	3	7.1
Total	42	100.0

According to the data in Table 4.1, 40.5% of the teachers indicate that they *almost always* make use of the Scientific Method during lessons and 35.7% of the teachers *often* make use of the Scientific Method. Only 7.1% of teachers *very seldom* make use of the Scientific Method.

Solving problems requires that teachers implement the process of Scientific Inquiry (*cf.* 2.2). Scientific Inquiry is often equated with the traditional Scientific Method which is based on the view that doing Science means doing experiments. Scientific Inquiry thus becomes a sequence of steps to be followed in order to reinforce concept objectives (*cf.* 2.3).

The results in Table 4.1 show that many teachers (76.2%) *almost always* or *often* implement the Scientific Method. This result is supported by the responses indicated in Table 4.12 where many teachers (61%) *almost always* or *often* feel that doing Science means doing experiments. Responses to the open-ended questions provide additional support for these findings (*cf.* 4.5.2; 4.5.9). This may pose a problem when it comes to developing the problem solving skills of Gr 9 Natural Sciences learners as Scientific Inquiry is seen to be more sophisticated than the Scientific Method (*cf.* 2.3). Scientific Inquiry incorporates the logic of problem solving that comes from the Scientific Method, but not necessarily the delineated, specific steps. Scientific Inquiry also recognises that results from Scientific Investigations are used to build scientific theories and models in order to solve problems (*cf.* 2.3).

Figure 4.1: Comparison of teachers who make use of the Scientific Method and those who claim that doing Science means doing experiments

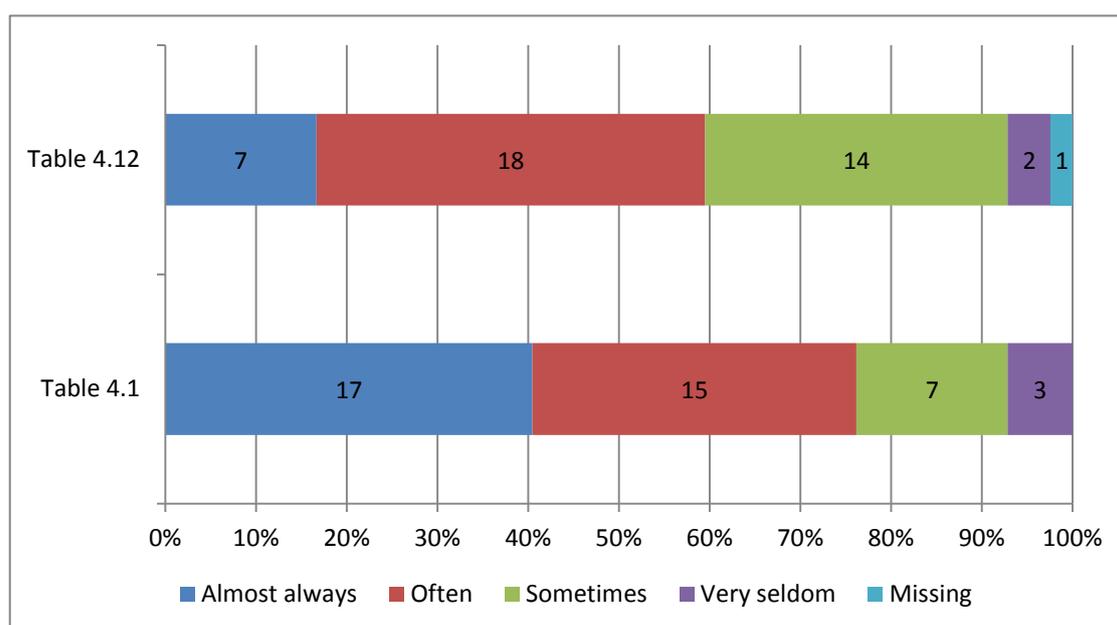


Table 4.2 depicts data on whether teachers think that Scientific Inquiry requires learners to solve problems.

Table 4.2: Scientific Inquiry requires learners to solve problems

	Frequency/ f	Valid Percent/ %
Almost always	20	48.8
Often	16	39.0
Sometimes	4	9.8
Very seldom	1	2.4
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.2, 48.8% of teachers recognise that Scientific Inquiry requires learners to *almost always* solve problems and 39.0% recognise that Scientific Inquiry *often* requires learners to solve problems. Only 2.4% of teachers recognise that Scientific Inquiry *very seldom* requires learners to solve problems.

Scientific Inquiry involves identifying problems and solving these problems by using various skills (*cf.* 2.4). However, the traditional Scientific Method also requires learners to identify and solve problems according to a sequence of steps (*cf.* 2.3). The results in this table show that a high percentage of teachers (87.8%) believe that Scientific Inquiry *almost always* or *often* requires learners to solve problems. Teachers may have answered this question in relation to the Scientific Method. In order to qualify this set of results, the researcher examined the open-ended question, “What does the term Scientific Inquiry mean to you?”

The responses to the open-ended question reveal that only 10 out of a possible 42 teachers are able to provide a quality explanation for Scientific Inquiry (*cf.* 4.5.2). Of the 42 teachers, 22 indicate that they received formal

training in the process of Scientific Inquiry. Teachers' responses to this question are supported by the data presented in Table 4.1 and 4.12 which show that many teachers *almost always* or *often* make use of the Scientific Method and many teachers *almost always* or *often* feel that doing Science means doing experiments.

It appears from the above data that there may be a need for training teachers in the process of Scientific Inquiry. It is however quite disconcerting that only 10 out of the 22 teachers who received training were able to provide a quality explanation for what the term Scientific Inquiry means.

It is the opinion of the researcher that many teachers have a limited understanding of Scientific Inquiry and see it more as the traditional Scientific Method that relates to a set of sequenced steps to be used to guide an experiment. If this is the case then teachers will be unsuccessful in the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.3 presents data on whether teachers design problems that stretch the learners' imagination.

Table 4.3: I design problems that stretch learners' imagination

	Frequency/ f	Valid Percent/ %
Almost always	12	28.6
Often	20	47.6
Sometimes	9	21.4
Very seldom	1	2.4
Total	42	100.0

The data in Table 4.3 reveals that 28.6% of teachers *almost always* design problems that stretch learners' imagination, 47.6% *often* design problems to stretch the learners' imagination, while only 2.4% *very seldom* design problems to stretch the learners' imagination.

During the solving of Science problems when learners come across information that does not match their existing ideas they need to employ thinking that is novel or 'outside the box' in order to solve the problem. Such thinking is known as creative thinking and is characterised by daring, uninhibited, fanciful, imaginative, free spirited, unpredictable and revolutionary thinking. Creative thinking skills are necessary for the development of the problem solving skills of learners (*cf.* 2.2.1.1).

The data presented in Table 4.3 is encouraging in that many teachers (76.2%) *almost always* or *often* recognise the need to employ problems where learners are required to think 'out the box' and thus stretch their imagination. However, responses to the open-ended questions (*cf.* 4.5.2; 4.5.9) indicate that many teachers present their learners with problems where the learners are given both the goal of the problem and strategies to reach the goal as well as step-by-step instructions to follow. These types of Science problems will not allow learners to employ creative thinking skills and thereby limit the development of their problem solving skills.

Table 4.4 depicts data on whether teachers allow their learners to wrestle with possible answers to problems before they tell them the answer.

Table 4.4: I allow learners to wrestle with possible answers to a problem before telling them the answer

	Frequency/ f	Valid Percent/ %
Almost always	15	35.7
Often	21	50.0
Sometimes	3	7.1
Very seldom	3	7.1
Total	42	100.0

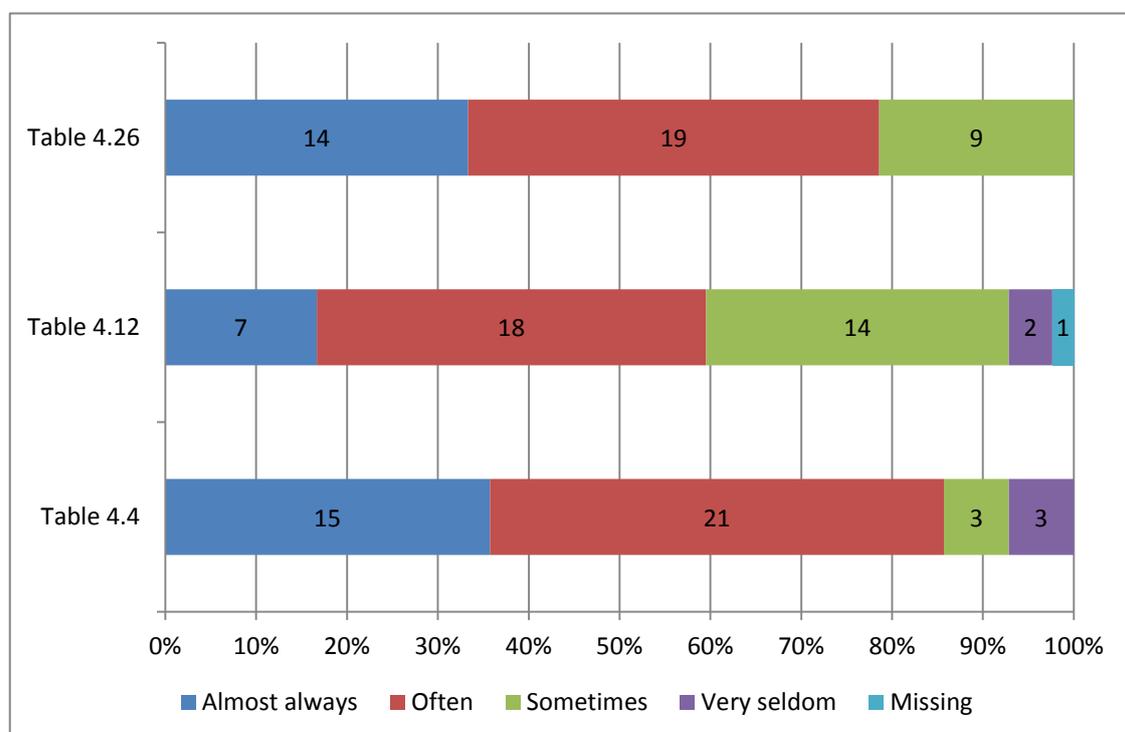
The data in Table 4.4 reveals that 35.7% of teachers *almost always* allow learners to wrestle with possible answers before telling learners the answer, 50.0% of teachers *often* allow learners to wrestle with answers and only 7.1%

very seldom allow learners to wrestle with answers before telling them the answers.

During Scientific Inquiry, learners should not only struggle with possible answers to problems, but they should also suggest and carry out simple Scientific Investigations to test some of their ideas or answers (*cf.* 2.4.1).

According to the data in Table 4.4, many teachers (85.7%) *almost always* or *often* allow their learners to wrestle with possible answers to a problem before telling them the answer. In terms of carrying out investigations to test their ideas or answers (*cf.* Table 4.26), many teachers (78.5%), *almost always* or *often* afford their learners such opportunities. This finding is in contradiction with the data presented in Table 4.12 where many teachers (61%) indicate that they *almost always* or *often* feel that doing Science means doing experiments.

Figure 4.2: Comparison of teachers who allow learners to wrestle with problems, perform experiments and perform Scientific Investigations



The responses to the open-ended questions (*cf.* 4.5.9) indicate that although teachers say they allow their learners to wrestle with problems before they tell them the answer, in reality they do not provide learners with such opportunities. The researcher is of the opinion that the above scenario may indicate that teachers think they are implementing Scientific Inquiry, when in fact they are not. This may be due to teachers possessing a limited understanding of what Scientific Inquiry entails as mentioned in the discussion under Table 4.2.

If teachers do not create opportunities for Gr 9 Natural Sciences learners to wrestle with problems before giving them the answer, it will lead to the incomplete development of their problem solving skills.

Table 4.5 depicts data on whether teachers think Scientific Investigations help learners to understand scientific ideas.

Table 4.5: Scientific Investigations help learners to understand scientific ideas

	Frequency/ f	Valid Percent/ %
Almost always	19	45.2
Often	17	40.5
Sometimes	5	11.9
Very seldom	1	2.4
Total	42	100.0

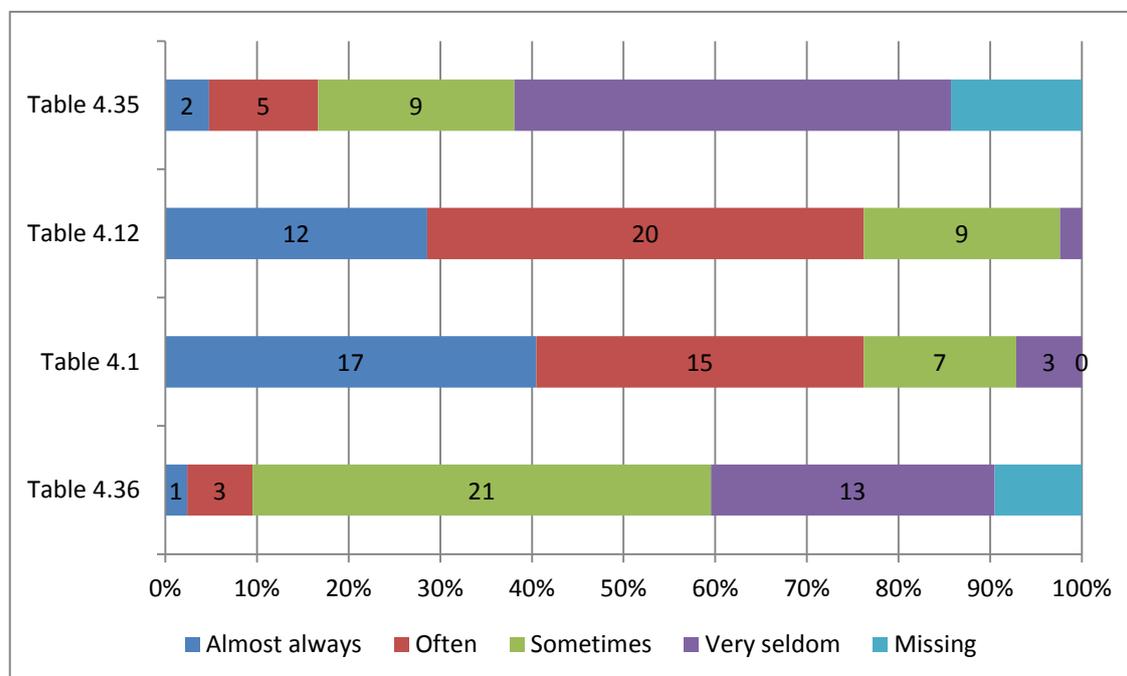
According to the data in Table 4.5, 45.2% of teachers feel that Scientific Investigations *almost always* help learners to understand scientific ideas, and 40.5% of teachers feel that Scientific Investigations *often* help learners understand scientific ideas. Only 2.4% of teachers feel that Scientific Investigations *very seldom* help learners to understand scientific ideas.

Scientific Investigations help learners to gain an understanding of Natural Sciences ideas when they use Science process skills to solve a problem.

Science process skills refer to the learners' cognitive activity of creating meaning and structure from new information and experiences. During a Scientific Investigation learners become engaged in Science process skills such as observation, classification, measurement, mathematic calculations and making predictions. These skills enable learners to make connections between ideas and concepts in their minds and to apply this knowledge to new contexts or situations (*cf.* 2.2.1.2).

The above results are encouraging in that they appear to indicate that many teachers (85.7%) recognise that Scientific Investigations are *almost always* or *often* valuable in helping learners understand scientific ideas. This relates to the data in Table 4.21 where many teachers (78.6%) indicate that they *almost always* regard Science as a process of improving understanding. Also, not only do teachers recognise the value of Scientific Investigations but 78.5% of teachers support this notion by *almost always* or *often* allowing their learners to perform Scientific Investigations (*cf.* Table 4.26). This results in 83.3% of the teachers *almost always* or *often* feeling confident that their learners are able to apply their existing knowledge to new situations (*cf.* Table 4.11).

Figure 4.3: Comparison of teachers who claim that Scientific Investigations help learners to understand scientific ideas, that Science is a process of improving understanding and who allow learners perform Scientific Investigations



The above findings indicate that teachers fully recognise the value of Scientific Investigations in promoting the problem solving skills of learners. However, although teachers may recognise the value of a Scientific Investigation, this does not mean they implement this realisation. Responses to the open-ended questions indicate that learners are presented with a problem along with step-by-step instructions to follow during the solving of the problem (*cf.* 4.5.2; 4.5.9). Such activities support the Scientific Method and although this method may help learners exercise their Science process skills, it provides for a limited form of understanding of Natural Sciences ideas and concepts. The Scientific Method merely acts to reinforce given ideas and concepts and does not help the learners to make connections between ideas and concepts in their minds. This limited understanding will not fully enable learners to apply their knowledge to new situations thereby hampering the development of learners' problem solving skills.

Table 4.6 depicts data on whether teachers connect new learning content with what the learner already knows.

Table 4.6: I connect new learning content with what the learner already knows

	Frequency/ f	Valid Percent/ %
Almost always	27	64.3
Often	11	26.2
Sometimes	3	7.1
Very seldom	1	2.4
Total	42	100.0

The data in Table 4.6 reveals that 64.3% of teachers *almost always* connect new learning content with what the learners already know. 26.2% *often* connect new learning content with what the learners already know, while only 7.1% *sometimes* connect new learning content with what the learners already know.

Constructivists perceive learning as a process by which learners are theory builders, where learners' constantly assimilate and accommodate knowledge in their minds through interpretations of their experiences. Constructivist teachers constantly connect their learners' prior knowledge and experiences with new knowledge and concepts. This constructivist approach supports the development of the problem solving skills of learners (*cf.* 2.4.2).

The responses indicated in the above table are encouraging in that many teachers (90.5%) feel they *almost always* or *often* connect new content with what the learner already knows. However, the data obtained from the open-ended questions (*cf.* 4.5.5; 4.5.9) show that few teachers connected prior knowledge and experiences to new knowledge and concepts.

If teachers are unable to connect new learning content with what the learner already knows it will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.7 indicates data on whether teachers teach higher order thinking skills.

Table 4.7: I teach higher order thinking skills

	Frequency/ f	Valid Percent/ %
Almost always	6	14.3
Often	24	57.1
Sometimes	9	21.4
Very seldom	3	7.1
Total	42	100.0

According to the data in Table 4.7, 14.3% of teachers *almost always* teach higher order thinking skills, while 57.1% *often* teach higher order thinking skills and 21.4% *sometimes* teach higher order thinking skills.

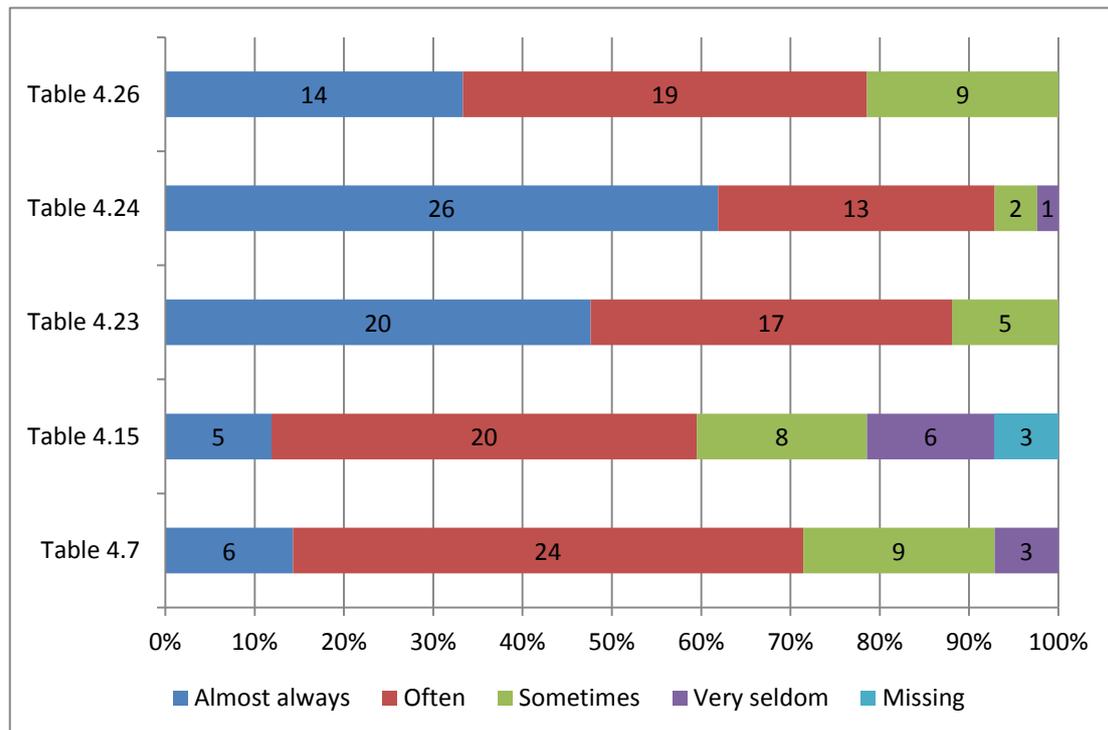
Higher order thinking skills are characterised by cognitive capabilities such as critical thinking, question asking, evaluative thinking, decision making and problem solving. This type of thinking requires that learners understand the facts, connect them together, categorise them, manipulate them, arrange them in new or novel ways, and apply them as they look for solutions to problems (*cf.* 2.2.2).

Higher order thinking cannot be realised by teaching alone. It is essential that connections be made between theory and practice in order that learners are enabled to apply higher order thinking during learning (*cf.* 2.2.2). Scientific Inquiry and Scientific Investigations help learners' improve their higher order thinking skills such as analysis, problem solving and evaluating (*cf.* 2.2.2; 2.4.1; 2.7.1.4).

The responses indicated by the data in Table 4.7 show that many teachers (71.4%) *almost always* or *often* teach higher order thinking skills. Also, 92.9% of teachers are of the opinion that higher order thinking skills *almost always* or *often* develop with practice (*cf.* Table 4.24). It is therefore promising to further see by the data represented in Table 4.23 that the teaching of higher order thinking skills is supported with practice where many teachers (88.1%) indicate that they encourage learners to *almost always* or *often* use these skills during problem solving. The practice of higher order thinking skills is supported by the data in Table 4.26 where many teachers (78.5%) claim that they *almost always* or *often* afford their learners the opportunity to perform Scientific Investigations.

Teaching and the practice of higher order thinking skills during Scientific Inquiry assists the learners in developing their problem solving skills. The above results are promising if teachers are indeed making connections between teaching higher order thinking skills and the practicing of these skills. Unfortunately, the data presented in Table 4.15 suggests otherwise, in that many teachers (64.1%) *almost always* or *often* formulate questions where learners are required to recite facts. As mentioned in the discussions of the data depicted in Table 4.15, 4.23 and 4.24, presenting learners with Science exercises that involve the simple recall of information as opposed to presenting learners with Science problems that involve higher order thinking, will not allow learners to practice their higher order thinking skills. This contradiction is further supported by the responses to the open-ended questions (*cf.* 4.5.9) that indicate problems are presented to learners in the form of Science exercises that involve the simple recall of facts during the application of step-by-step instructions to solve a problem. These Scientific Investigations merely allow learners to exercise their Science process skills.

Figure 4.4: Comparison of teachers who teach higher order thinking skills, who formulate questions where learners recite facts, who encourage learners to use higher order thinking skills during problem solving, who claim that higher order think skills develop with practice and who allow learners to perform Scientific Investigations



The researcher therefore wishes to voice concern that although it may appear as though higher order thinking skills are being taught and practiced this cannot happen when learners are being exposed to Science exercises only. This might imply that teachers may not fully understand what the practicing of higher order thinking skills entails and this could relate back to the discussion under Table 4.2 where the researcher suggests that Gr 9 Natural Sciences teachers possess a limited understanding of what Scientific Inquiry involves.

Table 4.8 depicts data on whether teachers act as facilitators during classroom discussions.

Table 4.8: I act as facilitator during classroom discussions

	Frequency/ f	Valid Percent/ %
Almost always	16	38.1
Often	13	31.0
Sometimes	9	21.4
Very seldom	4	9.5
Total	42	100.0

According to the data in Table 4.8, 38.1% of teachers *almost always* act as facilitators during classroom discussions and 31.0% *often* act as facilitators during classroom discussions. Only 9.5% indicate that they *very seldom* act as facilitators during classroom discussions.

In a constructivist classroom, the teachers' role is that of facilitator rather than a dispenser of information (Llewellyn, 2005:30). By using analogies and having learners raise their own questions, constructivist teachers are able to connect learners' prior knowledge and experiences to new knowledge and concepts. This means that during the process of Scientific Inquiry, upon completion of a Scientific Investigation, teacher led classroom discussions focus learners on their experience, data and conclusions related to a Science problem. When teachers act as facilitators in this regard they assist learners to reflect on their experiences; make sense of their data and connect learning to prior knowledge, thereby creating meaning (*cf.* 2.4.2).

The researcher feels that these results are disappointing in that only 38.1% of teachers indicate that they *almost always* act as facilitators during classroom discussions. The researcher is also of the opinion that *all* teachers should *always* act as facilitators during classroom discussions. It was further noted in the open-ended questions (*cf.* 4.5.6) that teachers act mostly as information providers and wish to elicit correct responses from learners to closed-ended questions. This indicates that few productive classroom discussions are entered into.

Facilitating classroom discussions instead of dispensing the correct information leads to the development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.9 indicates data on whether learners are encouraged to ask questions.

Table 4.9: Learners are encouraged to ask questions

	Frequency/ f	Valid Percent/ %
Almost always	37	88.1
Often	3	7.1
Sometimes	1	2.4
Very seldom	1	2.4
Total	42	100.0

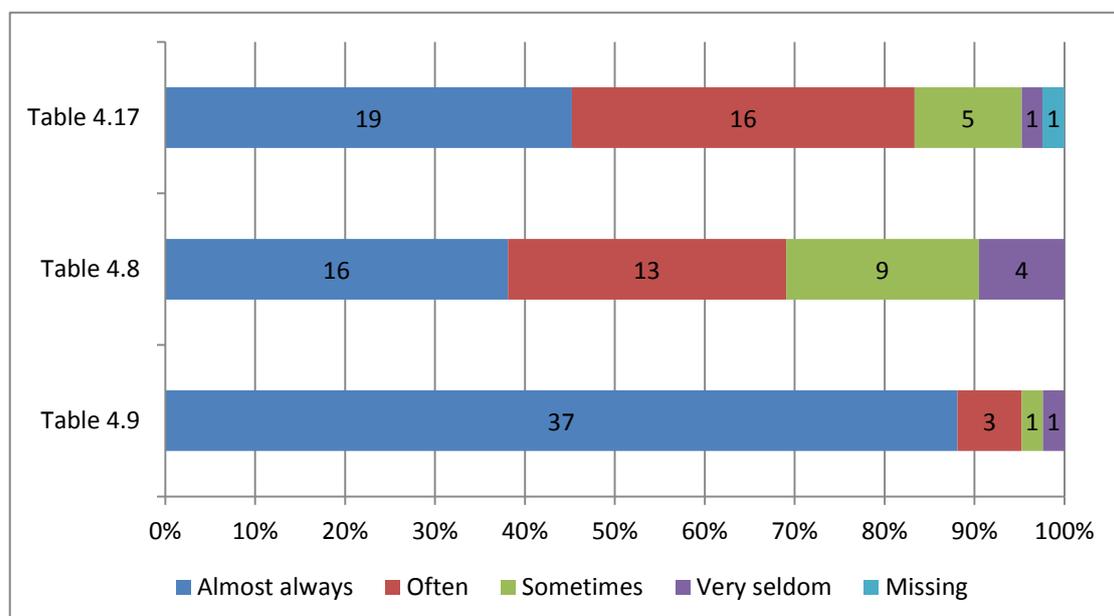
According to the data in Table 4.9, 88.1% of teachers said they *almost always* encourage learners to ask questions, 7.1% said they *often* encourage learners to ask questions while only 2.4% said they *very seldom* encourage learners to ask questions.

Apart from devising suitable activities for the effective development of the problem solving skills of learners, it is important to establish a classroom climate where learners are encouraged to ask questions so they may reflect on their learning. By encouraging learners to ask questions, teachers set the scene for learners to participate completely in classroom discussions where they are able to express their opinions and develop and validate claims arising from Scientific Investigations and support these claims with sound arguments. It is important, however, that teachers respond to learners questions in a positive manner and help them articulate their thoughts, provide them with feedback, encourage them to evaluate themselves and to draw connections without the teachers themselves evaluating the learner in the process (*cf.* 2.4.2; 2.5).

The data in Table 4.9 indicates that many teachers (88.1%) *almost always* encourage learners to ask questions. The data in Table 4.17 indicates that only 46.3% of teachers *almost always* encourage learners to exchange their ideas during classroom discussions and the data in Table 4.8 shows that few teachers (38.1%) *almost always* act as facilitators during classroom discussions. This means that although many teachers are encouraging learners to ask questions, far fewer teachers are acting as facilitators to encourage classroom discussions surrounding these questions.

The researcher is therefore of the opinion that the questions asked by learners may be largely closed-ended questions where learners are looking for the correct answer from the teacher. This was confirmed by responses to the open-ended questions (*cf.* 4.5.6). Although teachers indicate that learners are encouraged to ask questions, the questions raised are questions where teachers act as information providers. In so doing teachers inhibit the facilitation of classroom discussions surrounding a question that could allow learners to arrive at the answer to a problem for themselves.

Figure 4.5: Comparison of teachers who encourage learners to ask questions, who act as facilitator and who encourage learners to exchange ideas during classroom discussions



Classroom discussions surrounding learners' questions are necessary for learners to be able to develop and defend their ideas formulated from Scientific Investigations. These discussions lead to the development of higher order thinking skills necessary for developing the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.10 depicts data on whether teachers encourage learners to debate topics.

Table 4.10: Learners are encouraged to debate topics

	Frequency/ f	Valid Percent/ %
Almost always	17	40.5
Often	13	31.0
Sometimes	11	26.2
Very seldom	1	2.4
Total	42	100.0

According to the data in Table 4.10, 40.5% of teachers *almost always* encourage learners to debate topics, while 31.0% *often* encourage learners to debate topics. Only 2.4% revealed that they *very seldom* encourage learners to debate topics.

Debate is a method crucial to the development of problem solving skills. Scientific Inquiry uses debate as a method for confirming, rejecting or building the existing ideas of learners. Debates introduce a learner to the essential scientific practice of argumentation where learners need to consider alternative claims as well as critique the claims and justifications provided by other learners in the context of a classroom discussion or debate. This promotes learners' abilities to reason and justify their claims as well as interact with their teacher and peers in terms of both the building and critiquing of ideas (*cf.* 2.4.1; 2.4.2; 2.5).

The data presented in Table 4.9 suggests that many teachers (88.1%) *almost always* encourage learners to ask questions. The data in the above table, Table 4.10, indicates that fewer teachers (40.5%) *almost always* encourage learners to debate topics. The data in Table 4.10 relates well to the data in both Table 4.8, which suggests that few teachers (38.1%) *almost always* act as facilitators during classroom discussions, and Table 4.17 which indicates that only 46.3% of teachers *almost always* encourage learners to exchange ideas during classroom discussions. These results imply that although learners are *almost always* encouraged to ask questions they are not encouraged to enter into classroom discussions or debates surrounding the answers to their questions. The data in Table 4.9 is supported by the responses to the open-ended questions (*cf.* 4.5.6) that makes it evident that although learners are encouraged to ask questions they are not encouraged to present and debate answers to these questions. Teachers are regarded as the source of the correct answer to the problem and this prevents the learners from discussing or debating questions and thereby arriving at a solution to a problem for themselves. Such classroom discussions and debates are necessary for the development of the problem solving skills of Gr 9 Natural Sciences learners.

Figure 4.6: Comparison of teachers who encourage learners to debate topics, who act as facilitator and encourage learners to ask questions and exchange their ideas during classroom discussions

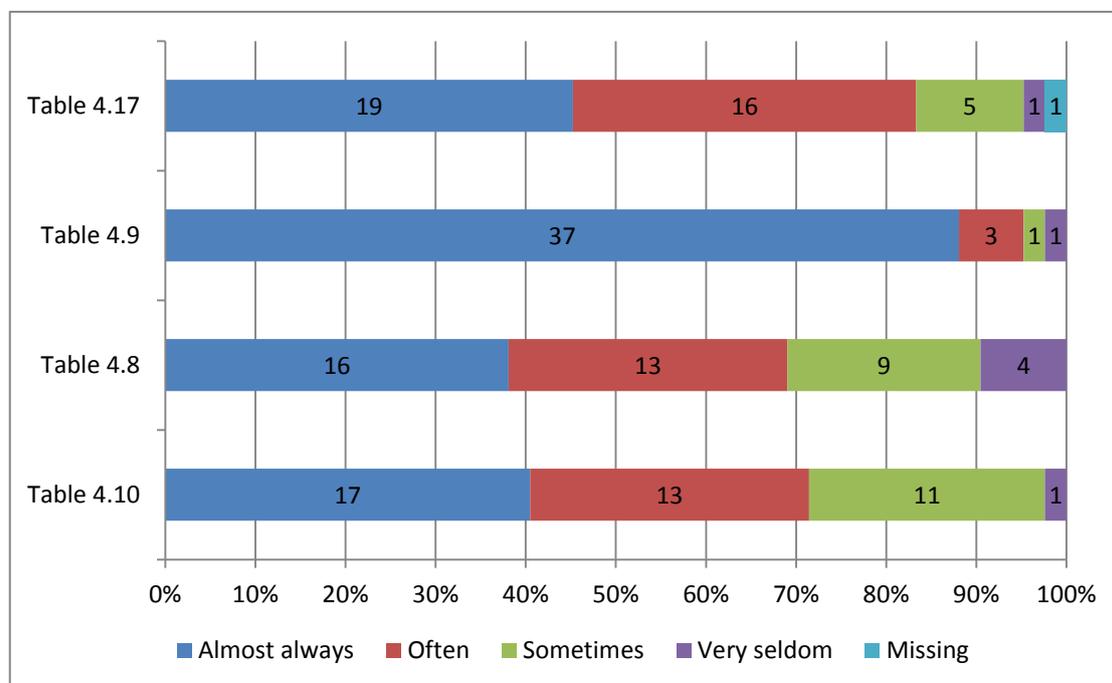


Table 4.11 depicts data on whether teachers think that learners are able to apply their knowledge to new situations.

Table 4.11: Learners are able to apply their knowledge to new situations

	Frequency/ f	Valid Percent/ %
Almost always	16	38.1
Often	19	45.2
Sometimes	5	11.9
Very seldom	2	4.8
Total	42	100.0

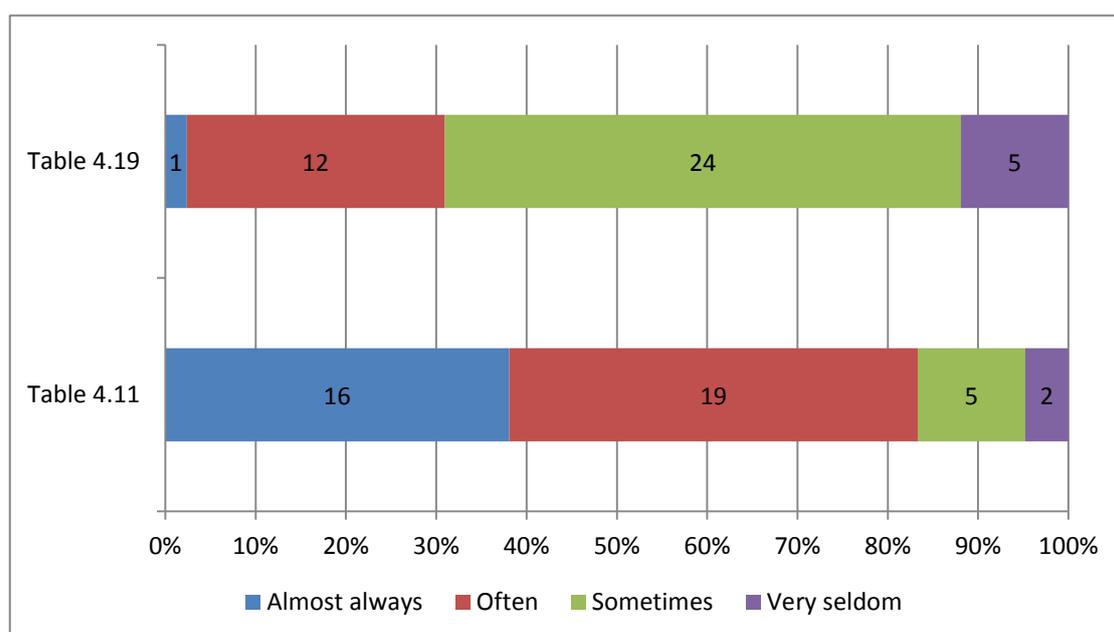
According to the data in Table 4.11, 38.1% of teachers indicate that learners are *almost always* able to apply their knowledge to new situations and 45.2%

indicate that learners are *often* able to apply their knowledge to new situations. Only 4.8% of teachers indicate that learners are *very seldom* able to apply their knowledge to new situations.

Solving a Science problem constitutes a process of mental and physical activities whereby learners are able to relate conceptual knowledge to a problem in such a way that the problem can be solved. It is therefore vital that learners are able to transfer cognitive content and skills of learning from one context to another context (*cf.* 2.2.2.2).

Being able to apply Natural Sciences knowledge to new situations is an important part of the process of developing the problem solving skills of learners. The results are therefore very encouraging as the data in Table 4.11 indicates that many teachers (83.3%) are confident that learners are *almost always* or *often* able to transfer their knowledge and skills to new situations. This confidence in their learners is supported by the data in Table 4.19 where the majority of teachers (69%) said that they believe learners possess the cognitive capabilities to think and solve problems.

Figure 4.7: Comparison of teachers who claim learners are able to apply their knowledge to new situations and who feel that learners have limited cognitive abilities



However, responses to the open-ended questions (*cf.* 4.5.2; 4.5.9) indicate that learners are presented with problems where teachers provide them with both the goal and strategies to solve the problem. The learners are therefore reliant on the teacher to direct their steps in solving a problem. Such practice will not facilitate the process of learners being able to transfer and apply their knowledge to new situations in order to solve a problem.

Table 4.12 depicts data on whether teachers think that learners do experiments because “doing Science means doing experiments”.

Table 4.12: Learners do experiments because “doing Science means doing experiments”

	Frequency/ f	Valid Percent/ %
Almost always	7	17.1
Often	18	43.9
Sometimes	14	34.1
Very seldom	2	4.9
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.12, 17.1% of teachers feel that learners *almost always* do experiments because doing Science means doing experiments. 43.9% of teachers feel that learners *often* do experiments because doing Science means doing experiments and only 4.9% feel that learners *very seldom* do experiments because doing Science means doing experiments.

The notion of doing Science means doing experiments is related to the traditional Scientific Method that constitutes a sequence of steps to be followed in a Scientific Investigation in order to reinforce concept objectives. This is not in line with Scientific Inquiry which is seen as a way of thinking

rather than a procedure and where Scientific Investigations are used to build scientific theories and models (*cf.* 2.3).

The data in Table 4.12 highlights the problem that many teachers (61%) *almost always* or *often* view doing Science as doing experiments. Responses to the open-ended questions (*cf.* 4.5.2; 4.5.9) indicate that although learners are involved in investigations, they are provided with the goal of the problem, strategies to reach the goal as well as step-by-step instructions to follow. These results are supported by the data presented in Table 4.1 which shows that many teachers (76.2%) *almost always* or *often* make use of the Scientific Method. As mentioned in the discussion of the data in Table 4.1 (*cf.* Figure 4.1), this may pose a problem when it comes to developing the problem solving skills of learners as Scientific Inquiry involves much more than the delineated steps of the Scientific Method. The researcher is therefore of the opinion that many Gr 9 Natural Sciences teachers possess a limited understanding of Scientific Inquiry.

Table 4.13 depicts data on whether teachers think their class time consists mainly of lectures.

Table 4.13: My class time consists mainly of lectures

	Frequency/ f	Valid Percent/ %
Almost always	2	4.9
Often	12	29.3
Sometimes	10	24.4
Very seldom	17	41.5
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.13, 4.9% of teachers indicate that their class time *almost always* consists mainly of lectures, and 29.3% indicate that their

class time *often* consists mainly of lectures. 41.5% of teachers indicate that their class time *very seldom* consists mainly of lectures.

Diverse teaching methods are recommended for the development of knowledge, understanding and the abilities of learners. Not all Natural Sciences lessons need to be taught by means of Scientific Inquiry which involves the solving of problems by manipulating information in order to construct meaning. Other methods include the use of lectures, presentations, demonstrations, classroom discussions, recitation, working from textbooks, brainstorming sessions, debates, field trips etc. (*cf.* 2.4.2).

The data depicted in Table 4.13 suggests that the majority of teachers (65.9%) employ the method of lectures only *sometimes* or *very seldom*. The top two choices of teaching methods used on a regular basis, as stated in the open-ended questions of the questionnaire (*cf.* 4.5.1), are identified as demonstrations and classroom discussions with lectures being placed third out of a possible nine teaching methods. These results are encouraging as they show that although teachers do opt for methods of teaching which may be classified as expository instruction, they do so on an infrequent basis. These choices also imply that most of the time in class is spent on teachers performing demonstrations and holding classroom discussions. These choices, however, are not supported by the data in Table 4.8 where few teachers *almost always* act as facilitators during classroom discussions. Discussions promote learners' abilities to reason and justify their claims as well as interact with the teacher and their fellow learners in terms of both building and critiquing ideas. Classroom discussions require that a teacher act as facilitator in this regard (*cf.* 2.4.2; 2.5). Responses to the open-ended questions (*cf.* 4.5.5; 4.5.6) show that discussions are limited to teachers acting mostly as information providers where they elicit correct responses from learners to closed-ended questions. Very few productive classroom discussions are entered into.

Noticeably absent from the top choices of teaching methods, used on a regular basis, as stated in the responses to the open-ended questions of the questionnaire (*cf.* 4.5.1) are the use of laboratory or hands-on activities as a

method of instruction. This absence of laboratory or hands-on activities as a top choice of method may be explained by the data presented in Table 4.14 where many teachers (60.5%) indicate that they *almost always* or *often* have an endless amount of information to cover. Laboratory or hands-on activities are time consuming and teachers may sacrifice this method of instruction in favour of completing the curriculum.

Figure 4.8: Comparison of teachers who employ the use of lectures, who act as facilitator during classroom discussions and those who feel they have an endless amount of information to cover

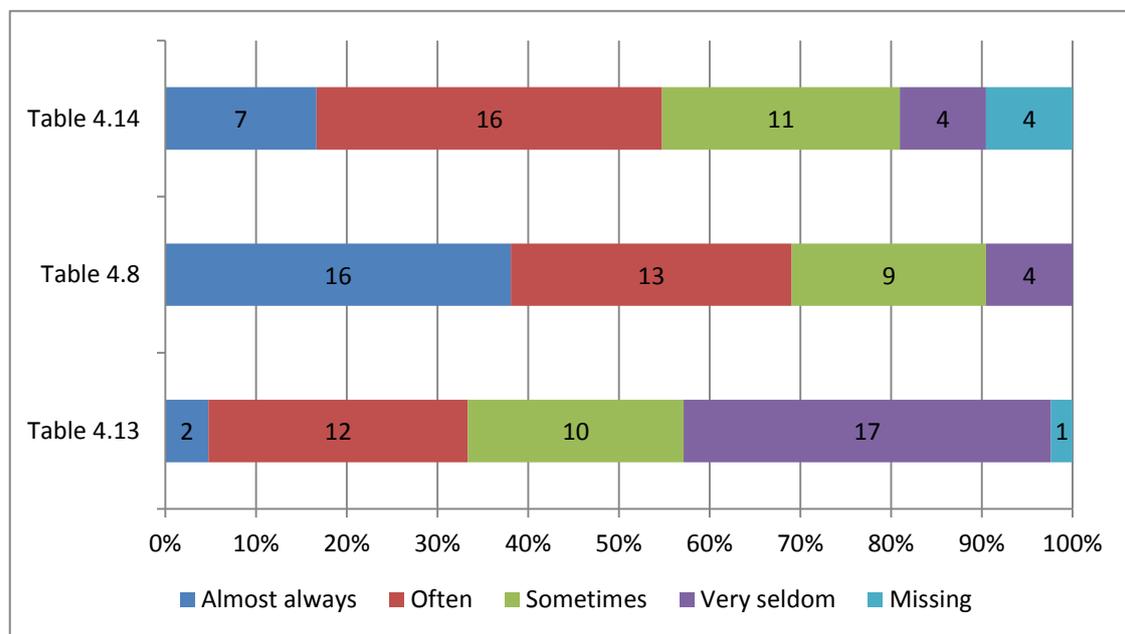


Table 4.14 depicts data on whether teachers feel that they need to cover an endless amount of information.

Table 4.14: I need to cover an endless amount of information

	Frequency/ f	Valid Percent/ %
Almost always	7	18.4
Often	16	42.1
Sometimes	11	28.9
Very seldom	4	10.5
Total	38	100.0
Missing	4	
Total	42	

According to the data in Table 4.14, only 18.4% of teachers feel that they *almost always* need to cover an endless amount of information. 42.1% feel they *often* need to cover an endless amount of information and only 10.5% indicate that they *very seldom* need to cover an endless amount of information.

According to literature, time has often been described as a major constraint for many teachers. Time constraints may be due to the Natural Sciences Curriculum containing a too heavy content load. A heavy content load may lead teachers to resort to expository instruction as Scientific Inquiry requires time for the development of suitable problems as well as preparation and execution time for ensuing Scientific Investigations (*cf.* 2.7.1.1).

The data in Table 4.14 suggests that many teachers (60.5%) *almost always* or *often* have an endless amount of information to cover. Although expository instruction may become the favoured approach when content load is too heavy (*cf.* 2.7.1.1), this does not appear to be the case as, in the open-ended questions of the questionnaire (*cf.* 4.5.1), teachers indicate lectures as their third favourite choice of teaching method employed on a regular basis. This information is supported by the data in Table 4.13 which shows that the majority of teachers (65.9%) use lectures (expository instruction) on an infrequent basis. The results for this question may however, explain why

teachers resort to demonstrations instead of laboratory or hands-on activities as a preferred teaching method as stated in the open-ended questions of the questionnaire, as demonstrations will save the teacher time.

Table 4.15 depicts data on whether teachers formulate questions where learners are required to recite facts.

Table 4.15: I formulate questions where learners recite facts

	Frequency/ f	Valid Percent/ %
Almost always	5	12.8
Often	20	51.3
Sometimes	8	20.5
Very seldom	6	15.4
Total	39	100.0
Missing	3	

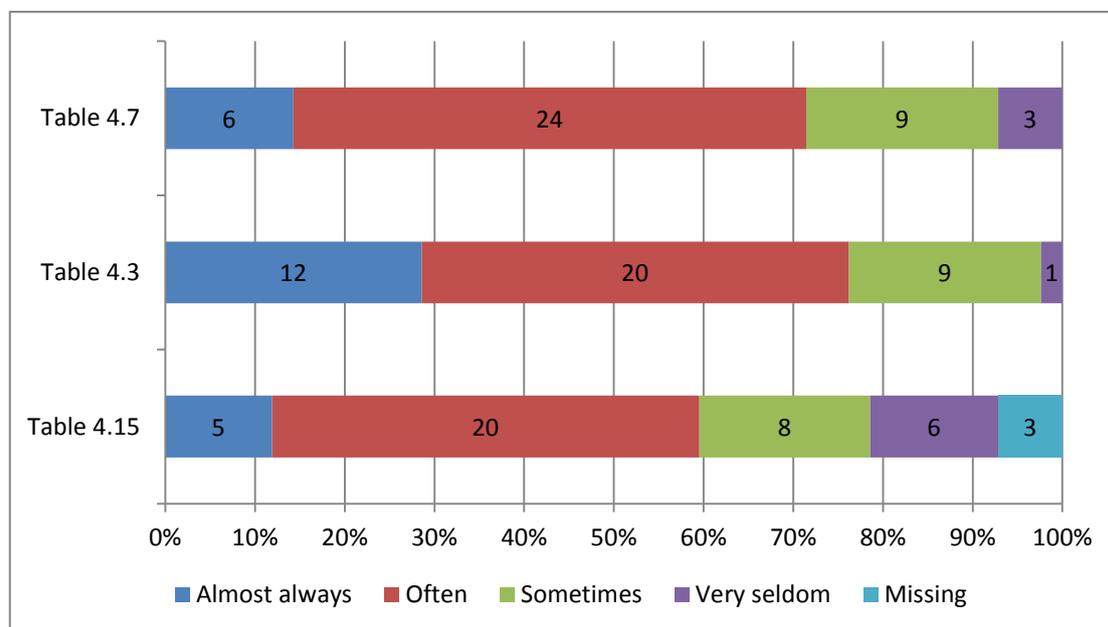
According to the data in Table 4.15, only 12.8% of teachers *almost always* formulate questions where learners recite facts and 51.3% *often* formulate questions where learners recite facts. Only 15.4% of teachers *very seldom* formulate questions where learners recite facts.

Traditional Natural Sciences education placed a high value on learners knowing the answers to standard questions whereas current practices place more value on learners being able to solve problems (*cf.* 2.1). Problem solving involves thinking that is on a higher level than just memorising facts, thinking that is not only content based but relies on skills and understanding (*cf.* 2.2.2). Problems or questions that require the simple recall of information or a routine application of a known method, theory or knowledge to familiar situations and contexts are known as Science exercises. Problems or questions that require higher order thinking skills of reasoning, analysis, synthesis and problem solving, making of connections and critical evaluative thinking, including the application of knowledge to unfamiliar situations are known as Science

problems (*cf.* 2.2.2.1). The development of the problem solving skills of learners relies on the latter type of problem or question.

The data presented in Table 4.15 indicates that many teachers (64.1%) *almost always* or *often* formulate questions where learners are required to recite facts. This implies that teachers present learners with Science exercises rather than Science problems. These results are not in accordance with the data depicted in Table 4.3 where many teachers (76.2%) stated they *almost always* or *often* design problems requiring learners to employ creative thinking skills. The data in Table 4.7 also indicates that many teachers (71.4%) *almost always* or *often* teach learners higher order thinking skills. The researcher is of the opinion that the results presented in Tables 4.3 and 4.7 are not reliable if learners are being presented with Science exercises. The data obtained from the open-ended questions (*cf.* 4.5.9) indicate that teachers favour Science exercises instead of Science problems. Teachers present their learners with problems where both the goal and strategies to reach the goal of the problem are specified. These activities involve the simple recall of information and routine application of theory to a familiar situation. This is more in line with a Science exercise where an experiment acts to confirm or reject what is already known and does not allow for the employment of higher order thinking skills.

Figure 4.9: Comparison of teachers who formulate questions where learners recite facts, who design problems that stretch learners imagination and those who teach higher order thinking skills



Gr 9 Natural Sciences teachers who formulate questions that require learners to recite facts discourage the development of the problem solving skills of learners as a well-designed Science problem focuses the attention of learners and helps them move beyond recall of facts to understanding and application (*cf.* 2.2.2).

Table 4.16 indicates data on whether teachers feel they do most of the talking during a lesson.

Table 4.16: I do most of the talking in a lesson

	Frequency/ f	Valid Percent/ %
Almost always	6	14.3
Often	12	28.6
Sometimes	15	35.7
Very seldom	9	21.4
Total	42	100.0

According to the data in Table 4.16, only 14.3% of teachers feel they *almost always* do most of the talking in a lesson, while 35.7% indicate that they *sometimes* do most of the talking and 21.4% feel they *very seldom* do most of the talking in a lesson.

According to the constructivist view of learning, learners are not blank slates that need to be filled with information. Constructivists perceive learning as a process whereby learners become theory builders as they actively construct their own knowledge and understanding through their experiences. Knowledge is constantly being assimilated and accommodated in the mind through learners' interpretations of their own experiences (*cf.* 2.2; 2.2.2.2; 2.4.2). In Natural Sciences this would translate into learners becoming involved with a problem where they are required to make observations, perform research and support their ideas with evidence obtained from a Scientific Investigation (*cf.* 2.2). In a constructivist classroom, the teachers' role in the process becomes that of a facilitator rather than a dispenser of information (*cf.* 2.4.2).

The data presented in Table 4.16 shows a wide spread of teachers' opinions but ultimately the data indicates that many teachers (57.1%) only *sometimes* or *very seldom* do most of the talking during a lesson. Doing most of the talking during a lesson would mean that teachers dispense information in the form of a lecture. The data presented in Table 4.16, is supported by the data in Table 4.13 that suggests that 65.9% of teachers employ the method of lectures only *sometimes* or *very seldom*. These results are further supported by the choice of lectures being placed third out of a possible nine teaching methods employed on a regular basis, as stated in the open-ended questions of the questionnaire (*cf.* 4.5.1).

The above still leaves a rather high percentage (42.9%) of teachers that *almost always* or *often* do most of the talking during a lesson. When a teacher does all the talking the implication is that the learners become passive recipients of Natural Sciences concepts and content rather than constructors of their own knowledge and understanding (*cf.* 2.4.2). The data obtained from the open-ended questions (*cf.* 4.5.2; 4.5.9) indicates that teachers present the

learners with step-by-step instructions to follow during Scientific Investigations. These instructions are continuously verbalised as learners are guided through the investigation with the teacher doing most of the talking during the learning experience.

This means the teacher does not act as a facilitator but rather as a dispenser of information. The high percentage of teachers that *almost always* or *often* do most of the talking during a lesson is further supported by the findings in Table 4.8 where only 38.1% of teachers indicate they *almost always* act as facilitators during classroom discussions. The above scenario does not lend itself to the development of the problem solving skills of Gr 9 Natural Sciences learners where learners are required to become active constructors of their own knowledge and understanding.

Figure 4.10: Comparison of teachers who do most of the talking during a lesson, who act as facilitator during classroom discussions and those whose class time consists mainly of lectures

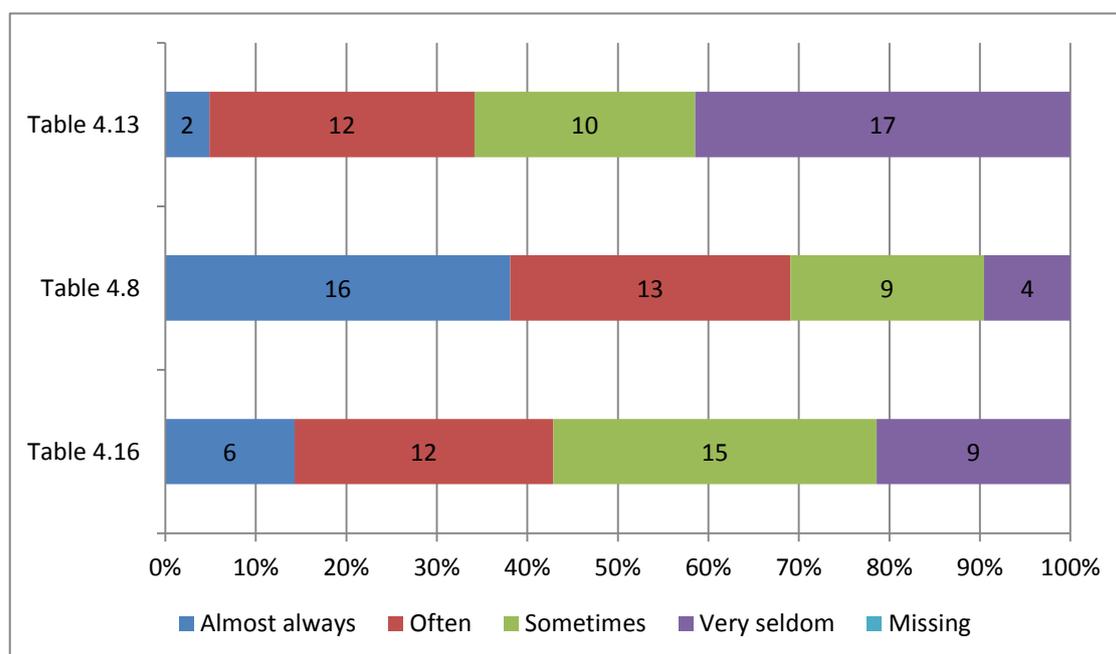


Table 4.17 depicts data on whether teachers encourage learners to exchange their ideas during classroom discussions.

Table 4.17: Learners are encouraged to exchange their ideas during classroom discussions

	Frequency/ f	Valid Percent/ %
Almost always	19	46.3
Often	16	39.0
Sometimes	5	12.2
Very seldom	1	2.4
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.17, 46.3% of teachers *almost always* encourage learners to exchange their ideas during classroom discussions and 39.0% of teachers *often* encourage learners to exchange their ideas during classroom discussions. Only 2.4% of teachers *very seldom* encourage learners to exchange their ideas during classroom discussions.

During the process of Scientific Inquiry, learners are required to construct and defend scientific arguments by weighing evidence from their Scientific Investigations against relevant scientific concepts, theories and models in order to reach a suitable conclusion to a problem (*cf.* 2.4.1). This process requires learners to present their findings to the class where the teacher facilitates any discussion arising from these findings. Classroom discussions allow learners to 'talk Science' and assist them in developing their problem solving skills. It is the teachers responsibility to guide and support learners in playing an active role in these classroom discussions. The teacher also needs to help learners articulate their thoughts, provide them with feedback, respond to any question in a positive manner and encourage them to evaluate themselves and draw connections without teachers, themselves, evaluating the learner in the process (*cf.* 2.5).

The data in Table 4.17 indicates that only 46.3% of the teachers *almost always* encourage learners to exchange their ideas during classroom discussions. The data correlates with the data presented in Table 4.8 and 4.10 which indicate that few teachers (38.1%) *almost always* act as facilitators during classroom discussions and that few teachers (40.5%) *almost always* encourage learners to debate topics.

This is a disappointing percentage as classroom discussions are the second most popular choice of teaching methods employed on a regular basis, as stated in the open-ended questions of the questionnaire (*cf.* 4.5.1). The above results imply that although classroom discussions are often held, teachers seldom encourage the learners to exchange ideas during these discussions. This could indicate that these discussions are one sided with teachers doing most of the talking. This assumption is supported by the data depicted in Table 4.16 which indicates that almost half the teachers participating in this study (42.9%) *almost always* or *often* do most of the talking during a lesson. This assumption is further supported by the data obtained from the open-ended questions (*cf.* 4.5) indicating that teachers act as information providers to questions asked by learners. Teachers also direct questions at learners but proceed to evaluate the learners' responses to their questions as being correct or incorrect after which they provide the learners with the correct answer (*cf.* 4.5.6). No discussion or debate surrounding the questions is encouraged.

The researcher is of the opinion that all teachers should encourage learners to exchange their ideas during classroom discussions. This will allow learners to practice 'talking science' and in so doing assist in the development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.18 depicts data on whether teachers feel their learners do not take other learners' viewpoints very seriously.

Table 4.18: Learners do not take other learners' viewpoints seriously

	Frequency/ f	Valid Percent/ %
Almost always		
Often	5	12.2
Sometimes	19	46.3
Very seldom	17	41.5
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.18, only 12.2% of teachers feel that *often* learners do not take other learners' viewpoints seriously. 46.3% of teachers are of the opinion that *sometimes* learners do not take other learners' viewpoints seriously and 41.5% feel that *very seldom* do learners not take other learners' viewpoints seriously.

Scientific discussions are an important part of the process of Scientific Inquiry where positive teacher-learner and learner-learner interactions are essential. Not only are learners expected to participate in classroom discussions but they are also expected to participate in the essential scientific practice of argumentation where they justify their claims from Scientific Investigations and interact with fellow learners and their teacher to both build and critique the ideas of others. In order for this to happen, learners need to feel that their viewpoints are valued by teachers and fellow learners so that they feel free to participate completely in the classroom discussions (*cf.* 2.4.1; 2.5). If learners are inclined not to take one another's viewpoints seriously it will hamper the process of Scientific Inquiry which will in turn hamper the development of the problem solving skills of learners.

Fortunately, many teachers (87.8%) feel that only *sometimes* or *very seldom* learners are not inclined to take other learners' viewpoints seriously. This result indicates that learners participate during classroom discussions when

afforded the opportunity for such discussions. Participation allows for the development of the problem solving skills of learners. Gr 9 Natural Sciences teachers claim that classroom discussions are their second most popular choice of teaching methods employed on a regular basis, as stated in the open-ended questions of the questionnaire (*cf.* 4.5.1), however, such discussions are not that forthcoming as indicated by the data shown in Table 4.8, 4.10 and 4.17 as few teachers *almost always* act as facilitator and encourage learners to debate topics and exchange ideas during classroom discussions.

Figure 4.11: Comparison of teachers who feel learners do not take other learners viewpoints seriously, who act as facilitator and who encourage learners to debate topics and exchange ideas during classroom discussions

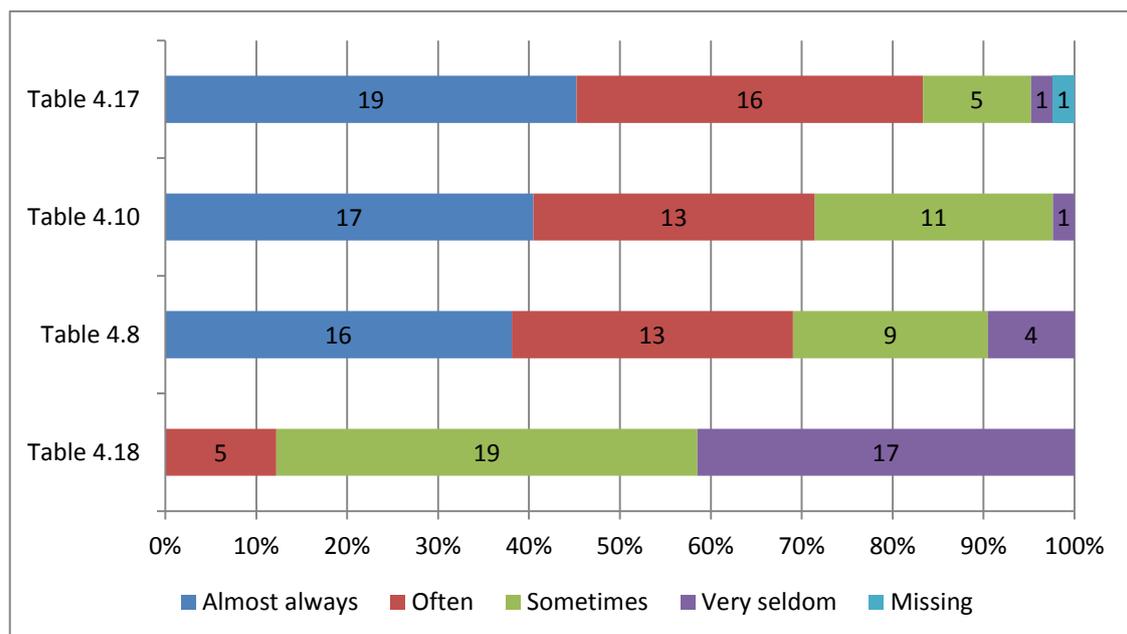


Table 4.19 depicts data on whether teachers feel their learners have limited cognitive abilities.

Table 4.19: Learners have limited cognitive abilities

	Frequency/ f	Valid Percent/ %
Almost always	1	2.4
Often	12	28.6
Sometimes	24	57.1
Very seldom	5	11.9
Total	42	100.0

According to the data in Table 4.19, only 2.4% of teachers feel their learners *almost always* have limited cognitive abilities. 57.1% of teachers feel their learners *sometimes* have limited cognitive abilities and 11.9% feel that *very seldom* do their learners have limited cognitive abilities.

Literature reveals that teachers sometimes have fixed ideas about learners' abilities. These ideas suggest that only some learners have the cognitive abilities of thinking and solving problems (*cf.* 2.7.1.3). However, research has shown that learners adapt to situations in which they find themselves. Classroom practices that insist on reasons and evidence, supplemented by teaching ways to structure, represent, and interpret data, make it more likely for learners to seek data to support their theories and to solve problems (*cf.* 2.5). Setting high expectations for learners, including engaging learners at high levels of cognitive demand in the classroom, is associated with improved learning and the development of the problem solving skills of learners (*cf.* 2.7.1.3). The problem solving abilities of learners have been known to improve when teachers show faith in their learners, have an encouraging attitude and are willing to spend time and effort in teaching higher order thinking skills (*cf.* 2.2.2).

The data presented in Table 4.19 shows that many teachers (69%) *sometimes* or *very seldom* feel that their learners have limited cognitive abilities. This result is encouraging as in general it would appear that teachers do expect a high level of cognitive engagement during classroom activities. This finding is supported by the data in Table 4.7 which suggests that many

teachers (71.4%) *almost always* or *often* spend time teaching higher order thinking skills. The teaching of higher order thinking skills relates to the data in Table 4.24 where 92.9% of teachers indicate that higher order thinking skills develop with practice. As discussed under Table 4.7, it is essential that the teaching of higher order thinking skills be related to the practicing of these skills. According to the researcher, this does not appear to be the case. The data presented in Table 4.15 suggests that many teachers (64.1%) *almost always* or *often* formulate questions where learners are required to recite facts. As mentioned in the discussions of the data depicted in Table 4.15, 4.23 and 4.24, presenting learners with problems referred to as Science exercises that involve the simple recall of information as opposed to presenting learners with Science problems that involve higher order thinking, will not allow learners to practice their higher order thinking skills. The data obtained from the open-ended questions (*cf.* 4.5) indicates that many teachers provide their learners with step-by-step instructions to follow in order to solve a problem (4.5.2; 4.5.9). The researcher is led to believe that although teachers indicate their learners do not have limited cognitive abilities they act as though they do. It is one thing to expect high levels of cognitive engagement from learners but if learners are not presented with opportunities to practice their higher order thinking skills then teachers will not be successful in developing the problem solving skills of their Gr 9 Natural Sciences learners.

Figure 4.12: Comparison of teachers who claim learners have limited cognitive abilities, who teach higher order thinking skills, who formulate questions where learners recite facts, who encourage learners to use higher order thinking skills and who claim that higher order thinking skills develop with practice

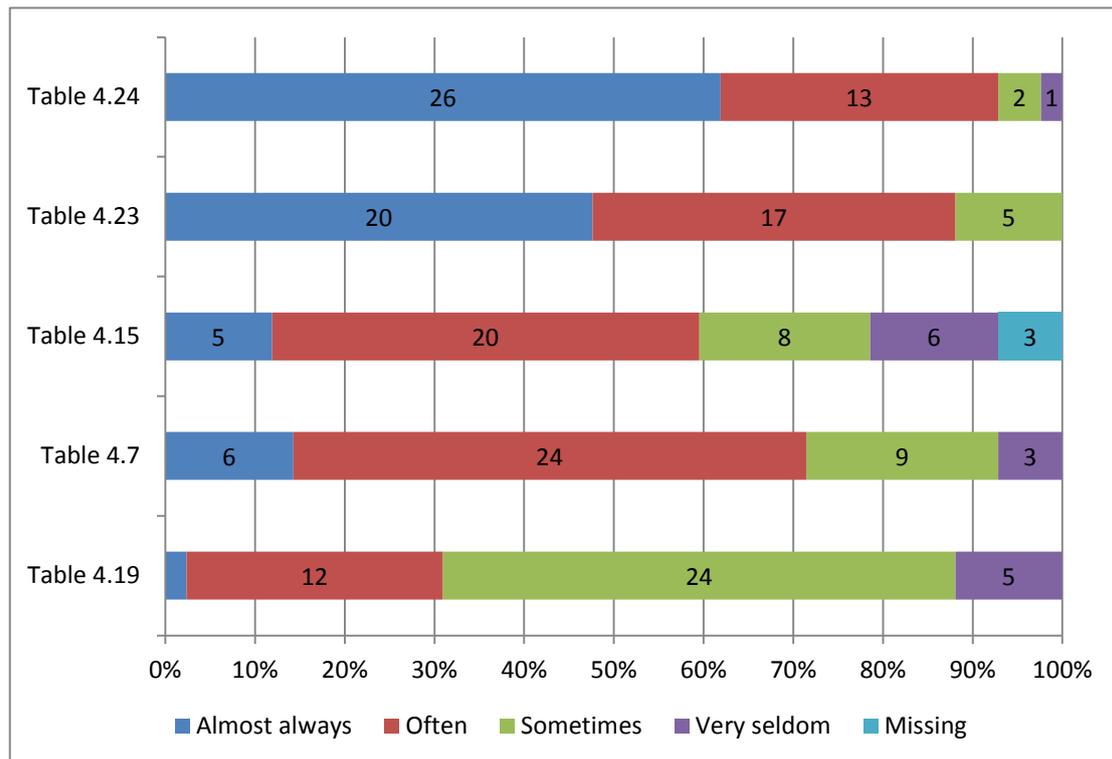


Table 4.20 indicates data on whether teachers feel that Science is a process of improving learners' knowledge.

Table 4.20: Science is a process of improving knowledge

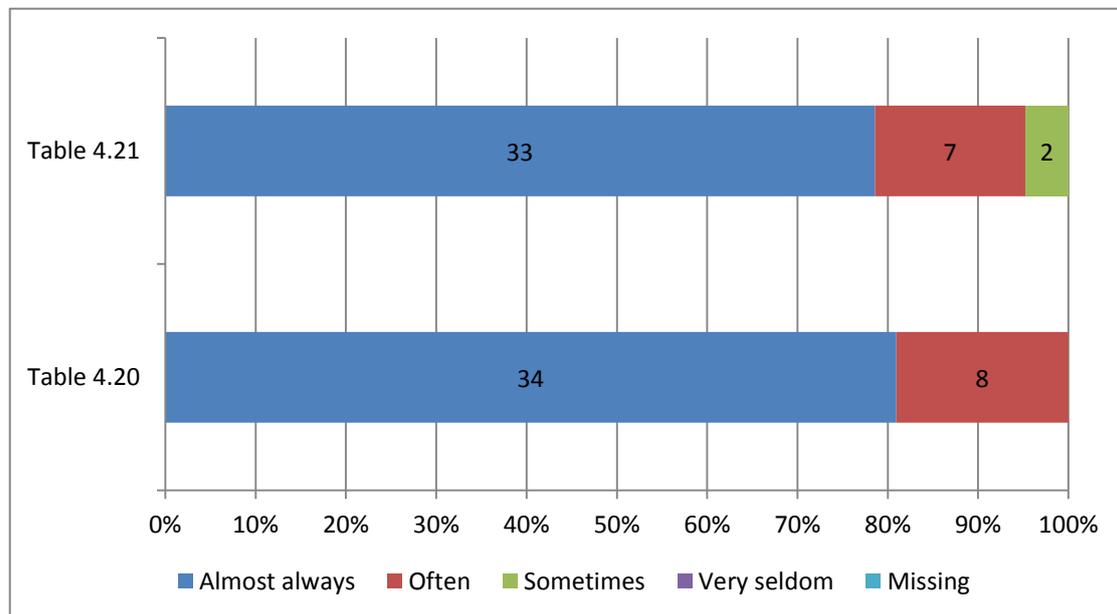
	Frequency/ f	Valid Percent/ %
Almost always	34	81
Often	8	19
Sometimes		
Very seldom		
Total	42	100.0

According to the data in Table 4.20, 81% of teachers feel that Science is *almost always* a process of improving knowledge and 19% of teachers feel that Science is *often* a process of improving knowledge.

Traditional Natural Sciences education placed a high value on learners knowing answers to standard questions (*cf.* 2.1). Although the process of knowledge development does involve acquiring knowledge of concepts and content, it also involves a deep understanding of these concepts and content (*cf.* 2.6.2.2). A lot of time in the classroom is spent on helping learners take in new information, with little attention on helping learners to apply this information (*cf.* 2.2). This means that some teachers see knowledge of Natural Sciences as knowing a lot of facts. Teaching and assessment practices that separate the teaching and learning of content from the teaching and learning of process (cognitive and manipulative) are ineffective in helping learners develop scientific reasoning skills and an understanding of Science as a way of knowing. This will lead to the ineffective development of the problem solving skills of learners (*cf.* 2.4.2).

The data depicted in Table 4.20 suggests that a high percentage of teachers (81%) *almost always* see knowledge development as acquiring knowledge. To put this result into perspective, one needs to relate this result to the data presented in Table 4.21. The data presented in Table 4.21 indicates that a high percentage of teachers, 78.6%, *almost always* see Science as a process of improving understanding. The combined results of these two tables are extremely encouraging as they show that teachers view Natural Sciences knowledge as not only about acquiring knowledge of concepts and content but also as developing a deep understanding of these concepts and content.

Figure 4.13: Comparison of teachers who claim that Science is a process of improving knowledge and those who claim Science is a process of improving understanding



Although teachers may possess this view, responses to the open-ended questions (*cf.* 4.5.6; 4.5.9) indicate that learners are not being afforded the opportunity for developing a deep understanding of concepts and content. Teachers provide learners with a problem where both the goal and strategies to reach the goal of the problem are specified. This allows for the acquisition of knowledge as opposed to a deep understanding of concepts and content as the teaching and learning of content is separated from the teaching and learning of process. This results in learners being unable to apply knowledge to different contexts and this will lead to the ineffective development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.21 depicts data on whether teachers feel that Science is a process of improving learners' understanding.

Table 4.21: Science is a process of improving understanding

	Frequency/ f	Valid Percent/ %
Almost always	33	78.6
Often	7	16.7
Sometimes	2	4.8
Very seldom		
Total	42	100.0

According to the data in Table 4.21, 78.6% of teachers feel that Science is *almost always* a process of improving understanding, and 16.7% feel that Science is *often* a process of improving understanding. Only 4.8% of teachers feel that Science is *sometimes* a process of improving understanding.

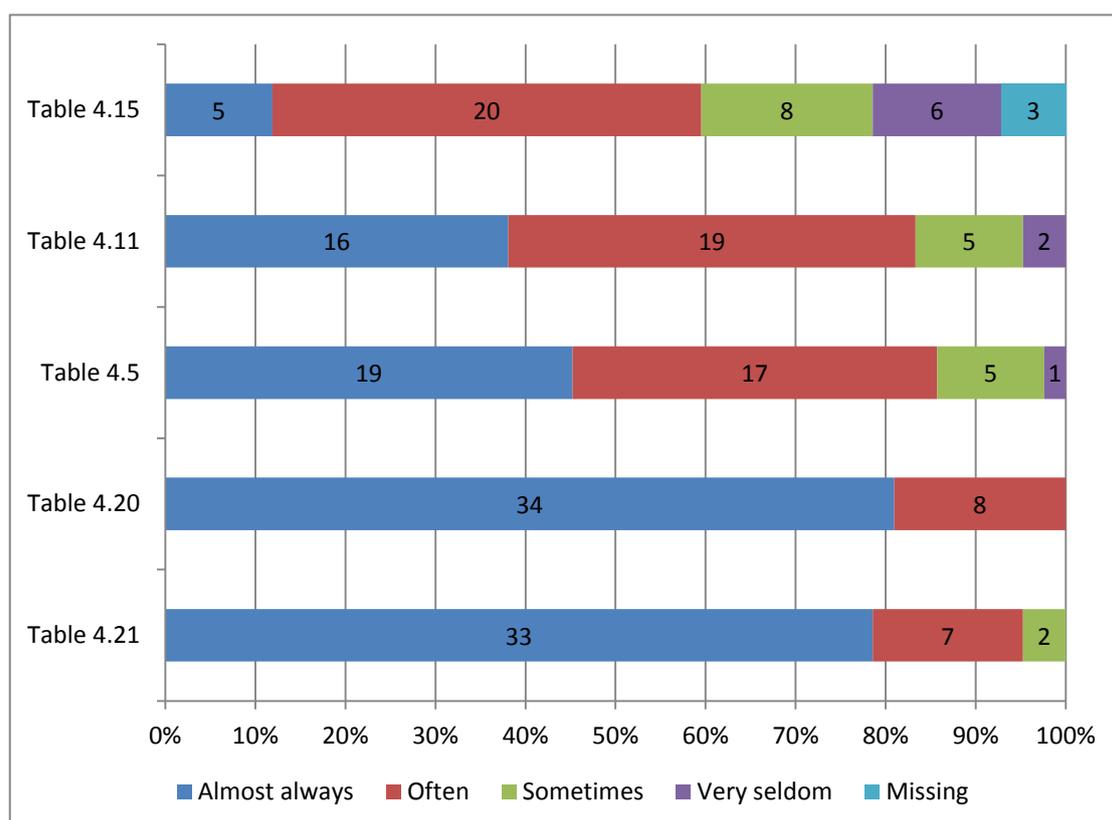
Knowledge of Natural Sciences concepts and content is about more than just knowing a lot of facts. This knowledge includes a deep understanding of Natural Sciences processes, phenomena, mechanisms, principles, theories, laws and models. This knowledge involves knowing, understanding and making sense of Natural Sciences in a way that enables learners to make connections between the ideas and concepts. Making such connections enable learners to apply their knowledge to new and unfamiliar contexts (*cf.* 2.6.2.2). When Scientific Inquiry is coupled with suitable Natural Sciences concepts and content in a specific context, it provides learners with a meaningful learning experience and promotes the effective development of the problem solving skills of learners (*cf.* 2.4.2).

The researcher regards the results of Table 4.21 as very encouraging as when these results are coupled with the results of Table 4.20 it would appear that the majority of teachers recognise that teaching Natural Sciences is about more than just improving the knowledge of learners. Learners are able to recall Natural Sciences concepts and content but they are also expected to understand these concepts and content. These results are supported by the data in Table 4.5 in that 85.7% of teachers *almost always* or *often* recognise that Scientific Investigations contribute to learners understanding scientific

ideas. The results of Table 4.21 are further supported by the data in Table 4.11 where many teachers (83.3%) indicate that they are confident that their learners are *almost always* or *often* able to apply their knowledge to new situations. This means that learners not only gain Natural Sciences knowledge but they also understand this knowledge and are therefore able to apply this knowledge to new contexts. Understanding Natural Sciences concepts and content is a critical part of the process of developing the problem solving skills of learners.

The researcher is concerned however, that although teachers appear to recognise that knowledge involves both the acquisition and understanding of concepts and content, the results of Table 4.15 show that many teachers (64.1%) *almost always* or *often* formulate questions where learners are expected to recite facts. Such questions do not lend themselves to the effective development of the problem solving skills of learners.

Figure 4.14: Comparison of teachers who claim that Science is a process of improving knowledge and understanding, Scientific Investigations help learners to understand scientific ideas, learners are able to apply their knowledge to new situations and those who formulate questions where learners recite facts



The data obtained from the open-ended questions (*cf.* 4.5) makes it evident that during a Scientific Investigation learners are presented with a problem as well as step-by-step instructions to follow during the solving of the problem (*cf.* 4.5.2; 4.5.9). This does not allow learners the opportunity to perform their own Scientific Investigations whereby they may develop their understanding of the content and concepts but rather allow learners to follow a prescribed sequence of steps that serve to confirm concepts and content. Such Scientific Investigations will not promote the transfer of knowledge to new contexts and will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.22 includes data on whether teachers afford learners the opportunity to apply scientific skills to real life problems.

Table 4.22: Learners have the opportunity to apply scientific skills to real life problems

	Frequency/ f	Valid Percent/ %
Almost always	25	59.5
Often	13	31.0
Sometimes	3	7.1
Very seldom	1	2.4
Total	42	100.0

According to the data in Table 4.22, 59.5% of teachers *almost always* afford learners the opportunity to apply scientific skills to real life problems and 31.0% of teachers *often* afford learners the opportunity to apply scientific skills to real life problems. Only 2.4% of teachers *very seldom* afford learners the opportunity to apply scientific skills to real life problems.

Natural Sciences should provide learners with an understanding of the natural world that will serve as a basis for their own personal choices and decisions. Understanding the natural world and being able to make informed decisions are two characteristics of scientific literacy. If learners are to become scientifically literate they will need to develop their problem solving skills (*cf.* 2.1). Problem solving involves the transfer of cognitive content and skills of learning from one context to another, thereby affecting the learning of new material (*cf.* 2.2.2.2). Real life problems will therefore allow learners the chance to practice their problem solving skills in an authentic context.

The results of Table 4.22 are very encouraging in that many teachers (90.5%) *almost always* or *often* recognise the value of using real life problems in order to develop the problem solving skills of learners and thereby promoting the scientific literacy of learners.

The data obtained from the open-ended questions (*cf.* 4.5) indicate that the problems presented to learners are related directly to Natural Sciences content and not to real life problems (*cf.* 4.5.9). It seems that although teachers recognise the importance of relating new learning, they do not appear to afford learners the opportunity to apply scientific skills to real life problems. This does not allow for an authentic context for the development of the problem solving skills of learners that will contribute to the scientific literacy of Gr 9 Natural Sciences learners.

Table 4.23 depicts data on whether teachers encourage learners to use higher order thinking skills during problem solving.

Table 4.23: During problem solving learners are encouraged to use higher order thinking skills

	Frequency/ f	Valid Percent/ %
Almost always	20	47.6
Often	17	40.5
Sometimes	5	11.9
Very seldom		
Total	42	100.0

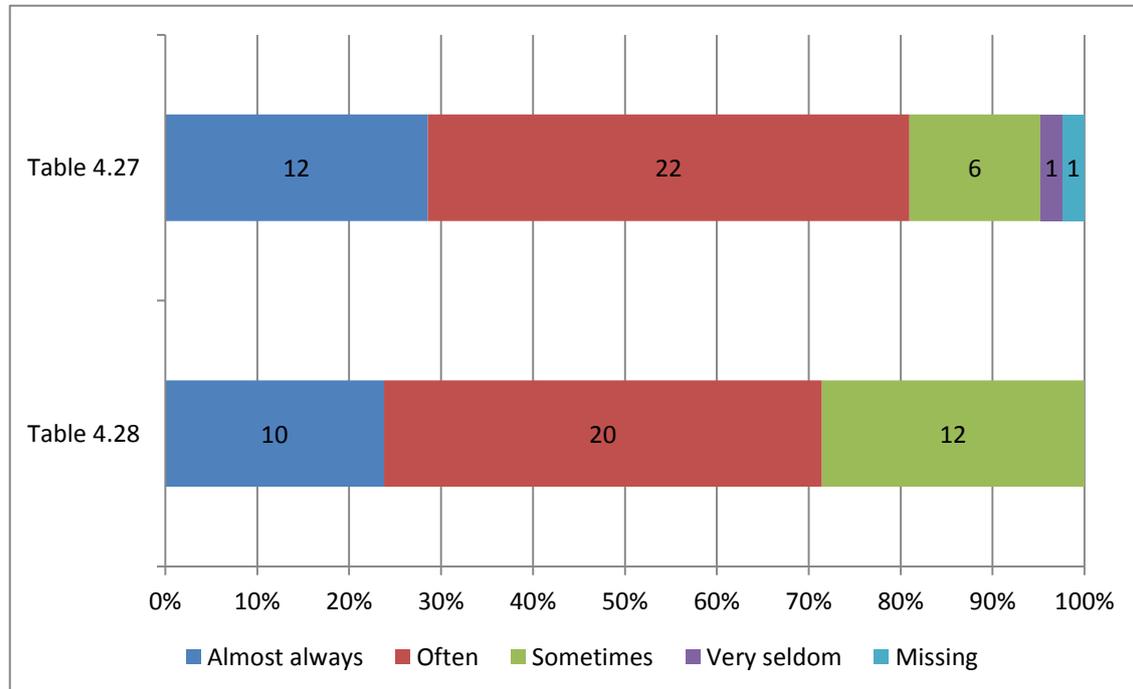
According to the data in Table 4.23, 47.6% of teachers *almost always* encourage learners to use higher order thinking skills and 40.5% of teachers *often* encourage learners to use higher order thinking skills. Only 11.9% of teachers *sometimes* encourage learners to use higher order thinking skills during problem solving.

As mentioned in the discussion under Table 4.7, higher order thinking skills are characterised by cognitive capabilities such as critical thinking, asking question, evaluative thinking, decision making and problem solving. This type of thinking requires learners to understand facts, connect them together, categorise them, manipulate them, arrange them in new or novel ways and apply them as they look for solutions to problems (*cf.* 2.2.2). Teachers

encourage learners to use higher order thinking skills by presenting them with Science problems. Many possible Science problems exist but not all of these require learners to employ higher order thinking skills. Science exercises are problems that require the simple recall of information or a routine application of a known method, theory or knowledge to familiar situations and contexts. Science problems on the other hand require the higher order thinking skills of reasoning, analysis, synthesis and problem solving, making of connections and critical evaluative thinking, including the application of known theory, knowledge or procedure to unfamiliar situations (*cf.* 2.2.2.1).

The data in this table shows that the majority of teachers (88.1%) *almost always* or *often* encourage learners to use higher order thinking skills during problem solving. This implies that teachers provide their learners with Science problems. The data in Table 4.15 suggests otherwise in that many teachers (64.1%) *often* formulate questions where learners are required to recite facts. This data implies that teachers present their learners with Science exercises rather than Science problems. Science exercises will not encourage learners to use higher order thinking skills and therefore not ensure the development of the problem solving skills of learners.

Figure 4.15: Comparison of teachers who encourage learners to use higher order thinking skills during problem solving and those who formulate questions where learners recite facts



The responses to the open-ended questions (*cf.* 4.5) indicate that teachers present their learners with problems where both the goal and strategies to reach the goal of the problem are specified (*cf.* 4.5.2; 4.5.9). This is more in line with a Science exercise where simple recall of information or routine application of knowledge may be applied to solve the problem. This will not allow for the use of higher order thinking skills and will therefore not lead to the development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.24 depicts data on whether teachers feel that higher order thinking skills develop with practice.

Table 4.24: Higher order thinking skills develop with practice

	Frequency/ f	Valid Percent/ %
Almost always	26	61.9
Often	13	31.0
Sometimes	2	4.8
Very seldom	1	2.4
Total	42	100.0

According to the data in Table 4.24, 61.9% of teachers feel that higher order thinking skills *almost always* develop with practice and 31.0% feel that higher order thinking skills *often* develop with practice. Only 2.4% of teachers feel that higher order thinking skills *very seldom* develop with practice.

Scientific Inquiry and the advantage of using a Scientific Investigation helps learners to improve their higher order thinking skills such as analysis, problem solving and evaluating (*cf.* 2.2.2; 2.4.1; 2.7.1.4). A Scientific Investigation provides learners with a challenging problem that draws on Natural Sciences principles and methods and leaves learners free to design and carry out an investigation to arrive at an answer to the problem (*cf.* 2.6.2.3). This process requires that learners are presented with Science problems that involve the use of higher order thinking skills instead of Science exercises that involve only the simple recall of information (*cf.* Table 4.23). When learners become involved with a Science problem they use various skills to gather the necessary information required to solve the problem and then use a Scientific Investigation to support their ideas with experimental evidence (*cf.* 2.2.2.2). This means that the more Scientific Investigations they perform and the more Science problems they solve, the more they practice their higher order thinking skills.

The data in Table 4.24 suggests that many teachers (92.9%) are of the opinion that higher order thinking skills *almost always* or *often* develop with practice. The data in Table 4.24 is supported by the data in Table 4.26 where many teachers (78.5%) state that they *almost always* or *often* afford their

learners an opportunity to perform Scientific Investigations. What does not support the above, however, are the results of Table 4.15 where many teachers (64.1%) *almost always* or *often* formulate questions that require learners to recall information and recite facts. This might imply that learners are being presented with Science exercises as opposed to Science problems and will result in learners' Scientific Investigations being reduced to simple experiments consisting of a sequence of steps to be followed to reinforce concept objectives rather than to encourage the use of higher order thinking skills. The data in Table 4.15 relates well to the data in Table 4.12 where the majority of teachers (61%) feel that doing Science is *almost always* or *often* about doing experiments. The data obtained from the open-ended questions (*cf.* 4.5) further supports this finding in that during the Scientific Investigation, many teachers provide learners with the goal of the problem as well as step-by-step instructions to be followed during the course of the investigation (*cf.* 4.5.2; 4.5.9). The above does not allow for the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

Figure 4.16: Comparison of teachers who claim that higher order thinking skills develop with practice, learners do experiments because doing Science means doing experiments, who formulate questions where learners recite facts, who encourage learners to use higher order thinking skills and those who allow learners to perform Scientific Investigations

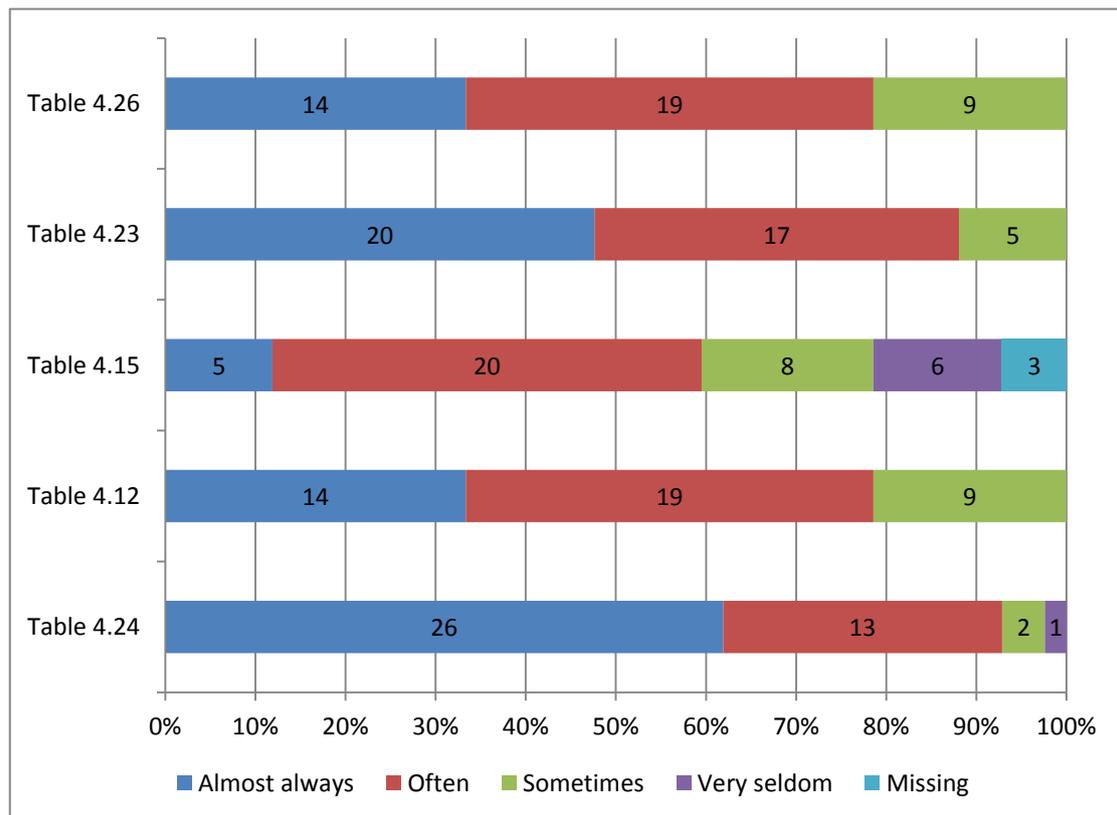


Table 4.25 depicts data on whether teachers feel their learners tackle problems that require them to think for themselves.

Table 4.25: Learners tackle problems that require them to think for themselves

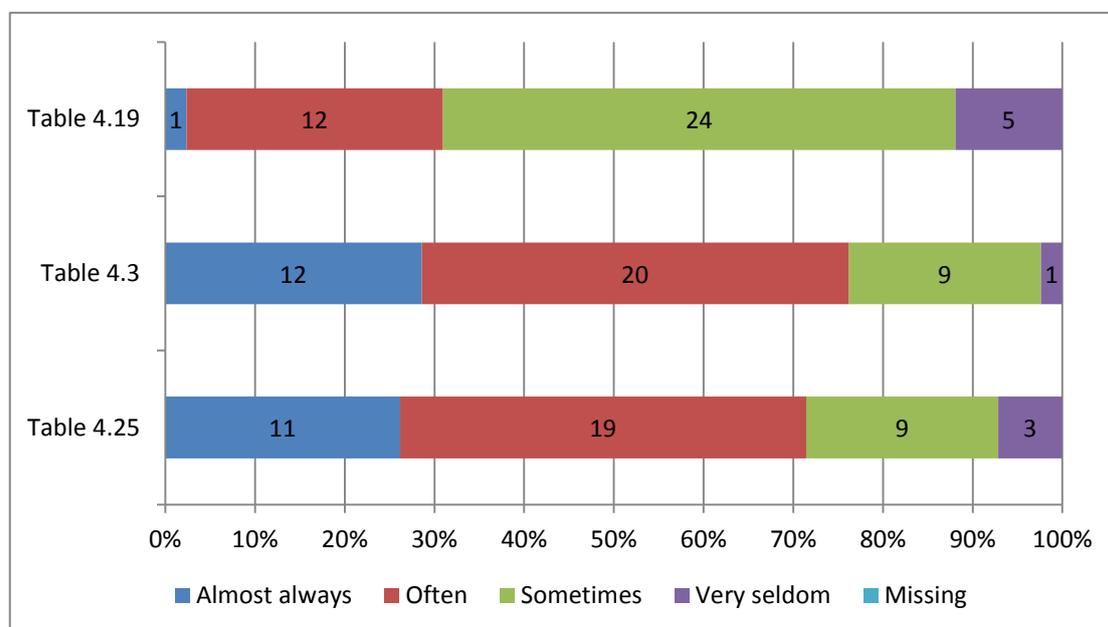
	Frequency/ f	Valid Percent/ %
Almost always	11	26.2
Often	19	45.2
Sometimes	9	21.4
Very seldom	3	7.1
Total	42	100.0

According to the data in Table 4.25, 26.2% of teachers feel their learners *almost always* tackle problems that require them to think for themselves. 45.2% of teachers feel their learners *often* tackle problems that require them to think for themselves and only 7.1% of teachers feel their learners *very seldom* tackle problems that require them to think for themselves.

If the Science problems that teachers set require learners to make choices then teachers can be assured that learners are thinking for themselves (*cf.* 2.2.2.2). Unfortunately some teachers believe that learners may not be inclined to want to tackle such problems. This relates to teachers having fixed ideas about their learners such as teachers who feel that their learners are too lazy to learn (*cf.* 2.7.1.3).

According to the results of this study it seems that teachers set problems for their learners that require them to stretch their imagination and thereby think for themselves (*cf.* Table 4.3). It also appears that teachers believe their learners possess the cognitive abilities to solve these problems (*cf.* Table 4.19). The question remains, do learners actually tackle such problems? The data in Table 4.25 shows that many teachers (71.4%) feel their learners *almost always* or *often* do tackle such problems. The researcher would translate this to mean that many teachers feel their learners are not too lazy to try and solve problems that require them to think for themselves therefore developing their problem solving skills.

Figure 4.17: Comparison of teachers who allow learners to tackle problems that require them to think for themselves, who design problems that stretch learners' imagination and those who feel their learners have limited cognitive abilities



The data obtained from the open-ended questions (*cf.* 4.5) indicates that teachers present their learners with problems where both the goal and strategies to reach the goal of the problem are specified (*cf.* 4.5.2; 4.5.9). This means that there is no need for learners to tackle problems as step-by-step instructions are provided to assist them in solving the problem. Why then, if teachers believe their learners possess the cognitive abilities to tackle problems, do they not afford their learners the opportunity to do so? The answer may be that although teachers say their learners possess the cognitive abilities, in reality they do not believe learners are able to tackle problems that require them to think for themselves. This belief will not promote opportunities for learners to practice their higher order thinking skills and will thereby limit the development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.26 depicts data on whether teachers allow learners to perform Scientific Investigations:

Table 4.26: Learners perform Scientific Investigations

	Frequency/ f	Valid Percent/ %
Almost always	14	33.3
Often	19	45.2
Sometimes	9	21.4
Very seldom		
Total	42	100.0

According to the data in Table 4.26, 33.3% of teachers *almost always* allow learners to perform Scientific Investigations and 45.2% *often* allow learners to perform Scientific Investigations. 21.4% of teachers *very seldom* allow learners to perform Scientific Investigations.

Scientific Inquiry and the advantage of using the laboratory to perform a Scientific Investigation helps learners to improve their higher order thinking skills such as analysis, problem solving and evaluating (*cf.* 2.2.2; 2.4.1; 2.7.1.4). A Scientific Investigation may be defined as an experience in the laboratory, classroom or field that provides learners with opportunities to interact directly with natural phenomena using scientific apparatus, measuring instruments, materials, data collection techniques and models. When learners are performing Scientific Investigations, they are able to develop hypotheses to test, work without direct instruction from the teacher, collect evidence and data, record and organise information and share their observations (*cf.* 2.2.2.2). A Scientific Investigation should provide learners with a challenging problem that draws on Natural Sciences principles and methods and leaves learners free to design and carry out an investigation to arrive at an answer or solution (*cf.* 2.6.2.3).

According to the data represented in Table 4.26, a total of 78.5% of teachers *almost always* or *often* afford their learners opportunities to perform Scientific Investigations. This result appears very encouraging for Scientific Inquiry purposes, however when the data in this table is compared with the data in Table 4.12, the results are not so encouraging. The data in Table 4.12

suggests that many teachers (61%) *almost always* or *often* view doing Science as doing experiments. Scientific Investigations are “not only about patterns in observable relationships but about how these relationships act as evidence for why a phenomenon happens in a particular way” (Windschitl *et al.*,2008:947). The data obtained from the open-ended questions (*cf.* 4.5) supports the notion that doing Science means doing experiments in that during the Scientific Investigation, many teachers provide learners with the goal of the problem and strategies to achieve the goal as well as step-by-step instructions to be followed during the course of the investigation (*cf.* 4.5.2; 4.5.9). This means that the Scientific Investigation is reduced to a sequence of steps to be followed in order to reinforce concept objectives. Experiments do not allow for the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

Figure 4.18: Comparison of teachers who allow their learners to perform Scientific Investigations and whose learners perform experiments because doing Science means doing experiments

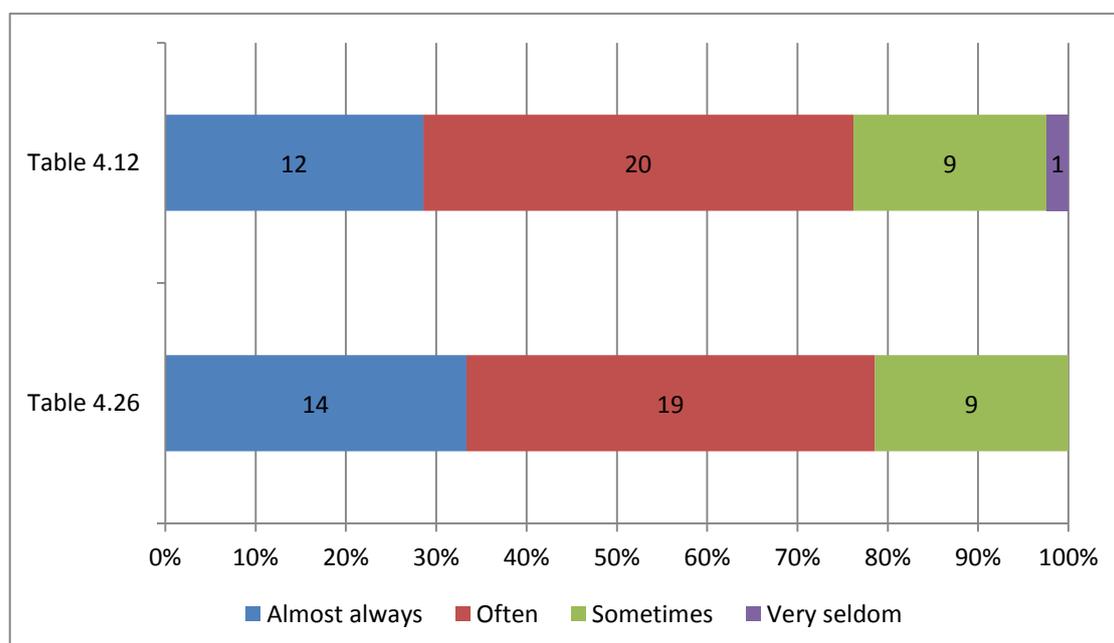


Table 4.27 includes data on whether teachers allow their learners to analyse data collected from their Scientific Investigations.

Table 4.27: Learners analyse data collected from Scientific Investigations

	Frequency/ f	Valid Percent/ %
Almost always	12	29.3
Often	22	53.7
Sometimes	6	14.6
Very seldom	1	2.4
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.27, only 29.3% of teachers *almost always* allow their learners to analyse data collected from Scientific Investigations and 53.7% of teachers *often* allow their learners to analyse data collected from Scientific Investigations. 14.6% of teachers *sometimes* allow learners to analyse data from Scientific Investigations.

When learners become involved in Scientific Investigations they develop the ability to think objectively and use a variety of forms of reasoning while they use Science process skills to investigate, reflect, synthesise and communicate. As part of this process, learners are required to collect evidence, record their data and subsequently analyse this data (*cf.* 2.2.2.2: 2.3).

According to the data in Table 4.26, 78.5% of teachers *almost always* or *often* allow their learners to perform Scientific Investigations. The data in Table 4.27 suggests that many teachers (83%) *almost always* or *often* allow their learners to analyse data collected from these Scientific Investigations. Although these results are encouraging, they do not necessarily differentiate between learners performing Scientific Investigations and learners performing experiments (*cf.* Table 4.12) as the Scientific Method (*cf.* Table 4.1) also incorporates the step of 'data analysis' (*cf.* 2.3).

In the responses to teaching methods employed on a regular basis, as stated in the open-ended questions (*cf.* 4.5.1) of the questionnaire, teachers appear to favour teacher demonstrations as opposed to Scientific Investigations. This is not necessarily incorrect practice as demonstrations also afford learners the opportunity to use their Science process skills to analyse the data obtained from these demonstrations. Learners use Science process skills when they observe, interact and discuss the results of the demonstration. This will assist learners in the development of their problem solving skills.

The data in Table 4.27, however, is not supported by the data obtained from the open-ended questions (*cf.* 4.5) that indicates that many teachers provide learners with the goal of the problem along with step-by-step instructions to be followed during the course of the Scientific Investigation (*cf.* 4.5.2; 4.5.9). This means that the investigation is reduced to an experiment involving a sequence of steps where the analysis of the data is used to reinforce concept objectives. Experiments do not allow for the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

Figure 4.19: Comparison of teachers who allow learners to analyse data collected from Scientific Investigations, who make use of the Scientific Method, whose learners do experiments because doing Science means doing experiments and those whose learners perform Scientific Investigations

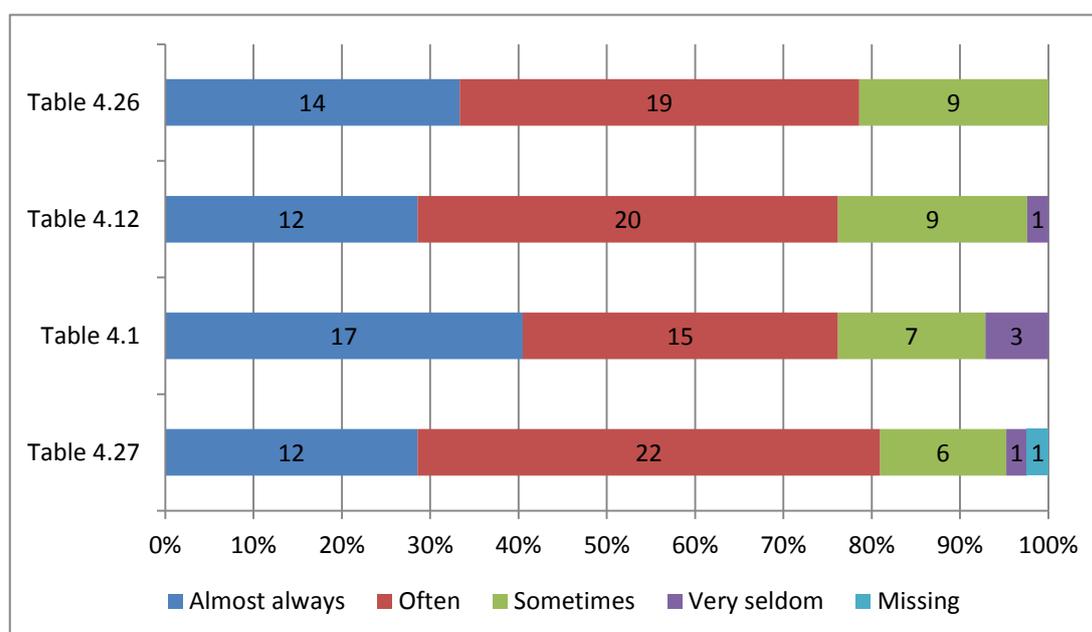


Table 4.28 depicts data on whether teachers allow learners to turn data collected from their Scientific Investigations into information.

Table 4.28: Learners turn data from Scientific Investigations into information

	Frequency/ f	Valid Percent/ %
Almost always	10	23.8
Often	20	47.6
Sometimes	12	28.6
Very seldom		
Total	42	100.0

According to the data in Table 4.28, only 23.8% of teachers *almost always* allow learners to turn data from Scientific Investigations into information and

47.6% of teachers *often* allow learners to turn data from Scientific Investigations into information. 28.6% of teachers *sometimes* allow learners to turn data from Scientific Investigations into information.

As mentioned in the analysis of the data in Table 4.27, when learners become involved in Scientific Investigations they develop the ability to think objectively and use a variety of forms of reasoning while they use Science process skills to investigate, reflect, synthesise and communicate. During Scientific Investigations, apart from analysing the collected data, learners are also expected to turn this data into information. This involves developing suitable forms of representing their data in order to communicate their results, e.g. in the form of a graph (*cf.* 2.2.2.2).

The data in Table 4.27 suggests that many teachers (83%) *almost always* or *often* allow their learners to analyse data collected from their Scientific Investigations. It is therefore encouraging to see that the data represented in Table 4.28 indicates that many teachers (71.4%) *almost always* or *often* allow their learners to turn data from their Scientific Investigations into information. However, when a comparison is made between the data in Table 4.27 and 4.28 it appears that fewer teachers encourage learners to turn their data into information. This is a necessary step in the process of Scientific Inquiry as learners are required to use this information when they share their findings with the class (*cf.* 2.2.2.2; 2.4; 2.4.1; Table 4.29).

Figure 4.20: Comparison of teachers whose learners turn data from Scientific Investigations into information and whose learners analyse data collected from Scientific Investigations

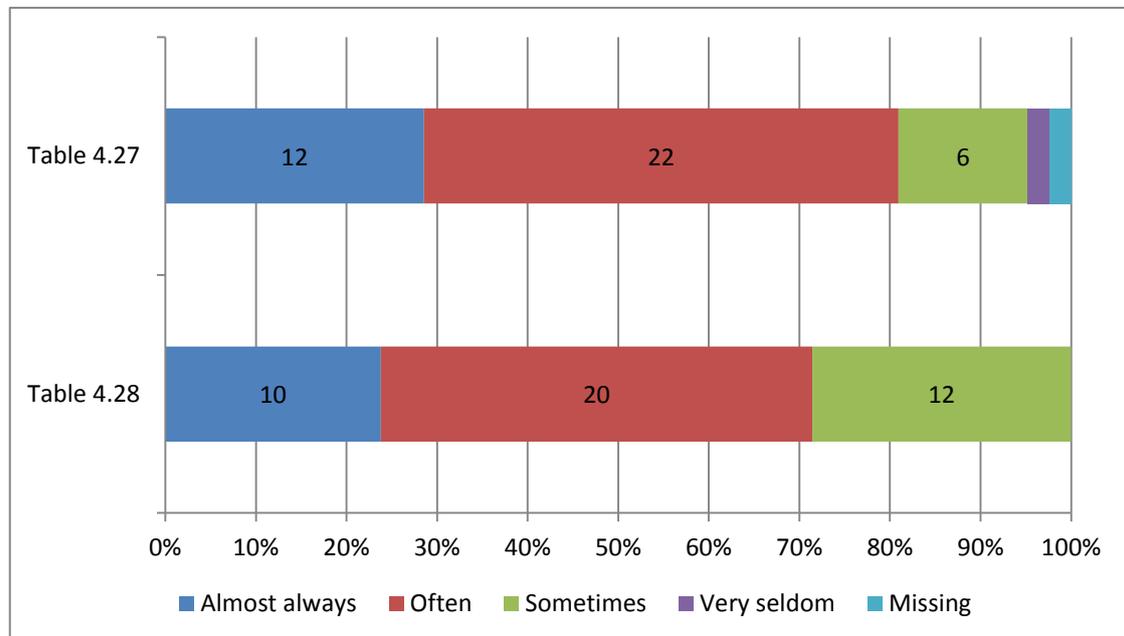


Table 4.29 depicts data on whether teachers allow their learners to communicate findings emanating from their Scientific Investigations to the class.

Table 4.29: Learners communicate findings emanating from Scientific Investigations

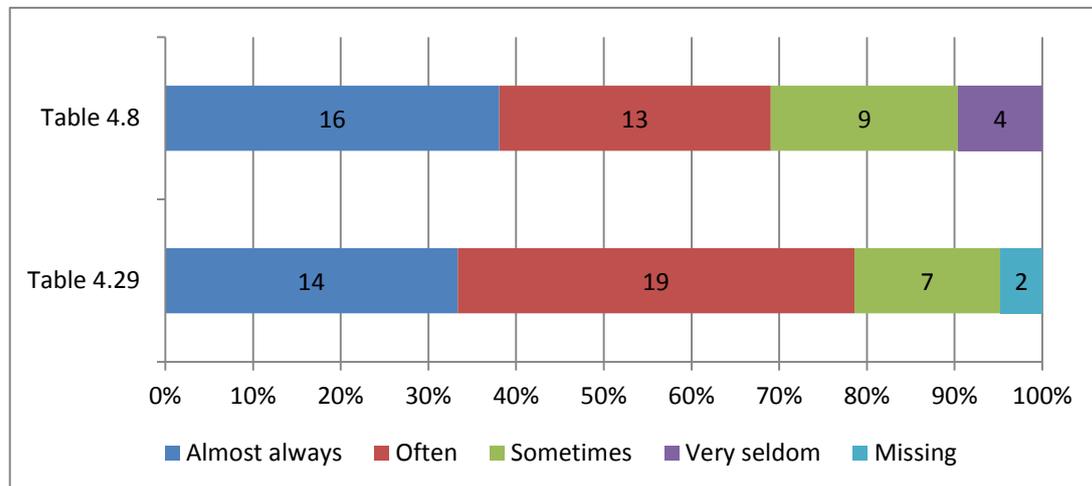
	Frequency/ f	Valid Percent/ %
Almost always	14	35.0
Often	19	47.5
Sometimes	7	17.5
Very seldom		
Total	40	100.0
Missing	2	
Total	42	

According to the data in Table 4.29, only 35.0% of teachers *almost always* allow learners to communicate findings emanating from Scientific Investigations. 47.5% of teachers *often* allow learners to communicate findings emanating from Scientific Investigations and 17.5% *very seldom* allow learners to communicate findings emanating from Scientific Investigations.

Scientific Inquiry requires learners to construct and defend scientific arguments by weighing evidence from their Scientific Investigations against relevant scientific concepts, theories and models in order to reach a suitable conclusion to a problem. Learners present their findings to the class where the teacher facilitates any classroom discussions arising from these findings. These classroom discussions allow learners to 'talk Science' and assist them in developing their problem solving skills (*cf.* 2.2.2.2; 2.4.1; 2.5).

The data represented in Table 4.29 suggests that many teachers (82.5%) *almost always* or *often* allow learners to communicate their findings emanating from their Scientific Investigations. In order for learners to successfully communicate these findings, teachers are required to act as facilitators. The data in Table 4.8 suggests that few teachers (38.1%) *almost always* act as facilitators during such communication. This result is disappointing in that teachers need to help learners articulate their thoughts, provide them with feedback, respond to their questions and encourage them to evaluate themselves and draw connections (*cf.* 2.5).

Figure 4.21: Comparison of teachers who allow learners to communicate findings emanating from Scientific Investigations and those who act as facilitator during classroom discussions



The responses to the open-ended questions (*cf.* 4.5) show that learners are not provided with an opportunity to present their findings to the class where discussions surrounding their findings can be facilitated by the teacher. Learners are encouraged to ask questions but they are not encouraged to enter into classroom discussions surrounding their questions or findings. Teachers are regarded as the source of correct information (*cf.* 4.5.5; 4.5.6). Classroom discussions play an essential role in the development of the problem solving skills of Gr 9 Natural Sciences learners.

Table 4.30 includes data on whether teachers feel that Scientific Inquiry promotes disciplinary problems in the classroom.

Table 4.30: Scientific Inquiry promotes disciplinary problems

	Frequency/ f	Valid Percent/ %
Almost always	11	26.2
Often	19	45.2
Sometimes	9	21.4
Very seldom	3	7.1
Total	42	100.0

According to the data in Table 4.30, 45.2% of teachers feel that Scientific Inquiry *often* promotes disciplinary problems and 21.4% feel that Scientific Inquiry *sometimes* promotes disciplinary problems. Only 7.1% of teachers feel that Scientific Inquiry *very seldom* promotes disciplinary problems.

Scientific Inquiry involves performing Scientific Investigations. A common problem in South African schools is large class sizes. Large numbers of learners in classrooms make Scientific Investigations more difficult to conduct as these investigations involve the preparation of equipment, individual assistance to learners and interactions between learners. With large learner numbers, noise levels increase and control and discipline might become adversely affected (*cf.* 2.7.1.7).

According to the data in this table many teachers (71.4%) feel that Scientific Inquiry *almost always* or *often* promotes disciplinary problems. The researcher is of the opinion that this may be the reason why demonstrations are the top choice of teaching methods employed on a regular basis, as stated in the open-ended questions of the questionnaire.

Table 4.31 depicts data on whether teachers feel they have enough time for learner activities.

Table 4.31: I have enough time for learner activities

	Frequency/ f	Valid Percent/ %
Almost always	13	31.7
Often	8	19.5
Sometimes	14	34.1
Very seldom	6	14.6
Total	41	100.0
Missing	1	
Total	42	

According to the data in Table 4.31, 31.7% of teachers indicate that they *almost always* have enough time for activities and 34.1% indicate they *sometimes* have enough time for learner activities. Only 14.6% indicate they *very seldom* have enough time for learner activities.

Literature highlights insufficient time for learner activities as a complaint of many teachers. Time constraints may be due to the Natural Sciences Curriculum containing a heavy content load as well as onerous administrative requirements. Scientific Inquiry requires time for the development of suitable Science problems as well as preparation and execution time for the ensuing Scientific Investigations (*cf.* 2.7.1.1).

When combining the responses to *almost always and often* and those to *sometimes and very seldom*, the data in the above table indicates a fairly even distribution of responses to this question. A total of 51.2% of teachers feel that they *almost always* or *often* have enough time for activities. On the other hand a total of 48.7% of teachers only *sometimes* or *very seldom* feel they have enough time for activities. The reason teachers feel they have sufficient time for activities may be related to demonstrations being their top choice of teaching method employed on a regular basis, as stated in the open-ended questions (*cf.* 4.5.1) of the questionnaire. The reason teachers feel they have insufficient time may be related to their employment of more

hands-on activities. The researcher feels that if Gr 9 Natural Sciences teachers were to employ more hands-on activities, such as Scientific Investigations conducted by learners themselves, then teachers who feel they have sufficient time may change their response, as more time is required for such activities. Although demonstrations provide for a limited form of Scientific Inquiry, Scientific Investigations conducted by the Gr 9 learners themselves will be more effective in developing their problem solving skills.

Table 4.32 depicts data on whether teachers feel they have enough scientific equipment to conduct Scientific Investigations.

Table 4.32: I have enough scientific equipment

	Frequency/ f	Valid Percent/ %
Almost always	10	23.8
Often	7	16.7
Sometimes	11	26.2
Very seldom	14	33.3
Total	42	100.0

According to the data in Table 4.32, 23.8% of teachers feel they *almost always* have enough scientific equipment and 26.2% feel they *sometimes* have enough scientific equipment. 33.3% of teachers feel they *very seldom* have enough scientific equipment.

The development of the problem solving skills of learners depends on their ability to perform Scientific Investigations. Scientific Investigations require the availability of laboratory equipment and chemicals and sadly research studies have indicated a lack of these resources in certain schools (*cf.* 2.7.1.4). Other research studies state that some teachers are too quick to blame the lack of equipment and chemicals for not performing Scientific Investigations and that these teachers need to take responsibility for the learning outcomes of their learners. This asks for a change of attitude on the part of teachers, from one that blames the situation on forces outside themselves such as a lack of

resources to one in which they feel they can improve their own situation by exercising enterprise and energy. This means that although teachers may have limited resources, they will need to exercise creativity to source alternative resources in order to implement Scientific Investigations if they wish to develop the problem solving skills of learners (*cf.* 2.7.1.4).

If the responses to *almost always and often* and those to *sometimes and very seldom* are combined, the data in the above table indicates a very even spread of responses but ultimately the results lean slightly more towards many teachers (59.5%) feeling that they only *sometimes* or *very seldom* have enough scientific equipment. Regardless of the higher percentage, this result is interpreted by the researcher as encouraging as it may indicate that teachers are exercising enterprise and energy where equipment is in short supply. The lack of equipment may also support demonstrations as being the top choice of teaching method employed on a regular basis, as stated in the open-ended questions (*cf.* 4.5.1) of the questionnaire, as demonstrations require the use of less scientific equipment.

Table 4.33 depicts data on whether teachers have books that show them strategies for Scientific Inquiry.

Table 4.33: I have books that show me strategies for Scientific Inquiry

	Frequency/ f	Valid Percent/ %
Almost always	14	33.3
Often	5	11.9
Sometimes	12	28.6
Very seldom	11	26.2
Total	42	100.0

According to the data in Table 4.33, only 33.3% of teachers *almost always* have books that show them strategies for Scientific Inquiry. 28.6% of teachers *sometimes* have books that show them strategies for Scientific Inquiry and 26.2% *very seldom* have books to show them strategies for Scientific Inquiry.

Textbooks offer a crucial resource for teachers in planning and gaining access to the appropriate knowledge and skills that they are required to teach. Many teacher manuals advocate the teaching of critical thinking skills but few include strategies that assist teachers with developing critical thinking activities. This means that although teacher manuals recognise the need for the development of the problem solving skills of learners, specific explanations of how these problem solving skills should be taught, are not included (*cf.* 2.7.1.5).

According to the data in this table, less than 50% of teachers feel they *almost always* or *often* have books that show them strategies on how to implement Scientific Inquiry. This suggests that teacher manuals that offer guidance with the implementation of Scientific Inquiry are in short supply in schools. However, when the results of this table are related to teachers' access to computers, there may be no excuse in this regard as the data in Table 4.34 indicates that a large number of teachers (61.9%) *almost always* or *often* have access to a computer. The researcher is of the opinion that teachers can exercise energy and enterprise and use the computer to generate activities aimed at developing the problem solving skills of Gr 9 Natural Sciences learners. In so doing, teachers are walking their talk as they themselves become involved in the process of Scientific Inquiry where they perform research using computers to address this problem of limited guidance concerning the implementation of Scientific Inquiry.

Table 4.34 depicts data on whether teachers have access to a computer.

Table 4.34: I have access to a computer

	Frequency/ f	Valid Percent/ %
Almost always	21	50.0
Often	5	11.9
Sometimes	7	16.7
Very seldom	9	21.4
Total	42	100.0

According to the data in Table 4.34, 50.0% of teachers *almost always* have access to a computer and 11.9% *often* have access to a computer. 21.4% of teachers *very seldom* have access to a computer.

Problem solving in Natural Sciences involves the process of Scientific Inquiry which involves making observations, posing questions and researching with books and other resources to enhance what is already known (*cf.* 2.2). In this case, other resources include the use of computers.

The results of the above table are promising in that more than half the teachers (61.9%) *almost always* or *often* have access to a computer and this means that teachers are able to assist learners, who do not have access to computers, with their research. These teachers will also be able to search for a wide variety of Scientific Inquiry activities that are relevant to the curriculum and more specifically to problem solving.

The data in Table 4.33 suggests that teacher manuals offering guidance with the implementation of Scientific Inquiry are in short supply in schools. The results of Table 4.34, indicate there may be no excuses in this regard as a large number of teachers have access to a computer. The researcher is therefore of the opinion that teachers who have access to a computer are able to generate activities to address the problem of limited guidance concerning the implementation of Scientific Inquiry.

Table 4.35 indicates data on whether teachers feel inadequate in teaching Natural Sciences.

Table 4.35: I feel inadequate teaching Natural Sciences

	Frequency/ f	Valid Percent/ %
Almost always	2	5.6
Often	5	13.9
Sometimes	9	25.0
Very seldom	20	55.6
Total	36	100.0
Missing	6	
Total	42	

According to the data in Table 4.35, only 5.6% of teachers *almost always* feel inadequate teaching Natural Sciences and 25.0% *sometimes* feel inadequate teaching Natural Sciences. 55.6% of teachers *very seldom* feel inadequate teaching Natural Sciences.

Research studies involving South African teachers show that they require training in knowledge, skills and methodologies to teach specific content, concepts and skills (*cf.* 2.7.1.6). These studies are not subject specific but the researcher would infer that the above statement could also apply to Natural Sciences teachers who require training in the development of the problem solving skills of learners.

The researcher is therefore very encouraged to see that in the subject Natural Sciences the majority of teachers (80.6%) *only sometimes* or *very seldom* feel inadequate in teaching the subject. This means that many teachers are confident in teaching Natural Sciences.

However, although many teachers may feel confident in this regard, this does not mean that they are teaching their subject effectively. To teach Gr 9 Natural Sciences effectively means to develop the problem solving skills of learners (*cf.* 2.1). This translates into teaching and assessment practices that incorporate the process of Scientific Inquiry (*cf.* 2.2). The data in Table 4.1

indicates that many teachers (76.2%) *almost always* or *often* make use of the Scientific Method. Coupled to this, the data in Table 4.12 suggests that many teachers (61%) view Science as doing experiments. These two factors do not contribute to the effective development of the problem solving skills of Gr 9 Natural Sciences learners. The results of these two tables lead the researcher to believe that teachers lack understanding of what it means to implement Scientific Inquiry. This lack of understanding reinforces the researcher’s claim that although Gr 9 Natural Sciences teachers may feel confident in teaching their subject they may not necessarily be teaching their subject effectively.

Figure 4.22: Comparison of teachers who feel inadequate teaching Natural Sciences, who make use of the Scientific Method, and whose learners do experiments because doing Science means doing experiments

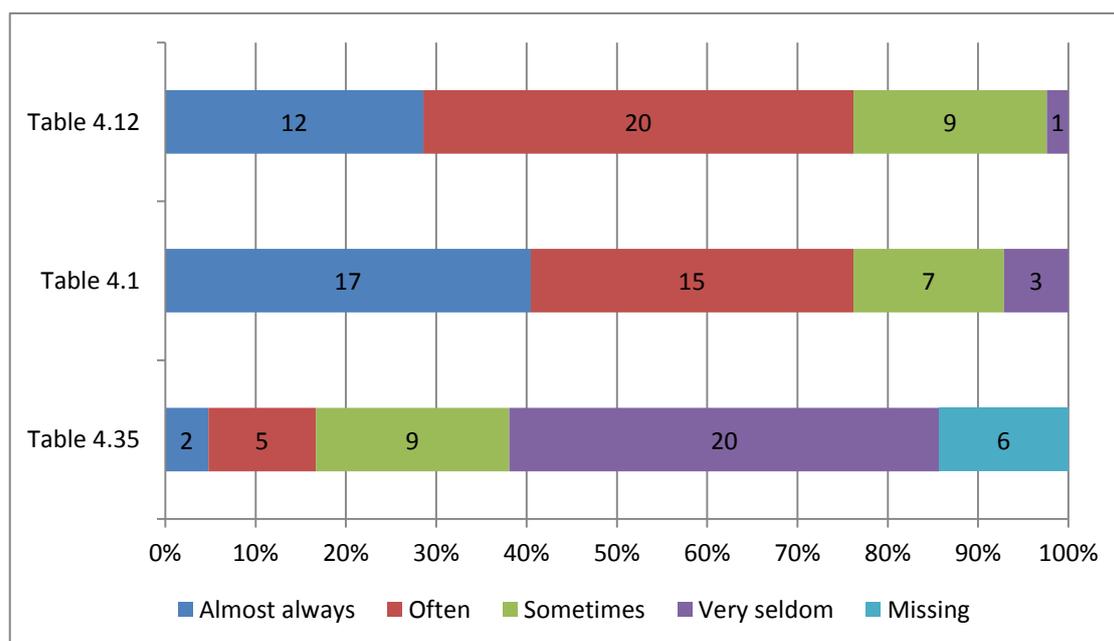


Table 4.36 depicts data on whether teachers feel they require training in teaching Natural Sciences.

Table 4.36: I require training in teaching Natural Sciences

	Frequency/ f	Valid Percent/ %
Almost always	1	2.6
Often	3	7.9
Sometimes	21	55.3
Very seldom	13	34.2
Total	38	100.0
Missing	4	
Total	42	

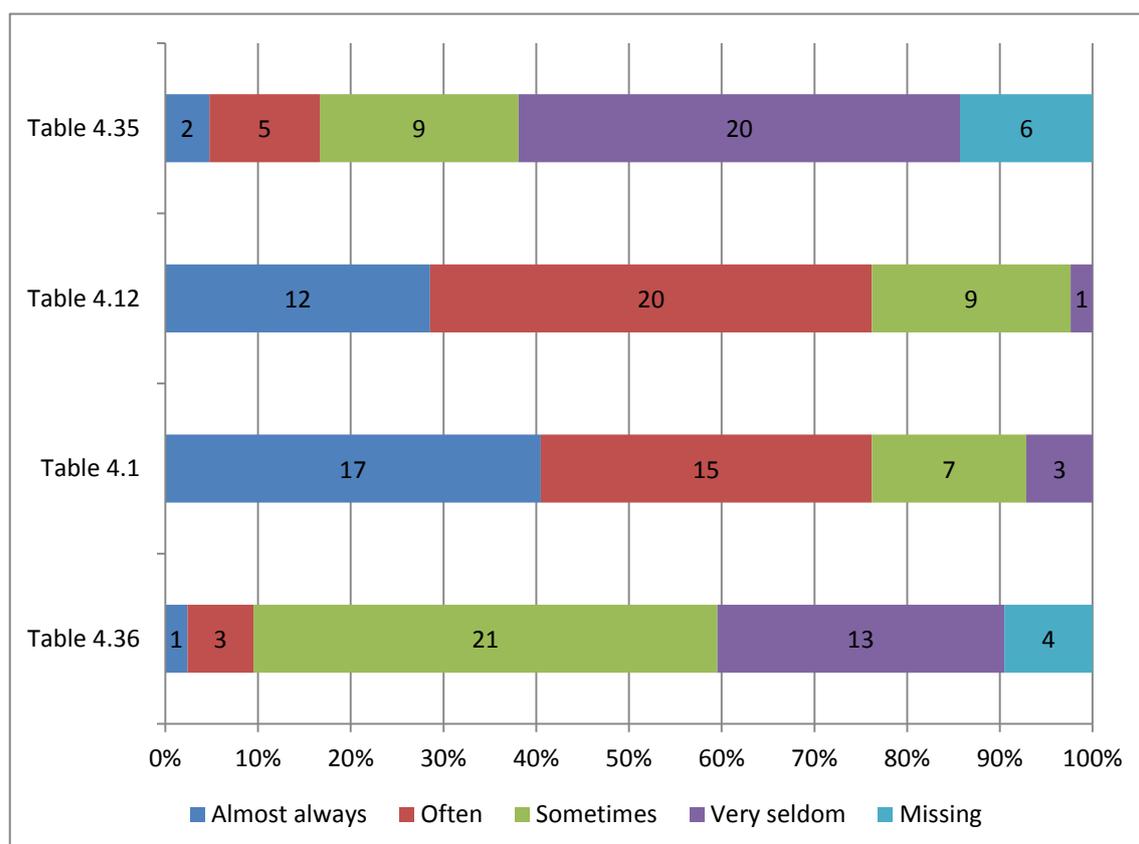
According to the data in Table 4.36, only 7.9 of teachers *often* feel they require training in teaching Natural Sciences. 55.3% of teachers feel they *sometimes* require training in teaching Natural Sciences and 34.2% feel they *very seldom* require training in teaching Natural Sciences.

As mentioned in the discussion of the data presented in Table 4.35, South African studies have indicated that teachers require training in subject knowledge; skills and methodologies to teach specific content; concepts and skills (*cf.* 2.7.1.6). The results of Table 4.36, however, suggest that many Natural Sciences teachers (89.5%) only *sometimes* or *very seldom* feel they need to receive training in their subject. This relates well to the results in Table 4.35 where the majority of teachers (80.6%) only *sometimes* or *very seldom* feel inadequate in teaching Natural Sciences.

The discussion of the data presented in Table 4.35, Table 4.1 and 4.12 highlights the limited understanding that many teachers appear to have of Scientific Inquiry. The data presented in these tables, confirms the researcher's concern that although teachers may feel confident in teaching Natural Sciences, this does not necessarily mean they are teaching Natural Sciences effectively. The researcher is therefore of the opinion that although teachers may not think they require training, a need may exist to update their

current knowledge and skills in order for them to be able to implement the process of Scientific Inquiry effectively.

Figure 4.23: Comparison of teachers who require training in teaching Natural Sciences, who make use of the Scientific Method, whose learners do experiments because doing Science means doing experiments and those who feel inadequate in teaching Natural Sciences



This opinion is supported by the responses to the open-ended questions (*cf.* 4.5.2; 4.5.9) in the questionnaire where teachers state that they use experiments to reinforce concept and content objectives. This is in line with the traditional Scientific Method rather than the process of Scientific Inquiry. This reinforces the researcher’s view that teachers may have a limited understanding of Scientific Inquiry. This limited understanding will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

4.5 SECTION D: PERCEPTIONS OF TEACHING AND ASSESSMENT PRACTICES – OPEN-ENDED QUESTIONS

The closed-ended questions were administered to find evidence of the implementation of Scientific Inquiry in the development of the problem solving skills of Gr 9 Natural Sciences learners. If the process of Scientific Inquiry is implemented correctly then it follows that the teacher will be able to effectively assess the Scientific Inquiry process. The researcher did not put forward any assumptions regarding teachers' assessment of Scientific Inquiry in the development of the problem solving skills of Gr 9 Natural Sciences learners. Methods for assessing Scientific Inquiry in the development of the problem solving skills of Gr 9 Natural Sciences learners were not provided for in the closed-ended questions.

The open-ended questions were included in the questionnaire to provide teachers with an opportunity to qualify their responses to the closed-ended questions as well as to discuss their assessment methods by answering the open-ended questions. A total of 9 open-ended questions were included in the questionnaire and responses to these are discussed below:

4.5.1 Two teaching methods employed on a regular basis

The top two choices of teaching methods used on a regular basis are identified as demonstrations and classroom discussions with lectures being placed third out of a possible nine teaching methods. These results are encouraging as they show that although teachers do opt for methods of teaching which may be classified as expository instruction, they do so, on an infrequent basis. However, the data might also imply that most of the time in class is spent on teachers performing demonstrations and holding classroom discussions.

The choice of classroom discussions is contradicted by the data presented in Table 4.8, 4.10 and 4.17 of the closed-ended questions which indicates that few teachers *almost always* act as facilitators during classroom discussions, few teachers *almost always* encourage learners to debate topics and that less

than half of teachers *almost always* encourage learners to exchange their ideas during classroom discussions.

Classroom discussions promote learners' abilities to reason and justify their claims as well as interact with the teacher and their fellow learners in terms of both building and critiquing ideas. These discussions require that a teacher act as facilitator in this regard (*cf.* 2.4.2; 2.5). Although classroom discussions are often held, it would appear that teachers seldom encourage the learners to exchange ideas during these classroom discussions. This could mean that during these discussions teachers are doing most of the talking. This assumption is supported by the data depicted in Table 4.16 which indicates that almost half the teachers participating in this study *almost always* or *often* do most of the talking during a lesson. The responses to the open-ended questions (*cf.* 4.5) indicate that teachers act as information providers to questions asked by learners where no classroom discussions or debates surrounding the questions are encouraged (*cf.* 4.5.5; 4.5.6). The researcher is of the opinion that all teachers should act as facilitators during classroom discussions and should encourage learners to exchange their ideas, debate and argue their scientific claims during these classroom discussions. This will allow learners to practice 'talking science' and in so doing assist with the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.5).

4.5.2 What does the term Scientific Inquiry mean to you?

The responses to this open-ended question reveal that unfortunately only 10 out of a possible 42 teachers are able to provide a quality explanation for the term Scientific Inquiry. Most responses support an explanation that is in line with the traditional Scientific Method.

Scientific Inquiry is a valuable practice for assisting teachers with the development of the problem solving skills of learners as it constitutes a process whereby learners make observations, pose questions and research with books and other resources to enhance what they already know. This process is supported with experimental evidence where learners use their

current scientific knowledge and understanding to guide a Scientific Investigation in their search for solutions to problems (*cf.* 2.4). Scientific Inquiry is not a self-contained procedure which is disconnected from scientific theories and models, with orderly steps to be followed such as the Scientific Method (*cf.* 2.4). Teachers need to understand the difference and ensure that Scientific Inquiry is included in their teaching and assessment practices to ensure the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

4.5.3 Have you received any formal training in Scientific Inquiry?

Of the 42 teachers who completed the questionnaire, 22 indicate they received formal training in the process of Scientific Inquiry. Out of these 22 teachers only 10 are able to provide a quality explanation for Scientific Inquiry (*cf.* 4.5.2).

Teachers' responses show that they see Scientific Inquiry more as the traditional Scientific Method. This method constitutes a procedure to be followed where a Scientific Investigation becomes reduced to performing a simple experiment. Although Scientific Inquiry incorporates the logic of problem solving that comes from the Scientific Method, it does not necessarily incorporate the delineated, specific steps or rigid approach of the Scientific Method. The Scientific Method serves to reinforce concept objectives whereas Scientific Inquiry serves to build concepts, theories or models (*cf.* 2.3). Teachers' poor explanation of Scientific Inquiry is also reflected in the closed-ended questions of the questionnaire (*cf.* Table 4.1; Table 4.12) where many teachers implement the Scientific Method as they view doing Science as doing experiments.

4.5.4 What learning opportunities do your learning methods provide for learners?

Many teachers feel their learning methods present learners with the opportunity to think critically and creatively as they explore and apply their scientific knowledge to help them understand the world around them. This gives them a sense of independence and enables them to function in society.

This would indicate that teachers appear to support the view that learners need to acquire a degree of scientific literacy if they are to function effectively in society. In Natural Sciences, an understanding of the world and being able to make informed decisions relating to the practices and policies that affect the natural world, are key characteristics of scientific literacy (*cf.* 1.1; 2.1).

4.5.5 What do you think is the teachers' role during a learning experience?

The majority of teachers see their role as that of facilitator and guide during a learning experience. Teachers suggest the use of demonstrations and classroom discussions in this regard which are also confirmed as being the top two choices of teaching methods used on a regular basis (*cf.* 4.5.1). Sadly, a number of teachers see their role as that of information provider during a learning experience.

Although the majority of teachers have the idea that they should act as a facilitator during classroom discussions, the results of the closed-ended questions contradict this idea, as the data presented indicate that few teachers *almost always* act as facilitators during classroom discussions and also less than half of teachers *almost always* encourage learners to exchange their ideas during classroom discussions (*cf.* Table 4.8; Table 4.17).

In a Natural Sciences classroom, the teachers' role is that of facilitator rather than dispenser of information (*cf.* 2.4.2). During the development of the problem solving skills of learners, learners are required to construct and defend scientific arguments by weighing evidence from their Scientific Investigations against relevant scientific concepts, theories and models in order to reach a suitable conclusion to a problem. This means that Natural Sciences classrooms should include many opportunities for learners to engage in classroom discussions. An important role of the teacher becomes to guide and support learners in playing an active role in these discussions. Teachers do this by helping learners articulate their thoughts, provide them with feedback, respond to any question in a positive manner and encourage learners to evaluate themselves and draw connections without teachers

evaluating the learner in the process (*cf.* 2.5). The effective facilitation of classroom discussions will assist Gr 9 Natural Sciences learners in developing their problem solving skills.

4.5.6 What do you expect from your learners during a learning experience?

The majority of teachers' responses to this question indicate that they expect learners to participate in the learning experience by asking questions and also provide answers to the questions asked of them. In so doing, teachers feel learners will acquire and develop an understanding of and be able to apply Natural Sciences concepts and content. However responses to the closed-ended questions show that very few teachers recognise the importance of classroom discussions surrounding these questions and how these discussions can help learners develop their understanding and application of Natural Sciences concepts and content.

If teachers wish to develop the problem solving skills of learners then it is not sufficient to expect learners to simply ask and answer questions during the learning experience as teachers only serve to act as information providers in this regard. Teachers also need to facilitate interactive classroom discussions surrounding these questions. Discussions allow learners to 'talk Science' as they reflect on their experiences, make sense of their data, connect learning to prior knowledge, create meaning, construct scientific arguments by weighing evidence from their Scientific Investigations and consider relevant Natural Sciences concepts, theories and models when answering questions and solving problems. It becomes the teachers' responsibility to guide and support learners in playing an active role in these classroom discussions and in so doing assist Gr 9 Natural Sciences learners in developing their problem solving skills (*cf.* 2.4.2; 2.5).

4.5.7 What important aspects do you keep in mind when you design your assessment tasks?

A number of teachers' responses indicate that the assessment tasks they design ensure that learners achieve the objectives of the learning experience

by being challenging and help learners grow and develop in their understanding of Natural Sciences concepts and content. The assessment tasks also cater for the different cognitive abilities of the learners.

When teachers design assessment tasks to assess the development of the problem solving skills of learners they need to design tasks that assess the Scientific Inquiry capabilities of learners (*cf.* 2.6.1). Scientific Inquiry requires that learners become involved with an intellectually and cognitively challenging Science problem where they use their current scientific knowledge to guide a Scientific Investigation. Within this Scientific Investigation learners raise questions, develop a hypotheses to test, and work without direct instruction from the teacher as they collect evidence and data, record and organise information and share their observations and findings with the class (*cf.* 2.2.2.1; 2.2.2.2). To assess the Scientific Inquiry capabilities of learners, teachers need to design assessment tasks that measure the physical processes (Scientific Investigation skills and Science process skills), thinking and reasoning skills as well as the development of knowledge of Natural Sciences concepts and content of the learners (*cf.* 2.6.2). In teachers' responses to this question no mention was made to any of these skills except for one teacher who mentioned the need to assess the thinking and reasoning skills of learners. This may be attributed to many teachers employing the traditional Scientific Method which provides for a limited form of Scientific Inquiry (*cf.* Table 4.1; Table 4.12; 4.5.2; 4.5.9). The incomplete assessment of the Scientific Inquiry capabilities of learners will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

4.5.8 What methods of assessment do you use?

Teachers' responses to this question indicate that tests are the most commonly used form of assessment, with Scientific Investigations and class work being the second most common form of assessment. Homework, classroom discussions and debates are the least common form of assessment.

Scientific Investigations, including classroom discussions and debates surrounding the Scientific Investigations provide teachers with a valuable tool for assessing the development of the problem solving skills of learners (*cf.* 2.6.1; 2.6.2.1). The responses to this question reveal that many teachers use Scientific Investigations as an assessment method. This is of concern to the researcher as teachers' responses to the closed-ended and other open-ended questions show that teachers favour the employment of the Scientific Method (*cf.* Table 4.1; Table 4.12; 4.5.2; 4.5.9). Problem solving requires that teachers implement the process of Scientific Inquiry rather than the Scientific Method. Scientific Inquiry incorporates the logic of problem solving that comes from the Scientific Method, but not necessarily the delineated, specific steps thereof and recognises that results from Scientific Investigations are used to build scientific theories and models in order to solve problems (*cf.* 2.2; 2.3). Teachers therefore need to assess learners' Scientific Inquiry skills if they wish to assess the development of the learners' problem solving skills.

As mentioned in section 4.5.7, the assessment of Scientific Inquiry involves addressing how well learners are able to carry out physical processes (Scientific Investigation skills and Science process skills), use their thinking and reasoning skills as well as develop knowledge of Natural Sciences concepts and content (*cf.* 2.6.2). If teachers are implementing the Scientific Method, they will only be able to assess the learners' ability to perform an experiment according to a sequence of steps that would involve the use of certain Scientific Investigation and Science process skills (*cf.* 2.3; 2.6.2.3; 2.6.2.4). Also, teachers will only be able to assess learners' acquisition of knowledge of Natural Sciences concepts and content. They will be unable to assess learners making meaning, achieving understanding, applying, analysing, evaluating and synthesising their knowledge of Natural Sciences concepts and content as the Scientific Method only serves to reinforce concepts and content objectives (*cf.* 2.3; 2.6.2.2).

As very few teachers use classroom discussions and debates as an assessment method they will be unable to assess learners' thinking and reasoning skills as discussions and debates assist teachers in making thinking

and reasoning visible (*cf.* 2.6.2.1). Ineffective assessment methods will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

4.5.9 Briefly describe a recent Scientific Investigation

Responses to this question show that many teachers present their learners with a problem, along with the goal of the problem as well as step-by-step instructions to follow during a Scientific Investigation. This shows that learners are reliant on the teacher to direct their steps during the solving of a Natural Sciences problem.

Providing the learners with the goal of the problem as well as step-by-step instructions to follow during the Scientific Investigation supports the notion that doing Science means doing experiments. Reducing a Scientific Investigation to an experiment supports the implementation of the Scientific Method rather than the process of Scientific Inquiry (*cf.* 2.3). The responses to this question are supported by the data presented in Table 4.1 and 4.12 which show that many teachers *almost always* or *often* make use of the Scientific Method and many teachers *almost always* or *often* feel that doing Science means doing experiments.

Although the Scientific Method may help learners to exercise their Science process skills as well as certain Scientific Investigation skills, the method allows for the acquisition of knowledge as opposed to a deep understanding of Natural Sciences concepts and content. The teaching and learning of content becomes separated from the teaching and learning of process and results in learners being unable to apply knowledge to different contexts (*cf.* 2.4.2).

The responses to this question also indicate that the majority of problems presented to the learners are in the form of Science exercises that involve the simple recall of facts or routine application of knowledge during the execution of the step-by-step instructions and do not allow for the employment of higher order thinking skills. No teachers provided the learners with an opportunity to perform their own Scientific Investigations and arrive at their own solution to

the problem. This leads the researcher to believe that although teachers indicate their learners do not have limited cognitive abilities (*cf.* Table 4.19) they behave as though they do. It is one thing to expect high levels of cognitive engagement from learners but if learners are not presented with opportunities to practice their higher order thinking skills then teachers will not be successful in developing the problem solving skills of their Gr 9 Natural Sciences learners (*cf.* 2.7.1.3).

All problems presented to learners were related directly to Natural Sciences content and not to real life problems. On completion of the problem, only one teacher attempted to relate and apply new learning to the learners' lives and society. It seems that although teachers recognise the importance of relating new learning to what the learners already know (*cf.* 2.4.2), they do not appear to afford learners the opportunity to apply scientific skills to real life problems. This does not allow for an authentic context for the development of the problem solving skills of learners that will contribute to the scientific literacy of Gr 9 Natural Sciences learners (*cf.* 2.2.1.2).

The above substantiates the researcher's view that teachers may possess a limited understanding of Scientific Inquiry. This limited understanding will lead to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners.

4.6 SUMMARY

The researcher wants to confirm teaching and assessment practices relating to the implementation of Scientific Inquiry as a process identified in literature that supports the development of the problem solving skills of Gr 9 Natural Sciences learners. Scientific Inquiry is a process whereby learners make observations, pose questions and research with books and other resources to enhance what they already know. This process is supported with experimental evidence where learners use their current scientific knowledge and understanding to guide a Scientific Investigation as they search for solutions to problems.

During the course of the Scientific Investigations, teachers should provide their learners with a challenging problem to solve. The data obtained in this research makes it evident that teachers provide learners with the goal of the problem as well as step-by-step instructions to follow during the course of the investigation. Learners therefore rely on the teacher to direct their steps in solving the problem. Learners are not expected to tackle the problem, perform their own Scientific Investigations and arrive at their own solution to the problem. Thoughts and ideas pertaining to the above discussion follow in the next few sections.

4.6.1 The Scientific Method

When a Scientific Investigation becomes a sequence of steps to be followed in order to solve a problem, it supports the notion that doing Science means doing experiments. Experiments act to confirm or reject what the learners already know and do not allow for the employment of higher order thinking skills. When an investigation is reduced to an experiment this supports the traditional Scientific Method rather than the process of Scientific Inquiry (*cf.* 2.3). By employing the Scientific Method, teaching and learning of content becomes separated from the teaching and learning of process as learners are unable to make connections between ideas and concepts in their minds. The Scientific Method allows for the acquisition of knowledge as opposed to a deep understanding of Natural Sciences concepts and content. Learners are therefore not fully enabled to apply their knowledge to new situations (*cf.* 2.4.2).

Teachers appear to have a limited view of the process of Scientific Inquiry and experiments and the employment of the Scientific Method will not allow for the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

4.6.2 The type of Science problem

The type of problem presented to the learners may be classified as a Science exercise. This type of problem specifies the goal of the problem as well as the steps to follow in solving the problem.

Science exercises involve the recall of information and routine application of theory to a familiar situation and do not present learners with an opportunity to develop their problem solving skills. Science problems on the other hand involve the use of higher order thinking skills such as reasoning, analysis, synthesis and problem solving, making of connections and critical evaluative thinking, including the application of known theory or knowledge or procedure, to unfamiliar situations. Science problems lead to the effective development of the problem solving skills of learners (*cf.* 2.2.2.1).

The researcher is of the opinion that learners should also be given the opportunity to solve problems relating to real life situations as this allows for an authentic context for the development of the problem solving skills of learners that will contribute to developing the scientific literacy of Gr 9 Natural Sciences learners.

4.6.3 Connecting knowledge

The analysis of the data obtained regarding Scientific Investigations and the information provided by this analysis shows that Scientific Investigations serve only to reinforce Natural Sciences concepts and content objectives. Few teachers attempt to connect prior knowledge and experiences to new knowledge and concepts.

Learners involved with the process of Scientific Inquiry grow in scientific literacy and knowledge as Scientific Inquiry allows them to answer questions that challenge their prior knowledge about themselves and their environment (*cf.* 2.4.1). In a Natural Sciences classroom teachers should value the learners' views and alter their teaching based on the prior knowledge and preconceptions of the learners. By teachers asking thoughtful questions and then constantly connecting their learners' prior knowledge and experiences to new Natural Sciences knowledge and concepts, learners are able to reflect on their experiences; make sense of data; create meaning; and apply learning to their lives, technology and society (*cf.* 2.4.2). In so doing teachers develop the problem solving skills of Gr 9 Natural Sciences learners and thereby ensure

they become scientifically literate so that they will one day be able to function in society to the best of their ability (*cf.* 2.1).

4.6.4 Classroom discussions

The researcher is of the opinion that many teachers do most of the talking in class. Learners are not provided with an opportunity to present their findings to the class where discussions surrounding their findings can be facilitated by the teacher. Although learners are encouraged to ask questions, they are not encouraged to enter into classroom discussions or debates surrounding these questions. Teachers evaluate the learners' responses to questions as being correct or incorrect after which they provide the learners with the correct answer. Very few open-ended questions are asked, resulting in very few productive classroom discussions being entered into.

Classroom discussions and debates play an essential role in the development of the problem solving skills of Gr 9 Natural Sciences learners. Teachers act as information providers when they elicit correct responses from learners to closed-ended questions and they become regarded as the source of the correct answer to questions and problems. This prevents learners from arriving at a solution to a problem for themselves.

The researcher is of the opinion that all teachers should encourage learners to exchange their ideas during classroom discussions. Facilitating classroom discussions instead of dispensing the correct information allows learners to practice 'talking science' which is a necessary step for learners in developing and defending their ideas formulated from their Scientific Investigations. These classroom discussions lead to the development of higher order thinking skills by allowing learners' to reason and justify their claims as well as interact with the teacher and fellow learners in terms of both the building and critiquing of ideas (*cf.* 2.4.1; 2.4.2; 2.5).

Classroom discussions and debates contribute to the effective development of the problem solving skills of Gr 9 Natural Sciences learners.

4.6.5 Assessment

Assessment forms a critical part of the development of the problem solving skills of learners. Assessing problem solving skills involves assessing the Scientific Inquiry capabilities of learners and is identified as a problem area in this study as the researcher could find no true evidence thereof. The reason for this is that teachers are implementing the Scientific Method as opposed to the process of Scientific Inquiry. The researcher is, however, of the opinion that should the process of Scientific Inquiry be implemented correctly, then the effective assessment of learners' Scientific Inquiry capabilities will follow naturally.

Assessment of the process of Scientific Inquiry requires assessing learners' thinking and reasoning skills, Natural Sciences concepts and content knowledge, Scientific Investigation skills and Science process skills. The researcher did find evidence of the assessment of Natural Sciences concepts and content where teachers ask learners closed-ended questions to which the learners respond with facts. The aim of these teachers is to elicit the correct responses to their questions, thereby reinforcing Natural Sciences concepts and content. This may be seen as a suitable assessment task for an investigation conducted according to the Scientific Method, however, the process of understanding Natural Sciences concepts and content is more than knowing a lot of facts. The assessment of Scientific Inquiry demands that learners possess not only factual knowledge but that this knowledge includes a deep understanding of Natural Sciences processes, phenomena, mechanisms, principles, theories, laws, and models as parts of the larger Natural Sciences conceptual schemes. This involves knowing, understanding, and making meaning of Natural Sciences in a way that enables learners to make many connections between the ideas and concepts in their minds. Making such connections enables learners to apply their knowledge to new and unfamiliar contexts (*cf.* 2.6.2.2).

No evidence was found concerning the assessment of learners' thinking and reasoning skills. Very few classroom discussions surrounding questions and results from the Scientific Investigations are entered into. Learners offer facts

in response to teachers' questions rather than explanations or arguments. Planned assessment discussions, debates and arguments permit teachers to recognise learners' conceptions, mental models, strategies, language use, or communication skills and make their thinking and reasoning skills visible for the purpose of assessment (*cf.* 2.6.2.1).

No evidence concerning the assessment of learners' Scientific Investigation skills were noted. During the Scientific Investigations, learners are presented with a problem where the goal as well as step-by-step instructions is provided in order to solve the problem. Learners are not expected to conduct their own Scientific Investigations. A fundamental aspect of Scientific Inquiry is the Scientific Investigation that provides learners with a challenging problem that draws on Natural Sciences principles and methods and allows learners to design and carry out their own investigation to arrive at an answer or solution to a problem. As learners engage in the Scientific Investigation, the teacher is able to collect a variety of information thereby gathering evidence of the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.6.2.3).

The researcher is of the opinion that if the process of Scientific Inquiry is implemented correctly by the teachers it will enable them to effectively assess the learners during this process. The effective assessment of the process of Scientific Inquiry will contribute to the development of the problem solving skills of Gr 9 Natural Sciences learners

4.7 CONCLUSION

Teachers' responses to most of the closed and open-ended questions indicate they believe they employ teaching and assessment practices that lead to the development of the problem solving skills of Gr 9 Natural Sciences learners. These responses also appear to suggest that learners are exposed to the process of Scientific Inquiry. However, teachers' responses to certain questions lead the researcher to assume that teachers may not fully understand what it means to implement Scientific Inquiry as their teaching and assessment practices are more in line with the traditional Scientific Method.

This assumption is evident in that:

- teachers make use of the Scientific Method;
- teachers view doing Science as doing experiments;
- few teachers *almost always* act as facilitators during classroom discussions;
- few teachers *almost always* encourage learners to exchange their ideas during classroom discussions;
- few teachers *almost always* encourage learners to debate topics; and
- many teachers *almost always* or *often* formulate questions where learners are required to recite facts.

Training may be seen as an immediate solution to assist teachers with the implementation of Scientific Inquiry, however, of concern to the researcher is that a large percentage of teachers, who already received formal training in Scientific Inquiry, were not able to provide a quality explanation for what it means to implement the process.

Added to the above, teachers' feel they have limited scientific equipment, an endless amount of information to cover and the idea that Scientific Inquiry promotes disciplinary problems in the class.

The above discussion suggests that there are a number of factors that may hamper a teacher's quest in developing the problem solving skills of Gr 9 Natural Sciences learners. The next chapter provides a summary of the chapters of this study and presents the findings and recommendations pertaining to the aim and objectives of this study.

CHAPTER 5

SUMMARY, FINDINGS AND RECOMMENDATIONS

5.1 INTRODUCTION

The aim of this study was to determine teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners. The specific objectives of the study were as follows:

- To determine the nature of teaching practices used in the development of the problem solving skills of Gr 9 Natural Sciences learners
- To determine the nature of assessment practices used to evaluate the development of the problem solving skills of Gr 9 Natural Sciences learners
- To develop recommendations to support teachers in the development of the problem solving skills of Gr 9 Natural Sciences learners.

The purpose of this chapter is to provide a summary of the chapters of this study and to present the findings and recommendations pertaining to the aim and objectives of this research. The researcher will also assess the achievement of the set objectives.

In the next section, a summary of the chapters is presented.

5.2 SUMMARY OF STUDY CHAPTERS

Chapter 1 provided an orientation of the study and focused on the background information, the problem statement, the aim and objectives of the study, as well as the conceptual framework and method of research. The measuring instrument was discussed. The quantitative empirical research approach, the population and sample were also presented. The statistical techniques, the possible contribution, challenges and the layout of the study were also covered in this chapter.

The focus of **Chapter 2** was on an in-depth literature survey that determined the nature of teaching and assessment practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

In **Chapter 3**, the purpose was to outline the design and methodology of the study used to explore South African teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

In **Chapter 4** the data analysis and interpretation thereof was presented.

In **Chapter 5**, the focus will be on the findings, recommendations and the conclusion of the study.

5.3 FINDINGS FROM THE RESEARCH AND RELATED RECOMMENDATIONS AND MOTIVATIONS

The findings of this research are related to the study objectives outlined in Chapter 1 (*cf.* 1.4).

5.3.1 Findings related to the literature review (i.e. research objectives 1 and 2)

5.3.1.1 Findings related to research objective 1

To determine the nature of teaching practices used for the development of the problem solving skills of Gr 9 Natural Sciences learners.

- Problem solving promotes scientific literacy in learners where learners understand and are able to make informed decisions relating to problems they will one day encounter in society (*cf.* 2.1).
- Teaching practices that involve the process of Scientific Inquiry, where learners make observations, pose questions, perform research and support the process with experimental evidence obtained from a Scientific Investigation, promote the development of the problem solving skills of learners (*cf.* 2.2; 2.2.2.2).

- Scientific Inquiry is underpinned with experimental evidence when learners use their current scientific knowledge and understanding to guide a Scientific Investigation in order to solve a problem (*cf.* 2.2; 2.4).
- Scientific discussions form a critical part of Scientific Inquiry in that these discussions help learners to reason appropriately using scientific concepts and models and introduce them to the essential scientific practice of argumentation (*cf.* 2.2; 2.4.1; 2.4.2; 2.5).
- Scientific Inquiry differs from the Scientific Method in that Inquiry is a way of thinking that is not limited to a sequence of steps and patterns in observable relationships but rather to how these relationships act as evidence for why a phenomenon happens in a particular way (*cf.* 2.3).
- The type of problem employed during Scientific Inquiry is critical when it comes to the successful development of the problem solving skills of learners (*cf.* 2.2.2.1).
- Limited resources may pose a problem when it comes to conducting Scientific Investigations used in support of the process of Scientific Inquiry (*cf.* 2.7.1.4).

5.3.1.2 Recommendations and motivations related to research objective 1

Recommendation 1

Teachers should focus on developing the problem solving skills of Gr 9 Natural Sciences learners to help them become scientifically literate.

Motivation

Problem solving in Natural Sciences will provide learners with an understanding of the natural world that will serve as a basis for learners' own personal choices and decisions thereby creating scientifically literate learners who will one day become responsible citizens in society (*cf.* 2.1).

Recommendation 2

Scientific Inquiry should form an integral part of lessons in the Natural Sciences classroom in order to develop the problem solving skills of Gr 9 learners.

Motivation

Scientific Inquiry is a process known to develop the critical and creative thinking skills as well as the Science process skills of learners, all of which are necessary if Gr 9 Natural Sciences learners are to become effective problem solvers (*cf.* 2.2.1.1; 2.2.1.2).

Recommendation 3

Teachers should expose Gr 9 Natural Sciences learners to Scientific Investigations to improve their problem solving skills.

Motivation

During a Scientific Investigation learners develop the ability to think objectively and use a variety of forms of reasoning while they employ Science process skills such as planning, observing, inferring, measuring, classifying, etc. as they investigate, reflect, synthesise and communicate in order to solve a problem (*cf.* 2.2.1; 2.2.1.2).

Recommendation 4

During the process of Scientific Inquiry, discussions facilitated by the teacher should encourage Gr 9 Natural Sciences learners to reflect on their experience, data and conclusions obtained from a Scientific Investigation used to address a Science problem (*cf.* 2.4.2).

Motivation

In the context of a Natural Sciences classroom discussion, Gr 9 learners justify their claims as well as consider alternative claims provided by other learners thereby promoting their abilities to reason as well as interact with

their teacher and peers in terms of confirming, rejecting or building upon their existing ideas (*cf.* 2.5).

Recommendation 5

It is recommended that teachers employ the practice of Scientific Inquiry as opposed to the Scientific Method in order to effectively develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Scientific Inquiry incorporates the logic of problem solving that comes from the Scientific Method, but not necessarily the delineated, specific steps thereof and also recognises that the results from Scientific Investigations are used to build scientific theories and models in order to solve problems (*cf.* 2.3).

Recommendation 6

During Scientific Inquiry, teachers should present learners with Science problems as opposed to Science exercises in order to assist Gr 9 Natural Sciences learners in developing their problem solving skills.

Motivation

Science problems require learners to employ higher order thinking skills including the application of knowledge to unfamiliar situations whereas Science exercises involve the simple recall of information or routine application of knowledge to familiar situations and contexts. Science problems lend themselves to the effective development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.2.2.1).

Recommendation 7

Gr 9 Natural Sciences teachers should exercise enterprise and energy where resources for Scientific Investigations are in short supply (*cf.* 2.7.1.4).

Motivation

Gr 9 Natural Sciences Teachers who exercise enterprise and energy do not blame external factors for the inability to conduct Scientific Investigations but take responsibility for developing the problem solving skills of their learners (*cf.* 2.7.1.4).

5.3.1.3 Findings related to research objective 2

To determine the nature of assessment practices used to evaluate the development of the problem solving skills of Gr 9 Natural Sciences learners.

- To assess the problem solving skills of learners, teachers need to assess the Scientific Inquiry skills of learners. To assess the Scientific Inquiry skills of learners, teachers need to assess learners' hands-on interaction with the natural world through a Scientific Investigation (*cf.* 2.6.2).
- During the assessment of Scientific Inquiry skills through a Scientific Investigation, teachers are required to assess:
 - learners' thinking and reasoning skills in solving a problem. Assessment of these skills is also achieved through open classroom discussions surrounding the investigation (*cf.* 2.6.2; 2.6.2.1);
 - the Natural Sciences concepts and content applied by learners in solving a problem (*cf.* 2.6.2; 2.6.2.2);
 - the Science process skills used by learners in solving a problem (*cf.* 2.6.2; 2.6.2.4); and
 - the Scientific Investigation skills that learners require to solve a problem (*cf.* 2.6.2; 2.6.2.3).

5.3.1.4 Recommendations and motivations related to research objective 2

Recommendation 1

Teachers should assess the Scientific Inquiry skills of Gr 9 Natural Sciences learners, by means of a Scientific Investigation conducted by the learners, in order to successfully assess their learners' ability to solve problems.

Motivation

Teachers will be able to assess Gr 9 Natural Sciences learners' Scientific Inquiry skills through a Scientific Investigation where learners address a challenging problem by employing higher order thinking skills as they design and carry out an investigation that allows them to interact directly with natural phenomena, using tools, materials, data collection techniques, and models to arrive at an answer to the problem (*cf.* 2.6.2; 2.6.2.3).

Recommendation 2

Teachers should assess Gr 9 Natural Sciences learners thinking and reasoning skills during problem solving by means of Scientific Investigations as well as during open classroom discussions.

Motivation

Scientific Investigations and open classroom discussions will assist the teacher in assessing whether Gr 9 Natural Sciences learners are able to employ higher order thinking skills by being able to draw valid conclusions, choose appropriate methods, recognise regularities in nature, etc. when they are involved in the process of problem solving (*cf.* 2.6.2; 2.6.2.1).

Recommendation 3

Teachers should assess Gr 9 Natural Sciences learners' grasp of concepts and content involved in problem solving in the context of content rich Scientific Investigations.

Motivation

Content rich Scientific Investigations require that Gr 9 learners possess knowledge of Natural Sciences concepts and content in order to be able to conduct an investigation and assist learners with knowledge development and applying this knowledge to new and unfamiliar contexts during problem solving (*cf.* 2.6.2.2).

Recommendation 4

Teachers should expose Gr 9 Natural Sciences learners to Scientific Investigations where learners are required to use appropriate Science process skills that can be assessed as learners solve problems.

Motivation

Science process skills involve tools and techniques such as following instructions, handling laboratory apparatus and measurement devices, making accurate measurements, making observations, recording and reporting data in tables and graphs and allow teachers to assess if Gr 9 Natural Sciences learners are able to use these tools and techniques safely and appropriately during the course of solving a problem (*cf.* 2.6.2.4). Science process skills enable learners to make connections between ideas and concepts in their minds and then to apply this knowledge to new contexts or situations in order to solve a problem (*cf.* 2.2.1.2).

Recommendation 5

Teachers should create opportunities through Scientific Investigations that allow Gr 9 Natural Sciences learners to demonstrate their Scientific Investigation skills in solving a problem.

Motivation

Scientific Investigation skills such as identifying a problem, hypothesising, selecting apparatus, planning an experiment, recording results and being able to replicate the results are important skills that need to be assessed when it

comes to Gr 9 Natural Sciences learners being able to solve a problem (*cf.* 2.6.2.3).

5.3.2 Findings related to the empirical research

5.3.2.1 Findings related to the closed-ended questions of the questionnaire

- Many teachers (76.2%) implement the Scientific Method (*cf.* Table 4.1).
- A high percentage of teachers (87.8%) believe that Scientific Inquiry requires learners to solve problems (*cf.* Table 4.2).
- A large number of teachers (76.2%) design problems that require learners to think 'outside the box' and thus stretch their imagination (*cf.* Table 4.3).
- Many teachers (85.7%) feel they allow their learners to wrestle with possible answers to a problem before telling them the answer (*cf.* Table 4.4).
- Many teachers (85.7%) recognise that Scientific Investigations are valuable in helping learners understand scientific ideas (*cf.* Table 4.5).
- A high percentage of teachers (90.5%) feel they connect new content with what the learner already knows (*cf.* Table 4.6).
- Many teachers (71.4%) feel they teach their learners higher order thinking skills (*cf.* Table 4.7).
- Only 38.1% of teachers almost always act as facilitators during classroom discussions (*cf.* Table 4.8).
- Many teachers (95.2%) encourage learners to ask questions (*cf.* Table 4.9).
- Few teachers (40.5%) almost always encourage their learners to debate topics (*cf.* Table 4.10).

- Many teachers (83.3%) are confident that learners are able to apply their knowledge and skills to new situations (*cf.* Table 4.11).
- A number of teachers (61%) view doing Science as doing experiments (*cf.* Table 4.12).
- A large number of teachers (65.9%) employ the lecturing method on an infrequent basis during class time (*cf.* Table 4.13).
- More than half the teachers (60.5%) feel they have an endless amount of information to cover (*cf.* Table 4.14).
- Many teachers (64.1%) formulate questions where learners are required to recite facts (*cf.* Table 4.15).
- Many teachers (57.1%) rarely do most of the talking during a lesson (*cf.* Table 4.16).
- 46.3% of teachers almost always encourage learners to exchange their ideas during classroom discussions (*cf.* Table 4.17).
- A significant number of teachers (87.8%) feel that learners take other learners' viewpoints seriously (*cf.* Table 4.18).
- Many teachers (69%) feel their learners' possess the cognitive abilities to solve problems (*cf.* Table 4.19).
- All teachers (100%) see Science as a process of improving knowledge (*cf.* Table 4.20).
- A significant number of teachers (95.3%) recognise that Science is a process of improving understanding of Natural Sciences concepts and content (*cf.* Table 4.21).
- The majority of teachers (90.5%) recognise the value of using real life problems in order to develop the problem solving skills of learners (*cf.* Table 4.22).

- Many teachers (88.1%) encourage learners to use higher order thinking skills during problem solving (*cf.* Table 4.23).
- A high percentage of teachers (92.9%) are of the opinion that higher order thinking skills develop with practice (*cf.* Table 4.24).
- A large number of teachers (71.4%) feel their learners tackle problems that require them to think for themselves (*cf.* Table 4.25).
- Many teachers (78.5%) afford their learners opportunities to perform Scientific Investigations (*cf.* Table 4.26).
- A high number of teachers (83%) encourage their learners to analyse data collected from their Scientific Investigations (*cf.* Table 4.27).
- Many teachers (71.4%) allow their learners to turn data from their Scientific Investigations into information (*cf.* Table 4.28).
- 82.5% of teachers encourage learners to communicate their findings, emanating from their Scientific Investigations (*cf.* Table 4.29).
- A number of teachers (71.4%) feel that Scientific Inquiry promotes disciplinary problems in the class (*cf.* Table 4.30).
- Teachers are almost equally divided in their response regarding having sufficient time for activities. 51.2% of teachers feel that time does not pose a problem and 48.7% feel that time does pose a problem for learner activities (*cf.* Table 4.31).
- Many teachers (59.5%) do not have sufficient scientific equipment (*cf.* Table 4.32).
- 54.8% of teachers have books that show them strategies on how to implement Scientific Inquiry (*cf.* Table 4.33).
- More than half of the teachers (61.9%) have access to a computer (*cf.* Table 4.34).

- Many teachers (80.6%) feel adequate in teaching Natural Sciences (*cf.* Table 4.35).
- Few Natural Sciences teachers (10.5%) feel the need to receive training in their subject (*cf.* Table 4.36).

5.3.2.2 Recommendations and motivations related to the closed-ended questions of the questionnaire

Recommendation 1

Teachers appear to have a limited understanding of the process of Scientific Inquiry and therefore require training in this area to enable them to effectively develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Teachers' limited understanding of Scientific Inquiry seems to stem from a lack of training which results in the employment of the traditional Scientific Method and the use of experiments during classroom activities. Training will ensure that teachers have a complete understanding of what it means to perform Scientific Inquiry and thereby equip them with knowledge of effective teaching practices to ensure the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.7.1.6).

Recommendation 2

During the process of Scientific Inquiry, teachers should present their learners with Science problems instead of Science exercises and experiments if they wish to develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Science problems require that learners employ higher order thinking skills such as reasoning, analysis, synthesis and problem solving, making connections and critical evaluative thinking, including the application of knowledge to unfamiliar situations whereas Science exercises and experiments involve the simple recall of information or routine application of

knowledge to familiar situations and contexts. Science problems therefore lead to the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.2.2.1).

Recommendation 3

During the process of Scientific Inquiry, upon completion of a Scientific Investigation, teachers should encourage classroom discussions and debates surrounding the investigation and act as facilitator during these sessions in order to develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Classrooms discussions and debates, where teachers act as facilitators, encourage learners to reflect on their experience, data and conclusions from Scientific Investigations in order to confirm reject or build their existing ideas and these discussions thereby contribute to the development of the problem solving skills of Gr 9 Natural Sciences learners. Such interactions also provide teachers with an opportunity to effectively assess the development of the problem solving skills of their learners (*cf.* 2.2.2.2; 2.4.2; 2.5; 2.6.2.1).

Recommendation 4

Gr 9 Natural Sciences teachers should be empowered to engage in effective classroom management when they experience disciplinary problems during the performance of Scientific Investigations.

Motivation

Specific methods and approaches to teaching large classes effectively encompass management principles that will assist the Gr 9 Natural Sciences teacher in restoring order during Scientific Investigations (*cf.* 2.7.1.7).

Recommendation 5

Gr 9 Natural Sciences teachers should exercise enterprise and energy in the case of limited resources such as a lack of scientific equipment required for

Scientific Investigations and also in the case of a lack of books detailing Scientific Inquiry tasks and teaching methods.

Motivation

Exercising enterprise and energy will ensure that teachers take responsibility for the development of the problem solving skills of their learners and not resort to blaming external factors for the lack of implementation of Scientific Inquiry thereby leading to the incomplete development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.7.1.4).

5.3.2.3 Findings related to the open-ended questions of the questionnaire

- Teachers' top choices of teaching methods include demonstrations and classroom discussions.
- A significant number of teachers are unable to provide a quality explanation for the term Scientific Inquiry.
- More than half the teachers have received formal training in Scientific Inquiry.
- Many teachers employ the traditional Scientific Method and not Scientific Inquiry.
- Teachers believe their learning methods contribute to developing the scientific literacy of learners.
- Learners' perform teacher guided experiments instead of Scientific Investigations.
- Teachers present their learners with Science exercises as opposed to Science problems.
- Teachers do not connect prior knowledge and experiences to new Natural Sciences knowledge and concepts.

- Teachers do not relate and apply new learning to the learners' lives and society.
- Teachers are unable to act as facilitators during classroom discussions as few productive discussions are entered into.
- Teachers act as information providers during classroom activities and wish to elicit correct responses from learners to closed-ended questions.
- Learners are not provided with an opportunity to communicate their findings from their Scientific Investigations to the class, where discussions surrounding these findings can ensue.
- During Scientific Investigations, teachers behave as though learners have limited cognitive abilities by providing them with the goal of the problem as well as step-by-step instructions to follow in order to solve the problem.
- Many teachers expect learners to develop an understanding of Natural Sciences concepts and content by asking and answering questions during a learning experience.
- The majority of teachers' believe they design challenging assessment tasks that help learners to grow and develop in their understanding of Natural Sciences concepts and content.
- Scientific Investigations and class work are the second most common form of assessment.
- Classroom discussions and debates are the least common form of assessment.
- Teachers are unable to assess the problem solving skills of learners as the process of Scientific Inquiry is not correctly implemented.

5.3.2.4 Recommendations and motivations related to the open-ended questions of the questionnaire

Recommendation 1

Teachers should provide Gr 9 Natural Sciences learners with opportunities to perform their own Scientific Investigations that allow them to practice their problem solving skills.

Motivation

Scientific Investigations present Gr 9 Natural Sciences learners with an opportunity to employ higher order thinking skills as they interact directly with natural phenomena using scientific apparatus, measuring instruments, materials, data collection techniques and models to arrive at an answer to a problem (*cf.* 2.2.1.2; 2.4; 2.6.2.3).

Recommendation 2

Teachers require further training in the area of Scientific Inquiry to enable them to effectively develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Further training will ensure that teachers have a complete understanding of what it means to perform Scientific Inquiry and will equip them with knowledge of effective teaching and assessment practices to ensure the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.7.1.6).

Recommendation 3

Teachers need to employ the process of Scientific Inquiry and not the Scientific Method if they wish to completely and effectively assess the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Scientific Inquiry is a process known to develop the problem solving skills of learners and the assessment thereof involves measuring the learners' ability to carry out physical processes (Scientific Investigation skills and Science process skills), use thinking and reasoning skills as well as develop knowledge of Natural Sciences concepts and content (*cf.* 2.4; 2.6.2). The teacher will be unable to assess these skills if they employ the Scientific Method and this will contribute to the incomplete and ineffective assessment of the development of the problem solving skills of learners.

Recommendation 4

During the process of Scientific Inquiry, teachers should present their learners with Science problems instead of Science exercises if they wish to develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Science problems require that learners employ the higher order thinking skills of reasoning, analysis, synthesis and problem solving, making connections and critical evaluative thinking, including the application of knowledge to unfamiliar situations whereas Science exercises involve the simple recall of information or routine application of knowledge to familiar situations and contexts. Science problems therefore encourage the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.2.2.1).

Recommendation 5

Teachers should connect learners' prior knowledge and experiences to new Natural Sciences concepts and content and relate this knowledge to the learners' lives and society in order to develop the scientific literacy of Gr 9 Natural Sciences learners.

Motivation

Learners involved with the process of Scientific Inquiry grow in scientific literacy as Scientific Inquiry allows them to answer questions that challenge their prior knowledge about themselves and their environment (*cf.* 2.4.1). When teachers connect prior knowledge and experiences to new Natural Sciences concepts and content and relate this new knowledge to the learners' lives, learners are able to reflect on their experiences; make sense of data; create meaning; and apply learning to society (*cf.* 2.4.2). In so doing teachers contribute to the development the problem solving skills of Gr 9 Natural Sciences learners.

Recommendation 6

During the process of Scientific Inquiry, on completion of a Scientific Investigation, teachers should encourage classroom discussions surrounding the investigation and act as facilitator during such discussions in order to develop the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Classrooms led discussions, where teachers act as facilitators, encourage learners to reflect on their experience, data and conclusions from Scientific Investigations so they may confirm, reject or build upon their existing ideas. These discussions contribute to the development of the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.2.2.2; 2.4.2; 2.5; 2.6.2.1).

Recommendation 7

Teachers should demand a high level of cognitive engagement from Gr 9 Natural Sciences learners during Scientific Investigations in order to develop the problem solving skills of the learners.

Motivation

Setting high expectations for learners, including engaging Gr 9 Natural Sciences learners at high levels of cognitive demand in the classroom, is

associated with improved learning which leads to the development of the problem solving skills of learners (*cf.* 2.7.1.3). Learners' problem solving abilities are known to improve when teachers show faith in learners, have an encouraging attitude and are willing to spend time and effort in teaching higher order thinking skills (*cf.* 2.2.2).

Recommendation 8

Teachers should encourage classroom discussions and debates to allow for the effective assessment of the development of the problem solving skills of Gr 9 Natural Sciences learners.

Motivation

Classroom discussions and debates make learners thinking and reasoning skills visible when learners use the language and reasoning of Science with their peers and teachers as they reflect on their experiences; make sense of data; connect learning to prior knowledge; create meaning; and apply learning to their lives, technology and society. These classroom discussions provide teachers with a valuable tool for assessing the problem solving skills of Gr 9 Natural Sciences learners (*cf.* 2.4.2; 2.6.1; 2.6.2.1).

5.3.2.5 Summary of empirical findings

When a comparison is made between teachers' responses to the closed and open-ended questions of the questionnaire contradictions are evident. These contradictions may be underpinned by the notion that teachers believe they are implementing the process of Scientific Inquiry. However, according to the literature study and empirical investigation of this research, their current teaching and assessment practices suggest otherwise. This leads the researcher to believe that teachers' possess a limited understanding of the process of Scientific Inquiry and therefore a general recommendation in this regard would be for teachers to receive training in Scientific Inquiry in order to effectively develop the problem solving skills of Gr 9 Natural Sciences learners.

5.4 LIMITATIONS

The researcher took into account the following limitations of using a structured questionnaire for the purposes of this study:

- The researcher was unable to gain a deep understanding of the teaching and assessment practices used in the development of the problem solving skills of Gr 9 Natural Sciences learners as questionnaires limit probing and the clarification of answers.
- Some teachers may not have been completely honest in terms of their responses regarding their teaching and assessment practices.
- Teachers may have answered the questionnaire by marking the options given to them without actually reading or even thinking about the questions
- Teachers may have answered superficially if the questionnaire took too long to complete.
- Teachers may have forgotten important issues as the questionnaire occurs after an event.
- Some teachers may have misinterpreted the questions.
- Some questionnaires were not completed in entirety.
- Some teachers did not return their questionnaires as they may not have been willing to answer the questions.

These limitations could have contributed to the incorporation and use of unreliable information in the study. To try to prevent this situation, the researcher made herself available for guidance during the completion of the questionnaire to eliminate any problems that arose. The researcher also supplemented the closed-ended questions of the questionnaire with open-ended questions so that teachers could not just hazard a guess, but had to think and reason before attempting to answer these open-ended questions.

The researcher acknowledges that the sample might be less representative of the population and that the generalising of the findings is limited to the teachers who took part in the study. The researcher also wishes to reiterate that caution needs to be applied when any inferences are made concerning this study as survey research captures a brief moment in time. The results of this study are dependent on teachers who told the researcher what they believe to be true or even perhaps what they thought the researcher wanted to hear. Furthermore as teachers' answers were constructed on the spot, they may have been influenced by recent events or contexts in their lives.

5.5 SUGGESTED TOPICS FOR FURTHER STUDY

There are topics that are deemed to be important for further studies. The suggested topics include:

- The effect of further training on the development of the Scientific Inquiry practices of Gr 9 Natural Sciences teachers.
- The management of Scientific Inquiry practices in large classes, related to the development of the problem solving skills of Gr 9 Natural Sciences learners.
- Exploring teaching and assessment practices for the development of the problem solving skills of Further Education and Training (FET) phase Physical Sciences learners.

5.6 CONCLUSION

This study attempted to explore teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners and also to develop recommendations to support teachers in the development of these problem solving skills.

The findings of the study, from the theoretical point of view and the empirical research, led to recommendations that were coupled with motivations for the recommendations put forward. The recommendations state clearly that there

is a need for improving teaching and assessment practices for the development of the problem solving skills of Gr 9 Natural Sciences learners.

Based on the empirical research findings, the researcher is of the opinion that Gr 9 Natural Sciences teachers in South Africa have a limited view of what problem solving involves. Problem solving involves the process of Scientific Inquiry where learners make observations, pose questions, perform research and support the process with experimental evidence obtained from a Scientific Investigation to solve a problem. Teachers' limited view of this process is related to the employment of the traditional Scientific Method where teachers view doing Science as doing experiments. Problem solving thus becomes reduced to a set of sequenced steps used to reinforce Natural Sciences concepts and content. Also, teachers present their learners with Science exercises that involve the recall of information or routine application of knowledge to familiar situations and contexts instead of Science problems that employ the use of higher order thinking skills and allow for the application of knowledge to unfamiliar situations.

Other problems associated with implementing the process of Scientific Inquiry include limited classroom discussions following Scientific Investigations as well as teachers favouring demonstrations as opposed to learners performing their own Scientific Investigations. Resources for Scientific Investigations, in certain cases, appear to be in short supply and this coupled with the management of large classes during Scientific Investigations may support the teachers' favoured choice of demonstration as a teaching method.

Assessment forms a critical part in the development of the problem solving skills of learners. Teachers are required to assess their learners' Scientific Inquiry capabilities during problem solving and supply the learners with feedback in this regard. This is identified as a problem area in the study. The reason for this is that teachers are implementing the Scientific Method as opposed to the process of Scientific Inquiry. Assessment of the Scientific Method will supply the teachers and learners with incomplete feedback concerning the development of problem the solving skills of learners. The researcher is, however, of the opinion that should the process of Scientific

Inquiry be implemented correctly, then the effective assessment of learners Scientific Inquiry capabilities will follow naturally.

Although training teachers with regards to the process of Scientific Inquiry may alleviate some of the above problems, the researcher is concerned that some teachers already exposed to training were left none the wiser concerning their implementation of Scientific Inquiry. However, the overall feeling of the researcher is that teachers invest a lot of time and effort in their learners and remain dedicated to their task of imparting their Natural Sciences knowledge and skills to the learners to the very best of their abilities. If these teachers were to align their teaching and assessment practices with the process of Scientific Inquiry then a high success rate would be achieved in developing the problem solving skills of Gr 9 Natural Sciences learners!

Problem solving is a crucial aspect in developing and equipping learners to function in society as they one day become responsible citizens. It is therefore vital that the challenges surrounding the development of the problem solving skills of learners be addressed if this valuable goal in education is to be realised.

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OED **see** Oxford English Dictionary

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APPENDIX A
TEACHER QUESTIONNAIRE

Teacher questionnaire

Section A

You are a Natural Sciences teacher. Please answer the following questions:

No.	Statement	Almost always	Often	Some-times	Very seldom
1	I make use of the Scientific Method				
2	Scientific Inquiry requires learners to solve problems				
3	I design problems that stretch learners' imagination				
4	I allow learners to wrestle with possible answers to a problem before telling them the answer				
5	Scientific Investigations help learners to understand scientific ideas				
6	I connect new learning content with what the learner already knows				
7	I teach higher order thinking skills				
8	I act as a facilitator during classroom discussions				
9	Learners are encouraged to ask questions				
10	Learners are encouraged to debate topics				
11	Learners are able to apply their knowledge to new situations				
12	Learners do experiments because "doing Science means doing experiments"				
13	My class time consists mainly of lectures				
14	I need to cover an endless amount of information				
15	I formulate questions where learners recite facts				
16	I do most of the talking in a lesson				
17	Learners are encouraged to exchange their ideas during classroom discussions				

No.	Statement	Almost always	Often	Some- times	Very seldom
18	Learners do not take other learners' viewpoints seriously				
19	Learners have limited cognitive abilities				
20	Science is a process of improving knowledge				
21	Science is a process of improving understanding				
22	Learners have the opportunity to apply scientific skills to real life problems				
23	During problem solving learners are encouraged to use higher order thinking skills				
24	Higher order thinking skills develop with practice				
25	Learners tackle problems that require them to think for themselves				
26	Learners perform Scientific Investigations				
27	Learners analyse data collected from Scientific Investigations				
28	Learners turn data from Scientific Investigations into information				
29	Learners communicate findings emanating from Scientific Investigations				
30	Scientific Inquiry promotes disciplinary problems				
31	I have enough time for learner activities				
32	I have enough scientific equipment				
33	I have books that show me strategies for Scientific Inquiry				
34	I have access to a computer				
35	I feel inadequate in teaching Natural Sciences				
36	I require training in teaching Natural Sciences				

Section B

Please answer the following questions:

1. Tick **two** teaching methods you employ on a regular basis:

- Lectures
- Demonstrations
- Laboratory/ hands on activities
- Classroom discussions
- Recitation
- Learners work from textbooks
- Brainstorming sessions
- Debates
- Field trips

2. What does the term *Scientific Inquiry* mean to you?

.....
.....
.....

Have you received any formal training in *Scientific Inquiry*?

.....

3. What learning opportunities do your learning methods provide for learners?

.....
.....
.....

4. What do you think is the teacher's role during a learner's learning experience?

.....
.....
.....

5. What do you expect from your learners during a learning experience?

.....
.....
.....

6. What important aspects do you keep in mind when you design your assessment tasks?

.....
.....
.....

7. What methods of assessment do you use?

.....
.....
.....

9. Briefly describe a recent Scientific Investigation.

.....
.....
.....

Thank you for taking the time to complete this questionnaire!

APPENDIX B
CONSENT FORM: PRINCIPAL

CONSENT FORM FOR PRINCIPALS

**TEACHING PRACTICES FOR THE DEVELOPMENT OF THE PROBLEM
SOLVING SKILLS OF GR 9 NATURAL SCIENCE LEARNERS**

SIGNATURE PAGE FOR PRINCIPAL

This is to confirm that I have read and understood the Research Information Sheet given and explained to me. I have been given a chance to ask questions which were answered to my satisfaction. I then hereby consent to participate in this study. I know that my participation

If you agree with each statement provided below, please place a **cross (X)** in the **box []** provided.

1. I have read and understood the Information Letter given and explained to me. **Yes I understand []**
2. I am aware of the fact that my teachers may/may not answer questions if they choose not to. **Yes I understand []**
3. My teachers will provide information by responding to questions in a questionnaire. **Yes I understand []**
4. I agree that the researcher may invite my teachers to take part in the research by giving them a questionnaire to respond to. **Yes I understand []**
5. I understand that they will not be personally identified. **Yes I understand []**
6. I agree that what they say may be quoted in publications, presentations and in the final report. **Yes I understand []**
7. I understand that if I am concerned about what they have said, I may ask for part or all information provided not to be quoted. **Yes I understand []**

Full name of principal

Signature of principal

Full name of researcher

Signature of researcher

Date

FUTURE CONTACT PAGE

You may contact me: yes [] / no []

[] If yes, the best way to reach me is:

Address:

E-mail:

Second E-mail:

Phone Number:

Cell Phone Number:

[] No, you may not contact me about future participation in this study.

Would you like us to send you a short summary of the study when it is complete?

[] Yes

[] No

Please provide an address to which you would like it sent:

Address:

E-mail:

Second E-mail:

APPENDIX C
CONSENT FORM: TEACHERS

CONSENT FORM FOR GR 9 NATURAL SCIENCE TEACHERS

**TEACHING PRACTICES FOR THE DEVELOPMENT OF THE PROBLEM
SOLVING SKILLS OF GR 9 NATURAL SCIENCE LEARNERS**

SIGNATURE PAGE FOR TEACHER

This is to confirm that I have read and understood the Research Information Sheet given and explained to me. I have been given a chance to ask questions which were answered to my satisfaction. I then hereby consent to participate in this study. I know that my participation

If you agree with each statement provided below, please place a **cross (X)** in the **box []** provided.

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3. I will provide information by responding to questions in a questionnaire. **Yes I understand []**
4. I agree that the researcher may invite me to take part in the research by giving them a questionnaire to respond to. **Yes I understand []**
5. I understand that I will not be personally identified. **Yes I understand []**
6. I agree that what I say may be quoted in publications, presentations and in the final report. **Yes I understand []**
7. I understand that if I am concerned about what I have said, I may ask for part or all information provided not to be quoted. **Yes I understand []**

Full name of principal

Signature of principal

Full name of researcher

Signature of researcher

Date

FUTURE CONTACT PAGE

You may contact me: yes [] / no []

[] If yes, the best way to reach me is:

Address:

E-mail:

Second E-mail:

Phone Number:

Cell Phone Number:

[] No, you may not contact me about future participation in this study.

Would you like us to send you a short summary of the study when it is complete?

[] Yes

[] No

Please provide an address to which you would like it sent:

Address:

E-mail:

Second E-mail:

APPENDIX D
INFORMATION SHEET: PRINCIPAL

RESEARCH INFORMATION SHEET (PRINCIPAL)

TITLE: *Teaching practices for the development of the problem solving skills of Gr 9 Natural Science learners*

Please read the following information carefully:

Your school is invited to participate in a research study. Provided below is the purpose of the study as well as other areas that concern this study.

The purpose of this research study is to collect information from Gr 9 Natural Science teachers regarding teaching practices used for the development of problem solving skills in learners. This information will be used to develop recommendations to assist teachers in this regard.

Your school was chosen to take part in this research study as you have Gr 9 Natural Science teacher/s.

Your participation in this study is strictly voluntary and you are free to withdraw at any time. If you decide to participate, you may keep this information sheet and you will be provided with a consent form to sign. You are still free to withdraw from this study even after having signed the consent form.

If you do agree to participate in the research study, a questionnaire and a letter permitting me to conduct the research, from the District Director and the Education Department Head Office, will be handed to you. Your teachers should complete and return the questionnaire to yourself within a week of having received it.

For each question, they will be requested to respond by making a cross in the block that best describes their perceptions and experiences. It will take them approximately twenty minutes to complete the questionnaire.

Feedback regarding the findings will be given to you on request and the thesis will be made available at the North West University library. The research study will be conducted after approval by the Ethical Committee of the North-West University, Vaal Triangle Campus.

Confidentiality and anonymity will be strictly adhered to. No space is provided on the questionnaire for a teacher's name. Completed questionnaires will be kept at the University for a period of ten years as per University policy on Academic Integrity. The right to share the information that your teachers provide will be based on your response on the consent form.

The study will ultimately benefit you as a principal as it will raise awareness in your teachers concerning the importance of teaching learners to solve problems. Also, this study intends to provide a general set of recommendations to assist your teachers in aligning their teaching practices with best practices identified in literature used in developing problem solving skills of Gr 9 Natural Science learners.

For further information regarding the study, please do not hesitate to contact the researcher Ann Vicente by phone: 084 890 9333 or by e-mail: avicente@telkomsa.net

Thank you for reading this information.

APPENDIX E
INFORMATION SHEET: TEACHER

GR 9 NATURAL SCIENCE TEACHER

RESEARCH INFORMATION SHEET

TITLE: *Teaching practices for the development of the problem solving skills of Gr 9 Natural Science learners*

Please read the following information carefully:

You are invited to participate in a research study. Provided below is the purpose of the study as well as other areas that concern this study.

The purpose of this research study is to collect information from Gr 9 Natural Science teachers regarding teaching practices used for the development of problem solving skills in learners. This information will be used to develop recommendations to assist teachers in this regard.

You were chosen to take part in this research study because you are a Gr 9 Natural Science teacher.

Your participation in this study is strictly voluntary and you are free to withdraw at any time. If you decide to participate, you may keep this information sheet and you will be provided with a consent form to sign. You are still free to withdraw from this study even after having signed the consent form.

If you do agree to participate in the research study, a questionnaire and a letter permitting me to conduct the research, from the District Director and the Education Department Head Office, will be handed to your principal. You should complete and return the questionnaire to your principal within a week of having received it.

For each question, you will be requested to respond by making a cross in the block that best describes your perceptions and experiences. It will take you approximately twenty minutes to complete the questionnaire.

Feedback regarding the findings will be given to you on request and the thesis will be made available at the North West University library. The research study

will be conducted after approval by the Ethical Committee of the North-West University, Vaal Triangle Campus.

Confidentiality and anonymity will be strictly adhered to. No space is provided on the questionnaire for a teacher's name. Completed questionnaires will be kept at the University for a period of ten years as per University policy on Academic Integrity. The right to share the information that you provide will be based on your response on the consent form.

The study will ultimately benefit you as a teacher as it will raise your awareness of the importance of teaching learners to solve problems. Also, this study intends to provide a general set of recommendations to assist you in aligning your teaching practices with best practices identified in literature used in developing problem solving skills of Gr 9 Natural Science learners.

For further information regarding the study, please do not hesitate to contact the researcher Ann Vicente by phone: 084 890 9333 or by e-mail: avicente@telkomsa.net

Thank you for reading this information.