Science Through the Camera Lens – Some Learners' Perceptions of Science

by

Vivienne Chelin

Submitted in partial fulfilment of the
academic requirements for the degree of
Master of Education in the
School of Education, Durban
Faculty of Education
University of Natal

June 2003

ABSTRACT

The role of science education is to pass on knowledge and understanding of science and its practices to learners. Learners' perceptions of science should therefore reflect those of the scientific community. The purpose of this study was to establish if learners in one South African school shared nature of science views common to the scientific community.

Two key questions framed this study: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives? Quantitative data was collected using a cartoon-style questionnaire to address the first research question. Qualitative data was collected from a photographic activity in which learners were asked to take photographs of science within the context of their daily lives and offer explanations of why the photographic images were representations of science. This qualitative data was used to address the second research question and map out more fully the complexity of learners' perceptions of the nature of science.

The findings of this study point towards a blur between learners' perceptions of science and their perceptions of technology and provide evidence that learners' perceptions of the nature of science are inadequate. However, this study also provides evidence to suggest learners do share some nature of science views with the scientific community. The findings of this study also lend support to the argument that the learning of science should involve an explicit initiation into the culture of science.

This study is a grassroots account of some attempts to include the nature of science construct within learning programs. It is simply a snapshot of what happened in one

South African secondary school at the cusp of curriculum change, a collection of learners' perceptions of science captured on film and an insight into some learners' perceptions of the nature of science.

PREFACE

The work described in this dissertation was carried out in the School of Education, Durban, University of Natal, from January 2002 to June 2003 under the supervision of Dr Paul Hobden (Supervisor).

This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

Vivienne Chelin
June 2003

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

This study was only possible thanks to the willing co-operation of my learners and colleagues and I would like to express my thanks to each one of them for their time, interest and enthusiasm. I would also like to express my gratitude to the staff of the Hillcrest branch of Kodak for their friendly and most efficient service. Finally thanks are especially due to my family for their unfailing love and support.

Dedication

This dissertation is dedicated to Matthew.

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

This study is rooted in my personal experiences of South African science education. This chapter begins with a reflection of my school-based experiences as a learner and as an educator. Curriculum 2005 is then briefly contrasted with the previous South African curriculum and the chapter concludes with an explanation of why this study focused on learners' perceptions of science.

1.2 PERSONAL REFLECTION

After 12 years of schooling I perceived science to be a vast collection of facts. Science held little appeal and I had no desire to pursue it any further. However, when I applied for teacher training, I was informed I could secure a bursary if I studied science. I could not afford to fund my further education, so I elected to study a discipline I perceived to be both dull and confusing. It is therefore not surprising that I look back at my early years as a science educator with some embarrassment. Not only were my perceptions of science flawed, I had little understanding of many of the science concepts I was required to teach.

During my early years of science teaching I had to unlearn misconceptions and reconstruct my understanding of the body of science knowledge. I empathized with learners that did not understand concepts and perceived my role as a science educator was to help learners understand science concepts and to help learners recall science facts, laws and principles. For many years I focused on teaching science knowledge and gave little thought to the nature of science.

1.3 CURRICULUM 2005 - A NEW ERA IN SOUTH AFRICAN SCIENCE EDUCATION

According to Bhengu (cited in Curriculum 2005 – lifelong learning for the 21st century, 1997), the South African Department of Education embarked on a process of curriculum review in 1995 and the first version of Curriculum 2005 was published in 1997. In response to widespread criticism of the new South African curriculum, a supporting policy document, The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002) was drafted in 2001, opened for public comment, and published in 2002. This supporting document, whilst still upholding the underlying principles of Curriculum 2005, outlines more practicable ways of implementing Curriculum 2005.

The focus of South African science education in the previous curriculum was on closed problem solving, transmission of scientific knowledge and demonstrative practical activity that served to verify, rather than question theory. Curriculum 2005, like the previous curriculum, still calls for learners to construct a broad understanding of science knowledge, but the nature of science is now given equal status to the body of science knowledge.

> Whereas it was once common for the school curriculum to present scientific discovery as the inevitable outcome of the 'correct' application of a rigorous, objective, disinterested, value free and all powerful scientific method, many contemporary science curricula are now beginning to realize that science and technology are human endeavors that influence and are influenced by the socio-cultural context in which they are located. (Hodson, 1999, p.229)

The learning area Natural Sciences is firmly based within these parameters and the type of science education envisaged by the new curriculum is therefore quite different to that of the old curriculum and the image of science Curriculum 2005 aims to impart reflects the dynamic nature of science itself – a human activity of creativity, inquiry and debate.

Rogan (2003) claims the implementation of the new curriculum is a long term, ongoing process. Although I have welcomed curriculum change, Curriculum 2005 has challenged my views of science education and my views of science. Consequently, I have found the implementation of the new curriculum challenging and bringing about change both in myself and in my practice has been easier said than done.

> If educators are to respond meaningfully to the challenges of the new curriculum demands, then they need to have developed meaningful understandings of interpretations of nature of science and have insight into the effect their own beliefs have on their interpretation of curricula and the way in which they go about teaching science. (P.Webb, Webb, Kurup and Cross, 2003, p.2)

1.4 SCIENCE THROUGH THE CAMERA LENS – SOME LEARNERS' PERCEPTIONS OF SCIENCE: AN OUTLINE OF THIS STUDY

Cobern (1995) describes learning as an active process of making sense of an experience and points out that this process is influenced by what is already known. I believe the goal of learning is for learners to develop conceptual structures that are more complex, more abstract and more powerful than the ones they already have and learning science involves the socialization into a particular way of looking at the world. I believe that my role as a science educator is to help learners make links between their existing conceptions and the accepted science view.

Ausubel (1968) claims that the most important factor influencing learning is what the learner already knows. Learners and educators need to be at the same starting point if any meaningful learning is to occur and the starting point is that of the learner, not that of the educator. Driver (1983) provides a useful analogy.

> If a visitor phones you up explaining he has got lost on the way to your home, your first reaction would probably be to ask "Where are you now?' You cannot start to give sensible directions without knowing where your visitor is starting from. (p.3)

Before starting a new section of work, I use a variety of activities to find out what learners already know about the topic concerned. Faced with the inclusion of the nature of science as one of the demands of Curriculum 2005, I began looking for activities that might be suitable for probing learners' ideas about the nature of science. After reading the findings of Settlage's (2000) study entitled "Views of science as represented in Urban Schoolchildren's Photographs", I decided to ask one of my Grade 9 classes to take photographs of what they thought was science, and then use the photographs to generate discussion about the nature of science. When the Grade 9 learners showed an unexpected keenness to be involved in such an activity, I considered the possibility of expanding the activity to include more of my classes within the same school. It was at this juncture I realized I had access to learners spanning the official change of curriculum divide and the originally intended classroom activity evolved into a small scale interpretive study of some learners' perceptions of the nature of science within the context of South African curriculum change.

Lederman (1992) claims numerous studies of learners' perceptions of the nature of science have been conducted over the past 40 years. He points out that the initial qualitative investigations were followed by much quantitative research. Lederman, Abd-El-Khalick, Bell and Schwartz (2002) and Webb et al. (2003) argue there is little more to be learned from mass assessments aimed at evaluating learners' understandings of science. Rather, they claim, more qualitative research is necessary that focuses on classroom interventions aimed at enhancing learners' nature of science views.

Millar (1996) writes: "First we need to decide why we want to teach science; from that we can perhaps work out what we want to teach and only then can we decide on what is the best way of how to teach these ideas" (pp.17-18). Curriculum 2005 policy documents clearly outline why the nature of science should be taught and what the intended outcomes of learning about the nature of science are. However, despite the new curriculum emphases, Rogan (2003) claims science knowledge rather than the nature of science is still the primary focus in many science classes. I believe this is because educators know how to teach science knowledge, but are unsure how to teach the nature of science.

This small-scale interpretive case study is simply a very small contribution towards a much needed data-base of 'first hand' accounts of the teaching and learning of the nature of science in South African classrooms. Two key questions framed this study: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives? To generate a response to the first question, learners were asked to complete a questionnaire pertaining to the nature of science. To generate a response to the second question, learners were asked to take photographs of science within the context of their daily lives and offer explanations of why the photographic images were representations of science.

The value of 'first hand' accounts is that they map out possible paths forward for other educators and stimulate the cyclic process of developing classroom interventions aimed at enhancing learners' nature of science views. This study is an account of my attempts to include the nature of science construct within my learning programs and is simply a snapshot of what has happened in one South African classroom, a collection of some learners' perceptions of science captured on photographic film and a glimpse of some learners' perceptions of the nature of science. To the best of my knowledge, no such study has been undertaken in South Africa.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Lederman (1992) states: "Although the 'nature of science' has been defined in numerous ways, it most commonly refers to the values and assumptions inherent to the development of scientific knowledge" (p.331). This chapter begins with an outline of the debate surrounding the nature of science within the scientific community. The focus then shifts towards science education and includes a review of how and why science education has changed in the last few decades, a discussion of contemporary science curricula and an analysis of Curriculum 2005. An outline of some of the literature pertaining to learners' perceptions of the nature of science is then provided and the chapter concludes with a discussion of why South African nature of science research is necessary.

2.2 THE NATURE OF SCIENCE

2.2.1 <u>The debate within the scientific community</u>

Science as a body of knowledge is characterized by facts, laws and theories, but the elusiveness of an answer to the question of how this knowledge is achieved is central to the debate surrounding the nature of science. As Webb et al. (2003) point out, members of the scientific community ascribe to different philosophies and therefore hold varied views of the nature of science.

Webb et al. claim it is difficult to define science and there is no one accepted view of science, of scientific knowledge or of scientific method. As Wellington (1994) points out, "there is no characteristic common to all concepts in science. At best they bear some kind of family resemblance to each other" (p.23). This notion is echoed by The Revised National Curriculum Statement Grades R-9 Schools Policy (2002). "Science seeks the most reliable and authoritative ways of explaining events in nature" (p.12) and "while there are similarities in the way scientists work, it is not possible to put all science knowledge and activity together under a single heading" (p.5). Webb et al. claim the worldviews of different cultures have their own influences on the interpretation of the nature of science. They maintain, the nature of science is fluid and dynamic and reflects the changing cultural context within which it is interpreted. As Nordwall (1980) notes, every scientific activity is characterized by two partial activities. One is some form of observation or perception and the other is some form of thought activity. She points out that if you look at what is today termed science, you find that only certain types of perception and certain types of conceptual formulations are permitted in activities that are characterized as scientific.

2.2.2 A brief history of modern science

During the Middle Ages an ideas-based representation of reality was prominent. According to Nordwall, the birth of modern science, and its associated practices was in reaction to scholasticism and the desire to reject mere argumentation as a source of new knowledge. The spatial-material representation of reality emerged during the mid 1600's when, according to Sutton (1989), researchers were required to exhibit standards of accuracy, reliability and repeatability. This way of representing reality laid the foundations for an empirical view and induction, as the method of science, was formalized in the seventeenth century. Sutton indicates that according to empiricists, science starts with unprejudiced observation and experimentation, and scientific laws are derived by induction from sense data.

Philosophers of science and scientists have for a long time recognized two limitations of the inductivist position. The first limitation is that observations are not objective and facts are not immutable (Driver, 1983; Hodson, 1992; Richardson and Boyle, 1979). As Driver points out, science is not "an international game of 'pass the parcel' in which the truth about the natural world will be unwrapped and gradually more will be revealed" (p.4). Driver maintains, "in the history of science there are many examples where scientists beliefs rather than their empirical results have been seen to govern the progress of their enquiries" (p.69). Richardson and Boyle argue, "complete objectivity, although patiently strived for, can never be achieved" (p.1). Wellington (1994) sums up the argument against objective observations, by proposing that scientific observations are theory dependent; theory directs scientists towards certain observations, and what a scientist observes is always only a small part of the whole domain of possible objects of observation. The second limitation is that induction as a process of reasoning from the particular to the general is found wanting on logical grounds. Hodson (1982) notes that in the same way singular statements may give rise to generalizations, so a singular statement may prove a generalization wrong. This is regarded as Popper's notion of falsification. No general statement can ever be verified, but it can be falsified. Richardson and Boyle (1979) state: "The realization that induction is not a logically valid process has been considered to be rather embarrassing for science" (p.6). They go on to say that either it is necessary to admit that scientific knowledge is not logically valid, or its essential logical structure must be construed in a different way. They claim the second alternative is usually chosen and suggest that deductive logical reasoning is at the heart of science.

According to the current view of science, the body of science knowledge is made up of concepts and theories, built from scientific facts and laws about nature. Facts are theory-influenced statements made after observation. Richardson and Boyle (1979) claim, "since facts are theory laden, they may be changed when their associated theories change" (p.2). According to Chalmers (1982), facts need to be located in a theoretical framework, and it is general theories which give science its explanatory power. Hodson (1982) claims scientific knowledge is tentative and progresses by trial and error through conjecture and refutation. Chalmers and Hodson agree science begins with problems, tentative conjectures (hypotheses) are invented as possible solutions and tested through observation and experimentation and a theory that can best explain the observations will be tentatively accepted. Chalmers (1982) claims major contributions to science occur when a bold conjecture is confirmed or a cautious conjecture is falsified. Richardson and Boyle (1979) claim that because facts depend on possibly unreliably perceived sense data, any new facts must be carefully screened before they become part of the established body of knowledge. According to Richardson and Boyle, "scientific laws are not ultimate truths which have been discovered in nature, but instead are idealizations created by scientists to describe approximately patterns discovered in the environment" (p.7). History shows that theories and anomalies can co-exist. As Driver (1983) explains, "there can be multiple explanations of events which each account for the data" (p.7).

It used to be thought that theories were logically derived from facts and laws, however in view of the theory-laden nature of facts and evidence from the history of science theories are currently attributed to a blend of imaginative and logical thinking. Driver (1983) states: "In this hypothetico-deductive view, theories are not related by induction to sense data, but are constructions of the human mind" (p.4).

2.2.3 Science is a social enterprise

Hodson (1992) claims science is a social enterprise and reflects the history, power structures and political climate of the supportive community. Driver (1983), Millar (1989) and Richardson and Boyle (1979), all agree that science is a co-operative exercise as opposed to an individual venture and the scientific 'audience' is an essential part of the knowledge creation process. As Driver (1989) points out, "this social dimension to the construction of scientific knowledge has resulted in the scientific community sharing a view of the world involving concepts, models, conventions and procedures" (p.85). However, according to Richardson and Boyle, "although considerable consensus among scientists exists about the knowledge which results from their activities, scientific knowledge is nevertheless tentative and uncertain and influenced by numerous social and cultural factors" (p.1).

Siraj-Blatchford (1990) points out that despite the great advances made historically in the Middle East, China, the Indian sub-continent and Africa, modern science did develop and become established in Europe from the sixteenth century onwards. Although western world-views do permeate modern science, Richardson and Boyle (1979) claim other cultures have possessed quite different worldviews based on different assumptions about the nature of reality. According to the Revised National Curriculum Statement Grades R-9 Schools Policy (2002), "one of the underlying differences between modern science and technology on the one hand, and traditional and indigenous knowledge systems on the other hand, is the existence of different world-views" (p.11). Hodson (1993) asserts, "once it is acknowledged that science is a human activity, driven by the aspirations and values of the society that sustains it, it is legitimate to ask whether different societies might define and organize science differently because their aspirations and values are different" (pp.700-701). Richardson and Boyle maintain that non-western knowledge systems although highly structured, are different to western worldviews. The Revised National Curriculum Statement Grades R-9 Schools Policy (2002) claims many South Africans hold a strong world-view that people are not separate from the earth and its living things and events happen for spiritual as well as physical reasons. Furthermore, traditional and indigenous knowledge systems and technologies have developed within this system of thought and there is much to be learned from these ways of knowing.

2.2.4 The nature of science – a brief summary

Empiricism has been effective in generating accurate and reliable knowledge about the natural world. However, the realization that observations are not objective, and induction is not logically valid challenged the empirical view of science. The hypothetico-deductive view proposes that theories are constructions of the human mind supported by empirical evidence, and science is a social enterprise that reflects the history, culture, power structures and political climate of the supportive community. The nature of science construct is complex. It is difficult to define science and there is no one accepted view of science, scientific knowledge or scientific method.

2.3 SCIENCE EDUCATION

Millar (1989) claims the role of science education is to introduce learners to science knowledge and practices. If Millar's claim is viewed within the context of the ongoing debate surrounding the nature of science within the scientific community, science education has been faced with a rather tall order. If the scientific community disagrees on what is accepted as science knowledge and science practices, it is hardly surprising that the nature of science has worn a number of hats within science curricula over the past few decades. It is therefore also not surprising that many science curricula have tipped the scales in favor of the safer ground of established science knowledge as opposed to a study of the nature of scientific inquiry.

2.3.1 Science education and the nature of science – a brief history

Lederman (1992) maintains that a study of the nature of scientific inquiry was advocated in some science education curricula as far back as 1907, but as Hodson (1993) points out, science curricula prior to 1960 were primarily concerned with acquisition of scientific knowledge. Science education was content-based and linked to behaviorist psychology in which teaching was expository and learners were passive recipients of knowledge. Sutton (1989) argues that the purpose of science education prior to the early 1960's was to introduce future science academics to some established science knowledge and the rigor of scientific writing. Sutton maintains that when secondary schooling was extended to the whole population in the early 1960's and 1970's, the long established traditions suitable for the academically select, did not match the new clientele. The 1960's also saw strong criticism of behaviorist approaches to teaching and learning and science education began a new era characterized by all children learning science. According to Sutton (1989), to accommodate mixed ability groups there was diminished use of whole class discussion and increased use of prepared worksheets that described what learners were required to do. Science to the uninitiated involved doing what you were told to do, describing what you had been told to do and recording what happened (or should have happened). Sutton claims doing was elevated above thinking, especially above thinking beforehand:

> It may not matter in the research world if the whole story is not told in a journal report, but in school the suppression of first thoughts, conjectures, preliminary beliefs, hopes or reasons for doing an experiment could be both a misrepresentation of science and an interruption in the development of the learner's own thought. (p.142)

Ironically as the scientific community shifted away from an empirical view and the nature of science debate became more heated, science education began in earnest to present scientific inquiry as the value-free application of an all-powerful scientific method. The 1980's are marked by an era of learners 'pretending to be scientists' as they quickly 'discovered' science facts with the aid of carefully designed activities that served to prove, rather than question theory. Collins, Osborne, Ratcliffe, Millar and Duschl (2001) claim science education became science's worst enemy, leaving learners with a confused sense of the significance of what they had learned. Of even greater concern was the steady decline of science's appeal for learners (Collins et al., 2001; Dlamini, 1997; Roberts, 1982).

According to Solomon (1999), science education is being re-examined in many countries around the world and the need to redefine the relationship between learners as individuals and the overwhelming authority of established science permeates recent curriculum development. Sutton (1989) claims the motives for reviewing curricula vary, but common to most contemporary curricula is an acknowledgement that if science education is ever established successfully in schools, the images of science learners take from their school experiences will be rather different from those they have carried away over the last four decades.

2.3.2 Contemporary science education curricula

Collins et al. (2001) argue that contemporary society requires a populace with a better understanding of the workings of science so it can engage in critical dialogue about the political and moral dilemmas posed by science and technology, arrive at considered decisions, distinguish whether an argument is sound and differentiate between hypotheses and evidence. Collins et al. also claim the dominance of science and technology in our society is another imperative driving the need to teach more about science. Hodson (1999), Roberts (1982), Swift (1992) and Salleh (1997) all agree that if science education curricula are to represent science as the untidy, unpredictable, idiosyncratic activity that it is, they need to provide opportunities for learners to address real life situations and relate science to wider societal and technological issues. Sutton (1989) states: "Test, observation, inference offers a view of science which is long out of date amongst philosophers, sociologists and historians of science, and it should be amongst teachers" (p.142).

Collins et al. (2001) claim that an understanding of science requires knowledge of scientific facts, laws and theories as well as knowledge of the processes of science and its epistemic base. Driver et al. (1996) support this notion and claim explicit reflection of the nature of scientific knowledge, the role of observation and experiment, the nature of theory and the relationship between evidence and theory is an essential component of developing an understanding of science. Millar (1989) and Lederman (1992) point out that although there is no consensus concerning the content to be included in contemporary curricula, or the instruction methods to be used, there is considerable agreement that science education should include some explicit treatment of the nature of science. Collins et al. acknowledge the contested nature of science within the scientific community, but argue that some consensus does exist regarding some elements of the nature of science that should be taught within schools. They identify 18 themes the scientific community proposes should be taught in schools.

2.3.3 Nature of science views shared by the scientific community and Curriculum 2005

An analysis of the study of Collins et al. (2001), The Revised National Curriculum (Draft) Statement (2002), The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002) and Curriculum 2005 Assessment Guidelines: Natural Sciences, Senior Phase (2002) reveals that each of the 18 essential nature of science themes the scientific community proposes should be taught in schools, are reflected in the new South African curriculum. The framework for analysis I have used is based on three groupings: the nature of science knowledge, the nature of scientific inquiry and the interaction between science and society. The discussion that follows highlights how the essential themes the scientific community proposes should be taught in schools, manifest in Curriculum 2005 and illustrates the contemporary nature of the new South African curriculum.

The nature of scientific inquiry. Collins et al. (2001) claim the scientific community view the theme, scientific method and critical testing as the articulation of the core process on which science is built and the experimental method defines science. According to the scientific community,

> Pupils should be taught that science uses the experimental method to test ideas, and in particular, about certain basic techniques such as the use of controls. It should be made clear that the outcome of a single experiment is rarely sufficient to establish a knowledge claim. (Collins et al., 2001, p.16)

Curriculum 2005 also ascribes priority to this theme and claims that what is today known as science has been shaped by the search to understand the natural world through observation, codifying and testing of ideas. According to Curriculum 2005,

> To be accepted as science, certain methods of inquiry are generally used. They promote reproductibility, attempts at objectivity, and a systematic approach to scientific inquiry. These methods include formulating hypotheses, and designing and carrying out experiments to test the hypotheses. Repeated investigations are undertaken and the resulting methods and results are carefully examined and debated before they are accepted as valid. (The Revised National Curriculum Statement Grades R-9 (Schools) Policy, 2002, p.4)

According to Collins et al. (2001), the scientific community describes science as "unfinished business" (p.17). This notion manifests as the theme hypothesis and prediction, and the theme science and questioning. Collins et al. claim the scientific community proposes learners should be taught scientists develop hypotheses and predictions about natural phenomena and this process is essential to the development of new knowledge claims.

> Pupils should be taught that an important aspect of the work of a scientist is the continual and cyclic process of asking questions and seeking answers, which then lead to new questions. This process leans to the emergence of new scientific theories and techniques which are then tested empirically. (Collins et al., 2001, p.17)

These two themes are evident in Curriculum 2005. According to the Revised National Curriculum Statement (Schools) Policy (2002), science knowledge production is an ongoing process that involves "formulating hypotheses and carrying out experiments to test the hypotheses" (p.5). Learners should engage in predicting and hypothesizing and "progress in this learning area is seen in terms of increasing competence in perceiving, describing and testing relationships between variables" (p.9).

According to Collins et al. (2001), the scientific community proposes learners should be taught science uses a range of methods and approaches and there is no one scientific method or approach. Curriculum 2005 reflects this theme (diversity of scientific thinking) and acknowledges different fields of inquiry need very different data and use very different methods of investigation. The Revised National Curriculum Statement (Schools) Policy (2002) states: "While there are similarities in the ways scientists work, it is not possible to put all scientific activity together under a single heading" (p.5).

In the study of Collins et al. (2001), the scientific community proposes learners should be aware that core activities of scientists are observation, measurement and skillful analysis and interpretation of data. According to Collins et al., the scientific community proposes learners should be aware most measurements are subject to some uncertainty and learners should be taught "scientific knowledge claims do not emerge simply form the data but through a process of interpretation and theory building that can require sophisticated skills" (p.19). They also claim learners should be aware that "it is possible for scientists legitimately to come to different interpretations of the same data and therefore, to disagree" (p.19). Collins et al. indicate the scientific community proposes learners should be able to distinguish between causal and correlational relationships and should be taught "a range of techniques for data representation and analysis commonly used in the sciences, with particular emphasis on those necessary for interpreting reports about science, particularly those in the media" (p.14). According to Collins et al., the scientific community considered the theme of creativity to be very important and propose school science should offer learners opportunities to be genuinely creative by encouraging learners to do science, rather than being taught about creativity. They point out "the analysis and interpretation of data would be more effectively taught if pupils were encouraged to generate and use their own data" (p.19). The scientific community claims,

> Pupils should appreciate that science is an activity that involves creativity and imagination as much as many other human activities and that some scientific ideas are enormous intellectual achievements. Scientists, as much as any other profession, are passionate and involved humans whose work relies on inspiration and imagination. (Collins et al., 2001, p.16)

These five themes: observation and measurement, analysis and interpretation of data, cause and correlation, specific methods of science, and creativity, identified by Collins et al. are reflected in Curriculum 2005. The Revised National Curriculum (Draft) Statement (2002) points out that the methods of scientific inquiry common to all cultures include careful observation, the search for pattern, and cause and effect (p.17). According to Curriculum 2005, learning programs should include activities that create opportunities for learners to develop an understanding of "scientific knowledge and how it is produced" (p.5). The following list of cognitive activities is according to The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002), essential for creating an understanding of science: "observing and comparing, measuring, recording information, sorting and classifying, interpreting information, predicting, hypothesizing, raising questions about a situation, planning science investigations, conducting investigations and communicating science information" (pp.13-14). Curriculum 2005 acknowledges the role of creativity and claims scientific inquiry proceeds through logic, intuition and inspiration. The new South African curriculum proposes that the teaching and learning of science should promote understanding of science as a human activity so as to develop "learners' imagination, curiosity and ability to ask good questions" (p.9).

The nature of science knowledge. The theme empirical base of science knowledge, identified by Collins et al. (2001) is outlined by the scientific community as the need for learners to be aware that science knowledge is supported by empirical evidence. Curriculum 2005 claims empiricism has been remarkably effective in generating accurate and reliable knowledge about the natural world and is used in all countries of the world as an approach to understanding the natural world. The Revised National Curriculum Statement Grades R-9

(Schools) Policy (2002) does however note that the empirical view "is challenged by those who argue that pure empiricism does not concern itself with questions of meaning and value and is therefore too limited a way of understanding the world" (p.11).

According to Collins et al. (2001), the scientific community outlines the theme of science and certainty as,

> Pupils should appreciate why much scientific knowledge, particularly that taught in school science, is well established and beyond reasonable doubt, and why other scientific knowledge is more open to legitimate doubt. It should also be explained that current scientific knowledge is the best we have but may be subject to change in the future, given new evidence or new interpretations of old evidence. (p.19)

Collins et al. also claim the scientific community proposes learners should develop an awareness that science knowledge is cumulative and builds on what is already known (cumulative and revisionary nature of science theme). Learners should be aware of the distinction between science and technology. The scientific community proposes learners should be taught science and technology are increasingly interdependent with new science reliant on new technology and new science enabling new technology (science and technology theme). Learners should be taught scientific knowledge aims to be general and universal and scientific explanations are based on models and representations of reality which are often simplifications of the complexity of the real world (characteristic features of science knowledge theme). Learners should be taught science produces reliable knowledge of the natural world that can be relied upon as a basis for action (status features of science knowledge theme). These five themes are evident in Curriculum 2005.

> Knowledge production in science is an ongoing process that usually happens gradually, but occasionally knowledge leaps forward as a new theory replaces the dominant view. Science and technology pull and push each other in a complex relationship that pushes back the knowledge frontier, and provides new processes and products for society. While the major generalizations and principles of science have stood the test of time, there is an openness to new theories and knowledge. While science can offer solutions to many of the problems of the world, there are some problems that cannot be solved by science and sometimes the solution of a problem may create another problem for society or the environment. (The Revised National Curriculum (Draft) Statement, 2002, pp.16-17)

Interaction between science and society. The theme cooperation and collaboration in development of scientific knowledge identified by Collins et al. (2001), is outlined by the scientific community as:

> Pupils should be taught that developments in science are not the result of individual endeavor. They arise from group activity and collaboration, often a multidisciplinary and international nature. New knowledge claims are generally shared and to be accepted by the community, must survive a process of critical peer review (p.21)

Curriculum 2005 reflects this view and describes scientific activity as a social process that involves the open contest of ideas. Curriculum 2005 also maintains peer review is a powerful mechanism for validating claims and information must be verified before it is made available to the public.

Collins et al. (2001) claim the scientific community proposes learners should be taught some of the historical background to the development of scientific knowledge. According to the scientific community the theme, historical development of scientific knowledge, "has the potential to facilitate an appreciation of developments in science, as well as the ways and extent to which such development had been affected by the demands and expectations of society at different parts in history" (p.17). Curriculum 2005 reflects this view. The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002) states: "The teaching and learning of science should promote understanding of the history of science" (p.5).

The theme moral and ethical dimensions in the development of science knowledge is outlined by the scientific community as: Learners should be taught the application of scientific and technological knowledge is not value-free and may be in conflict with the moral and ethical values held by groups within society. Curriculum 2005 claims scientific activity is subject to ethical considerations and learners should develop an awareness of the consequences of decisions that involve ethical issues. The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002) states: "The scientific and technological choices people make reflect their values. The values of people are seen in the ways they deal with problems and even in the choice of issues they define as problems" (p.11) and learners should be able to identify "the positive and negative effects of scientific developments or technological products on the quality of people's lives and the environment (p.20).

2.3.4 Science education – a brief summary

The role of science education is to introduce learners to science knowledge and practices. History shows that prior to 1960, science curricula were primarily concerned with acquisition of science knowledge. Post 1960 science curricula included the study of the nature of science, but an introduction to scientific practices manifested as learners pretending to do science, rather than actually doing science. Consequently many learners developed distorted perceptions of science and the appeal of science for learners declined.

Science education is being re-examined in many countries. The nature of science construct is complex and there is no one accepted view of the nature of science, science knowledge or scientific method, but the general idea that science education should include some explicit treatment of the nature of science is widely acknowledged. Although the nature of science is contested within the scientific community, there is some consensus regarding some elements of the nature of science that should be taught in schools. These ideas were analyzed using a framework based on three groupings: the nature of science knowledge, the nature of scientific inquiry and the interaction between science and society. An analysis of Curriculum 2005 using this framework revealed the new South African curriculum represents current thinking among the scientific community.

2.4 LEARNERS' PERCEPTIONS AND SCIENCE EDUCATION

2.4.1 Learners' perceptions and learning

According to Chalmers (1982) the development of contemporary science curricula has been influenced by the views of cognitive theorists. Cognitive theorists regard learning as an active process in which learners organize their perceived environment through the assimilation and accommodation of concepts. The ideas of Ausubel (1968) have resurged within the paradigm of constructivism. Driver (1989) writes: "The perspective whereby individuals through their own mental activity, experience with the environment and social interactions progressively build up and restructure their schemes of the world around them, has been broadly termed constructivist" (p.85). Ausubel claims meaningful learning occurs when new ideas are related to existing ideas and then appropriately subsumed into the hierarchical conceptual system. However, he also points out that preconceptions influence learning and are tenacious and resistant to extinction.

Driver (1989) cautions that whilst a teacher may plan a particular activity to introduce an idea, it is in the end the learners who have to think through and make sense of the experiences for themselves. She claims learners develop alternative ideas and frameworks over an extended period of time, and an idea or framework will not be rejected unless there is something adequate and reliable to replace it with. She also points out that sometimes this sense making process can happen quite quickly, whereas in other cases learners may take months or even years to reorganize their ideas and make sense of a new topic. Driver (1983) states: "This perspective on learning suggests that it is as important in teaching and curriculum development to consider and understand children's own ideas as it is to give a clear presentation of the conventional scientific theories" (p.3).

2.4.2 Curriculum 2005 – a learner centered curriculum

The Revised National Curriculum Statement Grades R-9 (Schools) Policy (2002) describes learning as a 'cognitive activity of creating meaning and structure from new information and experiences" (p.13). According to Curriculum 2005 Assessment Guidelines (2002), baseline assessment is used to "establish what learners already know" (p.6) and diagnostic assessment is used to "find out about the nature and cause of barriers to learning by specific learners" (p.6). These statements indicate Curriculum 2005 supports the notion that learners' preconceptions play a vital role in learning and influence the type of activities educators may choose to assist learners to make sense of new information and experiences.

2.4.3 Learners' perceptions and the nature of science

Driver (1983) claims by the time a child receives formal teaching in science a set of beliefs has already been constructed and in some cases, these beliefs or intuitions may differ from those accepted by the scientific community. Driver (1989) makes the point that the connections between ideas in science that are apparent to scientists may be far from obvious to learners and the ideas which are constructed and transmitted through the culture and social institutions of science, "will not be discovered by individuals through their own empirical enquiry; learning science involves being initiated into the culture of science" (p.85). Sutton (1989) also supports this notion:

> Science is about ideas and theories, as well as actions; and these ideas are made by people. If these features could be more adequately felt by school pupils, their own

personal involvement in starting to process and re-work ideas would probably follow easily. (p.149)

2.4.4 Learners' perceptions of the nature of science – a historical review of the research

Lederman (1992) claims numerous studies of learners' perceptions of the nature of science have been conducted over the past 40 years. He points out that the initial qualitative investigations were followed by much quantitative research. Lederman also points out that studies of learners' perceptions of science reveal similar findings – learners had little understanding of the nature of science.

The research of Wilson (1954) revealed learners believed the primary purpose of scientific activity was to uncover natural laws and truths. Mead and Metraux (1957) verified these findings. According to Lederman (1992), in 1961 Klopfer and Coley compiled a comprehensive review of several nationwide surveys using the Test on Understanding Science (TOUS). Lederman states: "Klopfer and Coley concluded that high school students' understandings of the scientific enterprise and of scientists was inadequate" (p.333). In 1963, Miller (cited in Lederman) found significant inadequacy of learners' understandings of the nature of science and the findings of Mackay (1971) also indicated learners lacked knowledge of the nature of science. Bady (1979) claimed learners tended to have simplistic and naive absolute views of the nature of science. Duveen, Scott and Solomon (1993) claim many pupils regard science as a fact collecting process and the purpose of experiments is to uncover yet more facts, leaving little room for either speculation or explanation – the most naive form of empiricism. According to their research, learners perceive experiments to be unthinking activities with surprising results and scientific knowledge progress may be attributed entirely to technological improvements. The study conducted by Settlage (2000) indicated that whilst young learners were able to view the science they had learned at school within the context of their daily lives, there was very little evidence of learners perceiving science as a process of inquiry.

2.4.5 Learners' perceptions and science education – a brief summary

The goal of science education is to introduce learners to science knowledge and practices. However, research spanning the last five decades, reveals that despite formal science education, many learners' have little understanding of the nature of science and their perceptions of science do not reflect those of the scientific community. The new, contemporary, South African curriculum reflects the views of cognitive theorists and the current views of the scientific community. Curriculum 2005 acknowledges that by the time learners engage in formal science education a set of beliefs about science has already been constructed and in some cases, these beliefs may differ from those accepted by the scientific community. Curriculum 2005 also acknowledges that these preconceptions influence learning and it is therefore equally important to consider and understand learners' own ideas as it is to present conventional scientific theories.

2.5 ARGUMENTS FOR SOUTH AFRICAN NATURE OF SCIENCE RESEARCH

2.5.1 The study of the nature of science is a new South African focus

South African science education is in a state of flux.

> It is possible that the learners are getting the worst of both worlds. Content is not being addressed, in some schools at any rate, in a systematic and sequential fashion as it might if the old syllabus were being followed. On the other hand, the intended benefits of OBE [outcomes based education] are hard to find. (Rogan, 2003, p.746)

Lederman (1992) indicates that although educators may feel the history and philosophy of science should be taught, a lack of knowledge of these areas leaves educators unsure of how such topics could be integrated within instruction and clearly influences the teaching of science. Webb et al. (2003) claim studies of the nature of science can promote understanding of nature of science within South Africa's historical, societal and cultural milieu and can promote further debate among South African science educators. They also claim increased nature of science debate will not only promote increased understanding of the nature of science, but will also promote the development of classroom activities that are aligned with national curriculum statements.

2.5.2 The argument for qualitative nature of science research

Lederman et al. (2002) and Webb et al. (2003) argue there is little more to be learned from mass assessments aimed at evaluating learners' understandings of science. They also argue that whilst research of educators' perceptions of the nature of science is necessary, the danger of focusing further research on educators' views, is that a particular view of the nature of science may be purported to be the 'correct' one, or worse, the nature of science may be perceived as unchanging. A further argument against exclusively focusing on educators' perceptions is presented by Lederman et al. (2002). They claim focusing on a single variable places nature of science research at risk of regressing to its former state during the 1950's and 1980's, which Lederman (1992) describes as chaotic research of learners' conceptions, educators conceptions and classroom interventions aimed at improving learners' perceptions of the nature of science. Lederman (1992), Lederman et al. (2002) and Webb et al. (2003) all argue for a coherent effort to improve science instruction. They propose more qualitative research that focuses on classroom interventions aimed at enhancing learners' nature of science views is needed.

2.5.3 The argument for teachers as researchers

The implementation of the new South African curriculum has met with resistance. As Rogan (2003) points out, Curriculum 2005 is not being implemented as intended in many South African schools. Jansen (1999) offers an explanation for resistance to curriculum change. He claims that in the wake of South Africa's first non-racial elections in 1994, the superficial revision of the inherited curriculum had more to do with the politics of transition than it did with changing the school curriculum. Jansen also argues that the superficial revision of the school curriculum set in place and consolidated a pattern of curriculum change that excluded grassroots participation, and generated a public understanding that minimalist revisions to school subjects are both acceptable and workable. Rogan (2003) claims the past decade has seen a renewed interest in the development of well-designed science curricula with laudable aims in many areas of the world. However, he claims many of the lessons of past efforts are not heeded and all too often the attention and energies of policy makers and politicians are focused on the 'what' of desired educational change, neglecting the 'how' with large scale programs tending to emphasize adoption and neglect implementation. He claims South Africa unfortunately fell into the same trap and Curriculum 2005 became yet another costly example of poor implementation of what was essentially a good idea. Rogan goes on to say that the combination of the superficial revision of the National Curriculum in 1994 and the problematic cascade attempts to implement Curriculum 2005 in 1998, has culminated in many educators being alienated from the process of curriculum change.

Sutton (1989) claims there is unlikely to be a shift in the dominant ways of working until outstanding success with the alternatives has been demonstrated and "we may all cling to the existing patterns by default, until new practices can be inspired and guided by a compelling and appealing example of a different approach" (p.156). Ownership is crucial to change. If Curriculum 2005 is to be implemented as intended, educators need to gain a sense of ownership of the new South African curriculum. When educators engage in research in their own schools and document their experiences, they develop ownership of the curriculum.

> Becoming a teacher researcher requires a shift from being a conventional teacher to becoming an extended professional involved in reflection and deliberation about classroom practice. Through research, teachers can become change agents bringing about change, both in themselves and in their classrooms. They grow professionally and improve their practice. (Majara and Raubenheimer, 1997, p.511)

2.5.4 The argument for South African nature of science research – a brief summary

Three arguments for South African nature of science research have been presented. Firstly, the study of the nature of science is a new focus in South African science education and literature pertaining to the study of the nature of science within a South African context is lacking. Secondly, nature of science research must be qualitative and should focus on classroom interventions aimed at enhancing learners' nature of science views. Thirdly, nature of science research provides an opportunity for educators to engage in research in their own schools, develop a sense of ownership of the new South African curriculum and bring about change, both in themselves and in their classrooms.

2.6 A BRIEF SUMMARY OF THE LITERATURE

Although empiricism has been effective in generating scientific knowledge, the realization that observations are not objective and induction is not logically valid, challenged the empirical view of science. The hypothetico-deductive view proposes theories to be constructions of the human mind, supported by empirical evidence. Science therefore reflects the history, culture, power structures and political climate of the supportive community. The nature of science construct is complex as there is no one accepted view of science, scientific knowledge or scientific method. However, although the nature of science is contested within the scientific community, there is considerable agreement that science education should include the study of the nature of science and there does exist some consensus among the scientific community regarding what should be taught in schools.

An analysis of the new South African curriculum revealed that Curriculum 2005 reflects the views of cognitive theorists and acknowledges learners' preconceptions influence learning. Curriculum 2005 advocates that it is equally important to consider and understand learners' own ideas as it is to present conventional scientific theories. A framework of analysis based on three groupings: the nature of scientific inquiry, the nature of science knowledge and the interaction between science and society revealed that the new South African curriculum reflects current views of the scientific community. Both Curriculum 2005 and the scientific community advocate learners develop the following perceptions of the nature of science:

The nature of scientific inquiry. Science is a cyclic process of inquiry that involves formulating hypotheses and designing and carrying out experiments to test the hypotheses. Although the core activities of scientists are observation and measurement, and science uses a range of systematic methods and approaches, there is no single scientific method. Most measurements are subject to some uncertainty and scientific knowledge claims do not simply emerge from data, but from a process of data analysis, interpretation and theory building. Scientific inquiry therefore proceeds through logic, intuition and inspiration and it is possible for scientists to legitimately come to different interpretations of the same data and therefore to disagree. Consequently the outcome of a single investigation is rarely sufficient to establish a new knowledge claim.

The nature of science knowledge. Science knowledge aims to be general and universal. Science knowledge is supported by empirical evidence, but scientific explanations are based on models and representations of reality that are often simplifications of the complexity of the real world. Science knowledge is cumulative and revisionary. Whilst much science knowledge is well established, reliable and beyond reasonable doubt and can be relied upon as a basis for action, science knowledge may be subject to change given new evidence or new interpretations of old evidence. Science can offer solutions to many of the problems of the world, but there are some problems that cannot be solved by science and sometimes the solution of one problem may create another problem for society or the environment. Science and technology are separate entities, but are increasingly interdependent with new science reliant on new technology and new science enabling new technology

Interaction between science and society. Scientific developments arise from group activity and collaboration. New science knowledge claims are generally shared and must survive a process of critical peer review. Science is located within a historical context and is affected by the demands and expectations of society. The application of scientific and technological knowledge is not value-free and may be in conflict with moral and ethical values held by groups within society.

The study of the nature of science was not afforded as much attention in the previous South African curriculum as it is in Curriculum 2005. Consequently, the study of the nature of science is a new focus for South African educators and is a new area of research. There is considerable agreement that nature of science research should be a coherent effort to improve science instruction by means of qualitative research that focuses on classroom interventions aimed at enhancing learners' nature of science views. It is also argued that through research, educators enhance their understanding of the nature of science, develop a sense of ownership of the new South African curriculum and improve their practice.

2.7 WHY THIS STUDY CONTRIBUTES TO NATURE OF SCIENCE RESEARCH

2.7.1 Lack of South African nature of science literature

The previous curriculum with its focus on science knowledge promoted South African research of learners' perceptions of science knowledge. Consequently learners' ideas about scientific principles are well documented as are classroom interventions aimed at improving learners' understanding of science knowledge. The study of the nature of science is a new South African focus and research of learners' perceptions of the nature of science is therefore lacking. This study contributes to a much needed data base of 'first hand' accounts of the teaching and learning of the nature of science within a South African context.

2.7.2 Unique timing of research

The focus of Curriculum 2005 is to introduce learners to science knowledge and practices of science, whereas the previous South African curriculum focused on introducing learners to science knowledge. This study was conducted at the cusp of curriculum change and provides a snapshot of learners' perceptions of science within the context of two different curricula and offers some insight into the extent to which the goals of Curriculum 2005 are being achieved in one South African school.

2.7.3 Research conducted within the context of resistance to curriculum change

Rogan (2003) claims Curriculum 2005 is not being implemented as intended in many South African schools. This was my personal experience as this study was conducted in a school that resisted curriculum change – whilst some attempts were made to implement Curriculum 2005, the content laden previous South African curriculum still prevailed. This study documents my attempts to include the study of the nature of science and is a grassroots account of the implementation of Curriculum 2005 within the context of a school resisting curriculum change.

2.7.4 The focus of this study

Two key questions framed this study: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives? To generate a response to the first question, learners were asked to complete a questionnaire pertaining to the nature of science. To generate a response to the second question, learners were asked to take photographs of science within the context of their daily lives and offer explanations of why the photographic images were representations of science. This study is therefore simply an account of some of my classroom interventions aimed at improving learners' perceptions of the nature of science and a presentation of some learners' perceptions of the nature of science after experiencing these interventions. This study does not purport to be anything more than an exploration of some South African learners' perceptions of science within the context of their daily lives and an analysis of some learners' perceptions of the nature of science at the cusp of South African curriculum change.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 SCIENCE THROUGH THE CAMERA LENS – SOME LEARNERS' PERCEPTIONS OF SCIENCE: FOCUS OF THIS STUDY

The purpose of this study was to determine some South African learners' perceptions of the nature of science and to consider how they might choose to represent their perceptions of science within the context of their daily lives, photographically.

Two key questions framed this study: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives? Lederman et al. (2002) and Webb et al. (2003) claim there is little more to be learned from mass assessments aimed at evaluating learners' perceptions of the nature of science and argue more qualitative research that focuses on classroom interventions aimed at enhancing learners' nature of science views is needed. Heeding their argument, this study includes descriptive accounts of classroom activities used to facilitate the study of the nature of science and both quantitative and qualitative data was used to address the two key questions.

A questionnaire was used to collect quantitative data to address the key question: What are learners' perceptions of the nature of science? A photographic activity was used to collect qualitative data to map out more fully learners' perceptions of the nature of science and to address the key question: What are learners' perceptions of science within the context of their daily lives?

3.2 RESEARCH STYLE

According to Merriam (1988), interpretive case studies are characterized by the inductive development of conceptual categories. Hitchcock and Hughes (1995) point out that the researcher is integrally involved in the case and case studies blend a description of relevant events with an analysis of them. An advantage of a case study, according to Cohen and Manion (2000), is that it can generate data that is strong in reality, catch unique features that might otherwise be lost in larger scale research and contribute to an archive of descriptive material sufficiently rich to admit subsequent reinterpretation. Nisbet and Watt (1984) do however point out that the subjective nature of a case study raises problems of respectability and legitimacy and achieving a positivist view of reliability is difficult as given the uniqueness of situations, case studies are selective and prone to problems of observer bias despite attempts to address reflexivity. Cohen and Manion (2000) also point out that whilst one of the strengths of teachers conducting research in their own schools is that they already know a lot about the school, staff and learners, such familiarity can be a drawback as things may be taken for granted that ought to be held in question. Cohen and Manion do however argue that despite these difficulties, case studies have gained popularity in response to the antipathy among researchers towards the statistical-experimental paradigm and have been widely used in educational research.

Case study researchers, according to Cohen and Manion (2000), typically observe the characteristics of an individual unit. The unit of analysis in this case study was a well-resourced co-educational South African secondary school. This case study was conducted in 2002 and data was collected during the period July 2002 to November 2002. I was the only researcher involved in this study

3.3 SAMPLE

I originally intended to include all learners who were studying science at one South African school, so I approached KODAK South Africa to request financial aid for the photographic costs. I was denied any assistance and rather than abandon the use of cameras as a research instrument, I considered how many disposable cameras and the associated processing and developing costs I could afford. Consequently due to financial constraints, the sample size was limited to 120 learners.

As this study was conducted at a time of curriculum change, I elected to include participants experiencing both the old and new South African curriculum. The purpose of this was to facilitate analysis at two levels: An analysis of the school and an analysis of subgroups officially experiencing different curricula within the school. Consequently the sample was comprised of one class of learners in each of Grades 8, 9,10 and 11. Grade 12 learners were excluded from the study as the data collection process coincided with their preparation for the matriculation examinations.

Cohen and Manion (2000) point out: "Small-scale research often uses non-probability samples because, despite the disadvantages that arise from their non-representativeness, they are far less complicated to set up, are considerably less expensive, and prove perfectly adequate where researchers do not intend to generalize their findings beyond the sample in question" (p.102). This study made use of convenience sampling – the participants selected for this study were learners I taught. There were a number of reasons why I selected participants from the classes I taught. Firstly, I had obtained permission from the principal to conduct the study, provided it did not disrupt teaching and learning. As I didn't want to disrupt other teachers' learning programs, I elected to limit the sample to learners I taught. Secondly, I felt I had sufficient rapport with the learners in my classes to ensure a high response rate. Thirdly, I would be able to include detailed descriptions of learning activities and fourthly, the classes I taught were co-educational and of mixed ability. I also wanted to engage learners I taught in an activity that would generate discussion of the nature of science so as to enhance their understanding of the nature of science construct.

Prior to the data collection process, I met with each class selected for the study and explained the purpose of the study was to gain insight into some South African learners' perceptions of science. I also explained that the findings of the study would be made public, but all participants would be guaranteed eventual anonymity. I indicated participation was voluntary and would therefore not affect school marks. Cohen and Manion (2000) point out that whilst respondents might be strongly encouraged to participate in research, the decision whether to become involved and when to withdraw from the research is entirely theirs.

3.4 STRATEGIES FOR DATA COLLECTION

Cohen and Manion (2000) define triangulation as the use of two or more methods of data collection in the study of some aspect of human behavior. In order to obtain relevant data to explore learners' perceptions of the nature of science, methodological triangulation was adopted in this study – different data collection methods were used to map out more fully the complexity of learners' perceptions of the nature of science. The data collection methods used in this study included a cartoon-style questionnaire and a photographic activity.

Oppenheim (1996) suggests cartoons can be used in attitudinal surveys because they help elicit ideas in non-threatening ways as respondents are provided with an opportunity to critically respond to others' views. According to Cohen and Manion (2000), "rating scales are particularly useful for tapping attitudes, perceptions and opinions of respondents" (p.225). A cartoon-style questionnaire (Appendix A) that made use of a semantic differential rating scale was used to collect quantitative data to address the key question: What are learners' perceptions of the nature of science?

The photographic activity was used to collect qualitative data to address the key question: What are learners' perceptions of science within the context of their daily lives? Settlage (2000) notes: "Contrary to the adage about a picture and a thousand words, a photograph alone disclosed little meaning until the child had provided a spoken caption" (p.2). The photographic activity was therefore comprised of three research instruments: photographic prints, interviews and report sheets. Learners were asked to take photographs using a disposable camera of what they perceived as science outside the bounds of science education classes. As time constraints ruled out a detailed interview with each learner, I considered a written description of each photograph accompanied by reasons for taking the photograph crucial to the data collection process. Each learner was therefore also given a report sheet (Appendix B) and I verbally reiterated that as soon as possible after taking each photograph learners should record a description of each photograph and a reason for taking each photograph on the report sheet. Whilst the qualitative data generated by the photographic activity was primarily used to gain insight into learners' perceptions of science within the context of their daily lives, it was also used to map out more fully learners' perceptions of the nature of science.

3.5 NATURE OF SCIENCE QUESTIONNAIRE

3.5.1 First pilot questionnaire

I initially elected to use a semi-structured questionnaire (Appendix C) entitled 'Views of nature of science Elementary/Middle School version' (Lederman, 2002, personal communication) that had been piloted with learners in the United States of America. Supplied with the questionnaire was an annotated scoring guide (Appendix D). At face value the questionnaire seemed ideal as an effective instrument for eliciting learners' perceptions of science and I decided to use six of the seven questions posed in the questionnaire. As an aside to eliciting learners' perceptions of the nature of science, I also included a further three questions pertaining to scientists so as to explore the findings of Dlamini (1997), who indicates school science does not encourage African learners to become scientists, and Bowtell (1996), who indicates Australian children hold negative perceptions of scientists.

I elected to pilot the questionnaire (Appendix E) with learners who were not in the sample selected for the study. The pilot questionnaire was therefore administered to 25 Grade 10 learners of mixed ability who I did not teach. According to the educator who administered the questionnaire, the learners took about 30 minutes to complete the questionnaire. I found the learners' responses to the nature of science questions in the pilot questionnaire difficult to interpret as the learners answers were vague and bore little resemblance to those provided in the annotated scoring guide. As Cohen and Manion (2000) express, "if a genuinely open-ended question is being asked, it is perhaps unlikely that responses will bear such a degree of similarity to each other to enable them to be aggregated too tightly" (pp255-256). I concluded that the nature of science questionnaire items in the pilot questionnaire would not be suitable for my study as due to time constraints I would not be able to conduct a lengthy interview with each learner to clarify responses. However, the learners' responses to the questions pertaining to scientists were easily analyzed. The learners' responses revealed that most learners had no desire to become scientists and they used terms such as 'crazy', 'freaks', 'loners', 'clever' and 'boring' to describe scientists. The drawings of scientists were analyzed using the indicators devised by Chambers (1983) and modified by Schibeci (1986). This analysis revealed that the standard image of scientists (lab coat, eyeglasses, facial hair, laboratory equipment and pens in a coat pocket) held true for this small group of learners. Whilst these findings were interesting and revealed issues that I would like to explore further, the questions pertaining to scientists did not generate data suitable for addressing the two key questions framing my study. Consequently these questionnaire items were also deemed unsuitable for my study.

3.5.2 Second pilot questionnaire

Based on the difficulties I had experienced with the analysis of the semi-structured pilot questionnaire, I elected to design my own structured cartoon-style questionnaire in which learners would be able to indicate agreement or disagreement with statements pertaining to the nature of science, by means of a seven point semantic differential rating scale. I chose to include statements pertaining to the nature of scientific inquiry, the nature of science knowledge and the interaction between science and society. The clustering of statements into these three areas was to facilitate an analysis at two levels: Firstly to ascertain if learners held similar views of the nature of science shared by the scientific community (Collins et al, 2001) and expressed in Curriculum 2005 and secondly to facilitate a comparison with the views of the nature of science as expressed in the learners' photographs of science.

Six questionnaire statements pertained to the nature of scientific inquiry:

Statement 1: There are fixed steps to follow in a scientific investigation.

Statement 8: Scientists decide what data to collect before they do an investigation.

Statement 10: When a scientific investigation is carefully repeated it produces exactly the same results.

Statement 11: Scientists do investigations to test their ideas.

Statement 15: Scientists have an idea of what will happen in an experiment before they actually do the experiment.

Statement 18: A scientific investigation involves collecting evidence, logical reasoning and imagination.

Six questionnaire statements pertained to the nature of science knowledge:

Statement 2: Science knowledge changes gradually.

Statement 3: The purpose of scientific investigations is to reveal the world as it really is.

Statement 6: Science facts are influenced by the opinions of scientists.

Statement 13: Scientists' explanations come partly from what they observe and partly from what they think.

Statement 14: There are certain events science will never be able to explain.

Statement 17: When a new theory is proposed, the old theory is quickly 'thrown out'.

Six questionnaire statements pertained to the interaction between science and society:

Statement 4: Important scientific contributions have been made by people from all different cultures.

Statement 5: Science can provide solutions to the problems faced by society and the environment.

Statement 7: Historical events are closely linked to science.

Statement 9. What makes science different is that any new information is carefully examined and debated before it is made available to the public.

Statement 12: All new science information must be verified by others before it is accepted.

Statement 16: Money and politics do not determine what scientists investigate.

The second pilot questionnaire was therefore comprised of 18 statements expressed as the speech bubbles of cartoon figures and respondents were required to indicate their level of agreement by circling a number on a seven point rating scale near each cartoon figure. Once again I chose to pilot the questionnaire with learners that were not included in the sample selected for my study. Consequently the questionnaire was piloted with 25 Grade 11 learners of mixed ability that I did not teach. The questionnaire was distributed and collected by the pilot groups' science educator. According to the educator, the pilot group took about 15 minutes to complete the questionnaire. I captured the questionnaire data and to check if my data capture matched the learners' intent, I met with the pilot group to discuss the questionnaire. During this whole group discussion I ascertained that the pilot group had found the questionnaire instructions easy to understand and they were able to complete the questionnaire without assistance (this was confirmed by the educator who had administered the questionnaire). I then conducted and recorded a whole group discussion for each questionnaire statement. I deliberately steered the discussion so that each learner commented on at least one of the questionnaire statements. I transcribed the whole group discussion and then used the transcript to compare learner's comments with their questionnaire responses. I found the learners had been able to select appropriate ratings to express their views of the nature of science. Based on these findings, I elected not to alter the questionnaire.

3.5.3 Views of science questionnaire – response rate

I administered the questionnaire "Views of science" (Appendix A) to the participants in November 2002 to complete during a science lesson. I indicated their participation was voluntary and would not affect their marks in any way. Most learners (92%) returned the questionnaire.

3.5.4 Views of science questionnaire – data used for analysis

The questionnaire rating scale was comprised of values ranging from –3 to +3. Osgood, Suci and Tannenbaum (1957) indicate that when rating scales are used, the questions should have approval ratings in the same direction. If questions are asked in a negative way, the negative scores should be changed into positive scores. Statements 6 and 15 were asked in a negative way, so once the data was captured on computer from the 110 completed and returned questionnaires, it was coded so as to facilitate data analysis with approval ratings for all statements in the same direction.

3.5.5 Views of science questionnaire – method of analysis

Hannagan (1982) writes: "Statistics is concerned with the systematic collection of numerical data and its interpretation" (p.1). The seven-point differential rating scale used in the questionnaire facilitated a numerical representation of learners' perceptions of the nature of science. However, as Hannagan argues, numerical data are not facts in themselves; it is only when they are interpreted that they become relevant to discussions – statistics merely provide a method of systematically summarizing some aspects of the complexities of human behaviour. The questionnaire data was subjected to two statistical analyses.

The purpose of the first analysis was to summarize the learners' responses. The frequency with which participants in the sample had indicated agreement, disagreement or indecision was therefore determined for each statement (Appendix F). This analysis was central to the interpretation of the quantitative questionnaire data. The second analysis was simply used to support the findings of this first, descriptive analysis.

The purpose of the second analysis was to determine the mean response to each statement. However, as Hannagan (1982) points out, if responses are widely dispersed, averages do not provide a clear summary of the distribution; distributions are not only clustered around a central point, but also spread out around it. The data was therefore subjected to further analysis to provide an indication of how the responses deviated around the central value (mean) and the maximum and minimum values learners used to indicate their response to each statement was noted. Whilst the maximum and minimum values indicated the range of learners' responses, these two values were not representative of all other values in the distribution. Hannagan claims the standard deviation shows the dispersion of values around the mean (variability): "The greater the dispersion, the larger the standard deviation" (p.160). The data collected for each statement was analyzed to determine learners' responses within two standard deviations – the upper and lower bounds were determined so as to include 95% of the learners' responses and the standard error was also calculated so as to provide an indication of the extent to which the sample means might have deviated from the population means (Appendix G).

3.6 PHOTOGRAPHS OF SCIENCE

3.6.1 Instructions for taking photographs

Ideally each leaner should have been issued with a camera, but only 20 disposable cameras were available for the study. This meant six learners were required to share a camera. Each camera had 27 exposures, enabling the participants to take one photograph of themselves and three photographs of science.

I met with each class for about 30 minutes to discuss the taking of photographs. During this time I explained how the disposable camera worked and verbally instructed the learners to: "Take one photograph of yourself and then three photographs of what you think is a good representation of science." I indicated that learners were not to take photographs within science classrooms, and that the photographs should be within the context of their daily lives. I also indicated that there were no 'right' or 'wrong' photographs. I explained the purpose of the photograph learners took of themselves was to help me match photographs with photographers and this photograph would be theirs to keep. I also indicated that completing the report sheet was a crucial aspect of the activity and each photograph should be accompanied by a written description and explanation of why the photograph represented science. The verbal instructions were reiterated on an instruction sheet (Appendix B) issued to each learner.

3.6.2 Response rate of disposable cameras and report sheets

When learners returned their camera, I requested the completed report sheet. Some learners had lost the report sheet by the time they took their photographs of science, so I issued another report sheet and the learner would fill it in while I waited. Unlike the Grade 8 and 9 learners that quickly returned a camera as soon as photographs had been taken, the Grade 10 and 11 learners often forgot to bring the camera to school to pass on to a fellow learner. This slowed the data collection process and eight learners were unable to gain access to a camera within the time allocated for data collection.

Learners were also asked to write a short reflection about the photographic activity on the report sheet. A total of 112 report sheets were issued and 107 report sheets were returned. With the exception of two learners, all respondents indicated that they had enjoyed the activity – this probably contributed to the high response rate. Although my request that learners photograph themselves was primarily to enable me to match photographs with report sheets, it served as an unexpected incentive for learners to return the cameras as most learners wanted to see (and keep) the photograph they had taken of themselves.

When I handed in the disposable cameras for developing and processing, I requested that all photographs be printed irrespective of the quality of the photographic print. Many photographs were not of print quality. Although each camera did have a flash, it was not automatic and learners would have needed to activate the flash when they took photographs at night or indoors. During the learner interviews, many learners indicated they infrequently took photographs and some learners indicated this was the first time they had used a camera. The high number of photographs not of print quality (56%) could possibly be attributed to insufficient use of the camera flash.

3.6.3 Photographs of science – data used for analysis

The 311 images of science generated in this study were essentially pieces of art open to individual interpretation and I found, as Settlage (2000) had indicated, without knowing the photographer's intent, the underlying science was virtually impossible to ascertain. Settlage (2000) had also indicated learner interviews were crucial to the data collection process as he claimed the learners in his study had either not returned the report sheet, or had provided inadequate written reports.

I conducted tape-recorded interviews with 11 learners that had taken print quality photographs of science. During these interviews the learner would positively identify their photographic prints and briefly discuss each photograph with me. These interviews lasted about six minutes. The tape-recorded interview was then transcribed and compared with the report sheet and photographic print.

I found there was a strong correlation between the description of the photograph provided on the report sheet and the photographic print. I also found there was a strong correlation between the explanation provided on the report sheet of why the learner had taken a photograph and the explanation for taking the photograph provided by the learner during the interview. These correlations are illustrated in Figure 3-1 and Figure 3-2.

Photographic print	*Interview*	*Report Sheet*
	Researcher: Is this your photo? [shows photograph of water boiling in a kettle] Learner: Yes, it's mine. Researcher: Why did you take this photo? Learner: We learned about phase change in science this year. This is a photograph of evaporation.	This is a photograph of: Boiling water in a kettle. I took this photograph because: It is undoubtedly, a representation of science. We learnt that substances can change into a different form and then back to the original. In this case, cold water heated up, boiled and turned into steam and back to water droplets (on the wall and fridge).

Figure 3-1 Correlation between photographic print, interview and report sheet

Photographic print	*Interview*	*Report sheet*
	Researcher: And this photo? [shows photograph of computer] Learner: It's mine. I took it because it's technology. Researcher: Why's that science? Learner: Because the inventers of the computer were scientists. Researcher: Oh. Learner: Technology is science	This is a photograph of: A computer I took this photograph because: Scientists invented the computer. Computers are technology. Technology is science.

Figure 3-2 Correlation between photographic print, interview and report sheet

Unlike the findings of Settlage (2000), the report sheets in this study closely matched learner interviews and most report sheets provided a clear description of what had been photographed and a lucid explanation of why the photograph represented science. Consequently most photographic prints could be matched with the correct report sheet prior to an interview with each learner. The most likely reason learners in this study were able to clearly articulate their intent on the report sheet was that they were considerably older than the participants in the study conducted by Settlage.

The report sheets proved to be more useful primary data than the photographic prints. The analysis of the learners' perceptions of science within the context of their daily lives, as represented by photographic images, is therefore based on the data generated by the report sheets together with the actual photographic prints. Photographic prints that were not accompanied by a report sheet were excluded from the data-base. If a clear description of what had been photographed and why the photograph represented science was provided on a report sheet, the image of science was included in the analysis, irrespective of the quality of the photographic print.

I interviewed each learner in the sample. These interviews were not tape-recorded and lasted about five minutes. During these interviews I elicited a more detailed description of what had been photographed and any detail the learner described that was not already recorded, I wrote on the report sheet. In an attempt to address validity, I requested learners dictate the phrases to be used, and I simply acted as a scribe.

3.6.4 Photographs of science – method of analysis

The photographs of science generated qualitative data that was analyzed by a process of systematic network analysis. According to Cohen and Manion (2000): "Essentially network analysis involves the development of an elaborate system of categories by way of classifying qualitative data and preserving the essential complexity and subtlety of the materials under investigation" (p.297). A photocopy of each report sheet was made and then cut up to produce four strips of paper: three strips of paper representing photographs of science and one reflection of the photographic activity. Each strip of paper representing a photograph of science included both the description of what had been photographed and why the photograph represented science. For discussion purposes, the strip of paper representing a photograph of science will henceforth be referred to as a 'photograph of science'. A total of 311 photographs of science were available for analysis.

Cohen and Manion (2000) point out that whilst descriptive validity rests on an accurate account of the research, interpretive validity rests on the ability of the researcher to catch the meanings and intentions of the participants. The description of what had been photographed was therefore considered in conjunction with the explanation of why the photograph had been taken. I elected to place each of the photographs within one group only and similar photographs of science were grouped together. This generated a large number of small groups of photographs. These initial groups of photographs were then reviewed and sub-categories were inductively developed. The sub-categories were then reviewed and three broad categories emerged.

3.7 METHOD OF REPORTING FINDINGS

Schofield (1993) writes of qualitative research: "It is important to provide a clear, detailed and in-depth description so that others can decide the extent to which findings from one piece of research are generalizable to another situation" (p.200). The findings of this study are reported in the following chapter. Chapter 4 begins with an outline of the learning programmes experienced by the learners in each grade, with particular emphasis on classroom activities aimed at enhancing learners' perceptions of the nature of science. The quantitative data generated by the questionnaire is then summarized, analyzed and interpreted. Attention is then turned to the qualitative data collected from the photographic activity and a summary, analysis and interpretation of these findings is presented. Chapter 4 then concludes with a summary of the findings of this study and the two key questions that framed this study are addressed: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives?

CHAPTER 4
RESULTS, ANALYSIS AND INTERPRETATION

4.1 INTRODUCTION

This chapter is comprised of four parts. The first part provides a detailed description of the case, the second part reports the findings of the views of science questionnaire and the third part describes the learners' photographs of science and their perceptions of why the photographs represented science. The fourth part comprises an analysis and an interpretation of these findings to address the two key questions: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives?

4.2 THE CASE

4.2.1 Unit of analysis – one South African school

The unit of analysis in this study was a well-resourced co-educational South African secondary school. Although the 942 learners at this school were from diverse cultural and socio-economic backgrounds, they were mostly from middle class families. The school employed 51 educators and there were approximately 30 learners in each class. English was the medium of instruction at this school.

4.2.2 Participants

The sample was comprised of four classes that I taught. The classes bore some similarity in that they were all co-educational, multi-cultural and the learners were of mixed ability. The sample composition is outlined in Table 4-1.

Table 4-1 Sample composition

	Number of participants	Males	Females
Grade 8	34	17	17
Grade 9	27	13	14
Grade 10	29	19	10
Grade 11	30	17	13
Total	120	66	54

Although English was the medium of instruction in all classes selected for this study, it was not the home language of all learners. English was not the home language of 30% of the learners in this study and I encouraged learners to discuss their learning in the vernacular.

4.2.3 Learning programmes at the time of this study

At the time of the data collection for this study, Grade 10 and 11 learners were still officially experiencing the old curriculum, whilst Grade 8 and 9 learners had officially experienced Curriculum 2005. Despite Curriculum 2005 policy documents outlining an outcomes-based approach with learning integrated across learning areas, subjects remained as separate entities at this school and the new learning area Natural Sciences manifested as a semester of Biology and a semester of Physical Science. I had based my science learning programmes for the 2002 academic year on Hodson's (1992) critique of the teaching of science. My learning programmes for each grade were therefore comprised of learning science (content prescribed by the old curriculum), learning about science (the nature of science) and doing science (conducting scientific investigations), albeit in varying proportions for each grade.

Grade 8 Natural Sciences learning programme. Grade 8 learners had spent the first half of the academic year learning Biology. When these learners moved across to the Physical Science department, their first unit of learning included the topics: particle model of matter, phase change, elements and compounds. This unit was primarily content-based and learners were required to learn definitions, explain phase change in terms of kinetic theory, name and give the symbols of some elements and distinguish between an element and a compound. Included in this unit was an activity that required learners to develop their own theory and then present their theory for peer scrutiny. This activity also required learners to distinguish between the concepts 'theory' and 'model', and during the activity the idea that science is a human activity shaped by the search to understand the natural world was discussed. Learners were also required to debate whether an old, but cheap science encyclopedia was a good buy. The purpose of this activity was for learners to view science knowledge production as an ongoing process that usually happens gradually. A historical case study of alchemists was used to portray science as a human activity in which all cultures participate.

The second unit of learning entitled "Using your microchem kit" served to introduce Grade 8 learners to conducting experiments on a micro scale. The purpose of this unit was for learners to develop some of the skills needed to competently use small-scale apparatus. (At this school most science practical work is conducted individually using a microchemistry kit.)

The third unit of learning dealt with density. In this unit learners were required to learn definitions, perform calculations, draw graphs and interpret data from graphs and tables. Learners were required to determine the density of unknown solid objects and liquids by means of accurate measurement and calculation and then identify the unknown substances by comparing their findings with data provided in a table.

Separating mixtures was the topic of the fourth unit of learning. Learners were introduced to some of the methods used to separate mixtures and initially conducted 'pen and paper' theoretical separations. They were then given a variety of mixtures to separate. Learners were also required to extract and mass the oil from a packet of potato chips – they worked in pairs and had to plan and conduct the investigation on their own in the allocated class-time.

The final unit of learning focused on electricity. Learners were required to learn definitions and symbols, interpret circuit diagrams, draw circuit diagrams and construct circuits from circuit diagrams. This unit also allowed learners to explore the concept of electricity, during periods of 'free-play' with circuit boards, ammeters, voltmeters, resistors, lamps, cells and switches.

Grade 9 Natural Sciences learning programme. The Grade 9 learners spent the first half of the academic year learning Physical Science. The first unit of learning dealt explicitly with the nature of science. There were a variety of activities in this unit of learning: Two case studies – one of a South African scientist and another that portrayed the use of systematic scientific inquiry to identify what was causing the death of chickens. Learners were required to research a scientist of their own choice and present their findings as a booklet that included a birth certificate, a diary entry and a newspaper front page that located the scientist within the correct historical context. Learners worked in groups of three to research the economical, environmental and sociological impact of a South African mine. Learners were given a list of possible actions and asked to debate if the actions were scientifically possible and if so, should they be carried out. Learners were required to present arguments for and against cloning. Learners engaged in role-play: each learner was allocated a role in a community meeting to decide if a local area should be mined. Learners were also required to conduct a consumer test on a food product and then present their findings to the class.

The second unit of learning dealt with the topics: force, work, energy, power and pressure. This was predominantly content-based and learners were required to learn definitions and perform various calculations. It also included an investigation that required learners to ascertain what size school-shoe each classmate wore, present the data in various formats, analyze the data and comment on who might find such data useful. The learners were then required to work in groups of three to determine the 'slipperiest' school shoe within their group. Learners were also required to construct a model 'dragster' powered by wound-up elastic bands. The 'dragsters' were then tested to determine which one traveled the fastest and which one traveled the furthest.

The third unit of learning dealt with the topics: elements, compounds and chemical reactions. This was predominantly content-based and learners were required to learn some elements' names and symbols and write simple formulae. The learners conducted numerous "recipe-following' experiments using their microchemistry kits and wrote and balanced simple equations for the various chemical reactions they had observed. Included in this unit was a theoretical geological investigation: learners were given an information pack of maps, interviews and 'river water samples' to test. They were then required to write a report, based on the test results and all other information supplied, in which they recommended a suitable mining site. Learners were required to mix water, sand, cement and stone, in varying proportions of their own choice, to make concrete mixtures. They then tested the concrete blocks and recorded their findings in the form of a written report.

The final unit of learning dealt with the topic electricity. This was predominantly content-based and learners were required to learn definitions, perform various calculations and conduct "recipe-following" experiments with circuit boards. This unit also allowed learners to explore the concept of electricity, during periods of 'free-play' with circuit boards, ammeters, voltmeters, resistors, lamps, cells and switches. Included in this unit of learning was a group-work comparative research project on different ways of generating electricity.

Learners were also required to construct a 'car' from waste materials that had working headlights.

Grade 10 Physical Science learning programme. The Grade 10 learning programme was content-based and exam driven. The topics covered were: current electricity, effects of electricity, atomic structure, chemical bonding, writing formulae, naming compounds, balancing equations, metal reactions, non-metal reactions, acids and bases, electrochemical cells, ionic reactions, chemical calculations, waves, light and sound.

Although learners did engage in frequent practical work, the purpose of practical work was predominantly to verify theory and most practical activity simply required learners to 'follow the recipe' and look for an anticipated outcome. The learners in this class were also required to conduct an open ended-investigation of their own choice. Working in pairs, the learners wrote a research proposal that was subjected to peer review. They were then required to conduct the proposed investigation and report their findings in the form of a booklet, a poster and a short verbal presentation.

Although the nature of science was not explicitly included in the learning program, I would try and include weekly whole class discussions about the nature of scientific inquiry, the nature of science knowledge and the interaction between science and society.

Grade 11 Physical Science learning programme. This learning programme was content-based and exam driven. The topics covered were: waves, light, writing formulae, naming compounds, balancing equations, the periodic table, the mole, chemical calculations, chemical bonding, intermolecular forces, kinetic theory (solids, liquids and gases), solutions, redox reactions, sulphur, nitrogen, halogens, vectors, graphs of motion and equations of motion. Most topics learned in Grade 11 were examinable in Grade 12, so the primary focus of this learning programme was to prepare learners for the content-based examination they would write at the end of 2003.

The Grade 11 practical work was predominantly 'recipe-following' and learners wrote reports on their 'findings'. These learners were also required to conduct an open ended-investigation of their own choice. Learners worked in pairs and had to discuss their proposed research with me prior to conducting the investigation. Learners were required to report their findings in the form of a booklet, poster and a short verbal presentation.

The nature of science was not explicitly included in the Grade 11 learning programme. I did however occasionally discuss the nature of scientific inquiry, the nature of science knowledge and the interaction between science and society. These discussions were infrequent and at times separated by two or three weeks.

4.2.4 The Case – a brief summary

The unit of analysis in this study was a well-resourced co-educational South African secondary school. The sample was comprised of four classes that I taught. The 120 participants bore some similarity in that they were all co-educational, multi-cultural and the learners were of mixed ability. At the time of the data collection for this study, the Grade 10 and 11 learners were still officially experiencing the old curriculum, whilst the Grade 8 and 9 learners had officially experienced Curriculum 2005. My learning programmes for each grade were comprised of learning science (content prescribed by the old curriculum), learning about science (the nature of science) and doing science (conducting scientific investigations), albeit in varying proportions for each grade.

4.3 VIEWS OF SCIENCE QUESTIONNAIRE

After a brief discussion of the questionnaire response rate and the data used in the analysis, the questionnaire findings are presented within a framework of analysis based on three groupings: learners' perceptions of the nature of scientific inquiry, learners' perceptions of the nature of science knowledge and learners' perceptions of the interactions between science and society. The questionnaire findings are then interpreted within the context of the existing literature.

4.3.1 Response rate of questionnaire

The learners completed the questionnaire during a science lesson. Although some learners were absent on the day the questionnaire was issued and some learners did not return the questionnaire, the response rate was high as illustrated in Table 4-2.

Table 4-2 Response rate of questionnaire

	Grade 8	Grade 9	Grade 10	Grade 11	Total
Number of learners in the study	34	27	29	30	120
Number of learners given questionnaires	31	27	28	28	114
Number of questionnaires returned	29	25	28	28	110
Response rate	85%	93%	97%	93%	92%

4.3.2 Data used in analysis

The questionnaire responses were coded and responses from 110 learners were captured on computer. The data was checked and edited prior to being subjected to statistical analysis to determine the frequency with which learners agreed or disagreed with each questionnaire statement (Appendix F) and the mean response to each statement (Appendix G).

4.3.3 Learners' perceptions of the nature of scientific inquiry

Both Curriculum 2005 and the scientific community advocate learners develop the following perceptions of the nature of scientific inquiry: Science is a cyclic process of inquiry that involves formulating hypotheses and carrying out experiments to test the hypotheses. Although the core activities of scientists are observation and measurement, science uses a range of systematic methods and there is no single scientific method. Most measurements are subject to some uncertainty and scientific knowledge claims do not simply emerge from data, but from a process of data analysis, interpretation and theory building. Scientific inquiry therefore proceeds through logic, intuition and inspiration. It is possible for scientists to legitimately interpret the same data differently and to disagree. The outcome of a single investigation is rarely sufficient to establish a new knowledge claim.

The questionnaire statements that pertained to the nature of scientific investigations were:

Statement 1: There are fixed steps to follow in a scientific investigation

Statement 8: Scientists decide what data to collect before they do an investigation.

Statement 10: When a scientific investigation is carefully repeated it produces exactly the same results.

Statement 11: Scientists do investigations to test their ideas.

Statement 15: Scientists have an idea of what will happen in an experiment before they actually do the experiment.

Statement 18: A scientific investigation involves collecting evidence, logical reasoning and imagination.

Table 4-3 summarizes the learners' responses to these statements. The learners' response to these statements is then discussed and an interpretation of the learners' perceptions of the nature of scientific investigations is then presented.

Table 4-3 The nature of scientific inquiry – learners' response to statements

		Questionnaire statements					
		1	8	10	11	15	18
Grade 8 learners' response to statements expressed as a %.	Agree	97	69	52	93	66	76
	Disagree	0	21	41	3	21	14
	Undecided	3	10	7	4	13	10
Grade 8 mean response to statements		2.14	1.03	-0.17	2.17	1.07	1.00
Grade 9 learners' response to statements expressed as a %.	Agree	92	68	36	100	68	32
	Disagree	8	24	56	0	12	48
	Undecided	0	8	8	0	20	2
Grade 9 mean response to statements		2.26	1.07	-0.59	2.89	0.93	-0.19
Grade 10 learners' response to statements expressed as a %.	Agree	68	50	57	96	14	71
	Disagree	25	39	43	4	79	29
	Undecided	7	11	0	0	7	0
Grade 10 mean response to statements		0.57	0.25	0.29	1.82	1.18	1.04
Grade 11 learners' response to statements expressed as a %.	Agree	93	71	29	93	46	79
	Disagree	4	18	68	7	36	14
	Undecided	3	11	3	0	18	7
Grade 11 mean response to statements		2.14	1.39	-0.61	2.00	0.32	1.50
Total response to statements expressed as a %.	Agree	87	65	44	95	48	65
	Disagree	9	25	52	4	37	25
	Undecided	4	10	4	1	15	10
Total mean response to statements		1.78	0.94	-0.27	2.21	0.87	0.85

Note: refer to appendix G for standard deviations and other statistics.

Statement 1: There are fixed steps to follow in a scientific investigation. In this study 87% of the learners agreed with this statement and the mean response was 1.78. Grade 8, 9 and 11 responses were similar, with over 90% of the learners in each of these grades indicating agreement with the statement. In contrast, only 68% of Grade 10 learners agreed there are fixed steps to follow in a scientific investigation.

Statement 8: Scientists decide what data to collect before they do an investigation. The mean response to this statement was 0.94 and 65% of the learners in this study agreed with the statement. Grade 8, 9 and 11 responses were similar with 69%, 68% and 71% of these learners indicating their agreement respectively. In contrast, only 50% of Grade 10 learners agreed scientists decide what data to collect before they do an investigation.

Statement 10: When a scientific investigation is carefully repeated it produces exactly the same results. The mean response for Grade 8, 9 and 11 tends to be negative. This indicates these learners tend to disagree with the statement. However the mean response of Grade 10 learners tends to be positive, with 57% of these learners indicating their agreement that carefully repeated scientific investigations produce exactly the same results.

Statement 11: Scientists do investigations to test their ideas. In this study, 95% of the learners agreed with this statement. The mean response to the statement was 2.21 and the learners' responses were similar, with over 93% of the learners in each grade indicating their agreement with the statement.

Statement 15: Scientists have an idea of what will happen in an experiment before they actually do the experiment. In this study only 48% of the learners agreed with this statement, 37% indicated disagreement and 15% were undecided. The mean response was 0.87. The Grade 8 and 9 response was similar with 66% of Grade 8 learners and 68% of Grade 9 learners indicating agreement. The Grade 11 response reflects that 46% of these learners agree with the statement, whilst only 14% of Grade 10 learners agreed that scientists have an idea of what will happen in an experiment before they actually do the experiment.

Statement 18: A scientific investigation involves collecting evidence, logical reasoning and imagination. This statement was queried by learners in each grade. The term 'imagination' was verbally queried by 7 learners and 32 learners wrote on the questionnaire that the term 'imagination' was 'incorrect' or 'the odd one out'. The mean response for this statement was 0.85 and 65% of the learners in this study agreed with the statement. The response of Grade

8, 10 and 11 learners were similar. However, only 32% of Grade 9 learners indicated agreement with the statement.

4.3.4 Learners' perceptions of the nature of science knowledge

Both Curriculum 2005 and the scientific community advocate learners develop the following perceptions of the nature of science knowledge: Science knowledge aims to be general and universal and is supported by empirical evidence. Much science knowledge is well established, reliable and beyond reasonable doubt and can be relied upon as a basis for action. Scientific explanations are based on models and representations of reality that are often simplifications of the complexity of the real world and science knowledge may be subject to change given new evidence or new interpretations of old evidence. Science can offer solutions to many of the problems of the world, but there are some problems that cannot be solved by science and sometimes the solution of one problem may create another problem for society or the environment. Science and technology, whilst separate entities, are interdependent with new science reliant on new technology and new science enabling new technology

The questionnaire statements that pertained to the nature of scientific investigations were:

Statement 2: Science knowledge changes gradually

Statement 3: The purpose of scientific investigations is to reveal the world as it really is.

Statement 6: Science facts are influenced by the opinions of scientists.

Statement 13: Scientists' explanations come partly from what they observe and partly from what they think.

Statement 14: There are certain events science will never be able to explain.

Statement 17: When a new theory is proposed, the old theory is quickly 'thrown out'.

Table 4-4 summarizes the learners' responses to these statements. The learners' response to these statements is then discussed and an interpretation of the learners' perceptions of the nature of science knowledge is then presented.

Table 4-4 The nature of science knowledge – learners' response to statements

		Questionnaire statements					
		2	3	6	13	14	17
Grade 8 learners' response to statements expressed as a %.	Agree	86	72	50	61	72	7
	Disagree	11	21	36	32	14	93
	Undecided	3	7	14	7	14	0
Grade 8 mean response to statements		1.62	1.17	0.45	0.48	1.34	-2.24
Grade 9 learners' response to statements expressed as a %.	Agree	80	88	40	72	80	0
	Disagree	20	4	48	24	16	96
	Undecided	0	8	12	4	4	4
Grade 9 mean response to statements		1.19	2.15	-0.37	1.07	1.67	-2.30
Grade 10 learners' response to statements expressed as a %.	Agree	64	86	54	68	82	4
	Disagree	36	14	39	32	18	93
	Undecided	0	0	7	0	0	3
Grade 10 mean response to statements		0.71	1.39	0.29	0.36	1.54	-1.57
Grade 11 learners' response to statements expressed as a %.	Agree	79	79	57	68	82	7
	Disagree	21	14	29	25	7	82
	Undecided	0	7	14	7	11	11
Grade 11 mean response to statements		1.21	1.32	0.82	1.07	1.93	-1.50
Total response to statements expressed as a %.	Agree	77	62	51	67	79	5
	Disagree	22	33	37	28	14	91
	Undecided	1	5	12	5	7	4
Total mean response to statements		1.19	1.50	0.30	0.74	1.62	-1.90

Note: refer to appendix G for standard deviations and other statistics

Statement 2: Science knowledge changes gradually. In this study 77% of the learners agreed with this statement and the mean response was 1.19. The Grade 8, 9 and 11 responses were similar with 86%, 80% and 79% of the learners indicating their agreement respectively. However 36% of Grade 10 learners disagreed with the statement and only 64% of Grade 10 learners agreed science knowledge changes gradually.

Statement 3: The purpose of scientific investigations is to reveal the world as it really is. The mean response to this statement was 1.50 and 62% of the learners agreed with the statement. Grade 9 learners agreed most strongly with this statement with a mean response of 2.15.

Statement 6: Science facts are influenced by the opinions of scientists. In this study, 51% of learners agreed with the statement and the mean response was 0.30. The mean response of Grade 9 learners was negative and only 40% of Grade 9 learners indicated agreement, with the statement.

Statement 13: Scientists' explanations come partly from what they observe and partly from what they think. In this study, 67% of learners agreed with the statement (mean response of 0.74). Grade 10 and 11 learners indicated similar agreement with this statement.

Statement 14: There are certain events science will never be able to explain. The mean response for this statement was 1.62 and 79% of the learners in this study agreed with the statement. The Grade 9, 10 and 11 responses were similar.

Statement 17: When a new theory is proposed, the old theory is quickly 'thrown out'. In this study, 91% of learners disagreed with this statement. The mean response for Grade 8 and 9 was similar, whilst the mean response for Grade 10 and 11 was similar.

4.3.5 Learners' perceptions of the interaction between science and society

Both Curriculum 2005 and the scientific community advocate learners develop the following perceptions of the interaction between science and society: Scientific developments arise from group activity and new science knowledge claims must survive critical peer review. Science is located within a historical context and is affected by the demands and expectations of society. The application of scientific and technological knowledge is not value-free and may conflict with moral and ethical values held by groups within society.

The questionnaire statements that pertained to the interaction between science and society were:

Statement 4: Important scientific contributions have been made by people from all different cultures.

Statement 5: Science can provide solutions to the problems faced by society and the environment.

Statement 7: Historical events are closely linked to science.

Statement 9: What makes science different is that any new information is carefully examined and debated before it is made available to the public.

Statement 12: All new science information must be verified by others before it is accepted.

Statement 16: Money and politics do not determine what scientists investigate.

Table 4-5 summarizes the learners' responses to these statements. The learners' response to these statements is then discussed and an interpretation of the learners' perceptions of the interaction between science and society is then presented.

Table 4-5 The interaction between science and society – learners' response to statements

		Questionnaire statements					
		4	5	7	9	12	16
Grade 8 learners' response to	Agree	83	100	28	86	86	38
statements expressed as a %.	Disagree	14	0	38	3	3	48
	Undecided	3	0	34	11	11	14
Grade 8 mean response to statements		1.76	2.34	-0.45	2.28	2.14	0.10
Grade 9 learners' response to	Agree	92	92	60	96	80	24
statements expressed as a %.	Disagree	0	8	8	0	8	48
	Undecided	8	0	32	4	12	28
Grade 9 mean response to statements		2.52	2.26	0.59	2.33	1.67	0.41
Grade 10 learners' response to	Agree	93	89	64	89	96	68
statements expressed as a %.	Disagree	7	7	18	7	0	29
	Undecided	0	4	18	4	4	3
Grade 10 mean response to statements		1.96	1.75	0.93	1.75	2.04	-1.14
Grade 11 learners' response to	Agree	71	79	46	93	82	43
statements expressed as a %.	Disagree	18	11	29	0	7	46
	Undecided	11	10	25	7	11	11
Grade 11 mean response to statements		1.43	1.68	0.04	2.07	1.75	-0.07
Total response to statements	Agree	85	71	49	91	86	44
expressed as a %.	Disagree	10	25	24	3	5	43
	Undecided	5	4	27	6	9	13
Total mean response to statements		1.91	2.01	0.27	2.11	1.90	-0.18

Note: refer to appendix G for standard deviations and other statistics

Statement 4: Important scientific contributions have been made by people from all different cultures. In this study, 85% of learners agreed with this statement and the mean response was 1.91. Grade 9 learners agreed most strongly with the statement – 92% of learners in agreement with a mean response of 2.52, whilst Grade 11 learners agreed less strongly with only 71% of the learners in agreement with a mean response of 1.43.

Statement 5: Science can provide solutions to the problems faced by society and the environment. The mean response for this statement was 2.01 and 71% of the learners in this study agreed with the statement. The Grade 8 and 9 responses were similar.

Statement 7: Historical events are closely linked to science. Whilst 27% of the learners in this study were undecided, 49% of learners agreed with this statement. The mean response was 0.27. The mean response for Grade 8 learners was negative (-0.45), with only 28% of Grade 8 learners indicating agreement with the statement.

Statement 9: What makes science different is that any new information is carefully examined and debated before it is made available to the public. The mean response to this statement was 2.11, with 91% of learners indicating their agreement with this statement.

Statement 12: All new science information must be verified by others before it is accepted. In this study, 86% of the learners agreed with this statement and the mean response was 1.90.

Statement 16: money and politics determine what scientists investigate. In this study, 44% of the learners agreed with this statement and the mean response was 0.18. Whilst 68% of Grade 10 learners agreed money and politics determine what scientists investigate, only 24% of Grade 9 learners agreed with this statement.

4.3.6 Learners' perceptions of the nature of science – discussion of the findings

In this study 95% of the learners strongly agree (mean response of 2.21) scientists do investigations to test their ideas and 87% of the learners agree there are fixed steps to follow in an investigation (mean response 1.78). This is in accordance with the views of the scientific community (Collins et al., 2001) that science involves formulating hypotheses and designing and carrying out systematic experiments to test the hypotheses. In this study, 65% of the learners agree scientists decide what data to collect before they do an investigation (mean response 0.94), but only 48% of the learners agree scientists have an idea what will happen in an experiment before they actually do the experiment (mean response 0.87). The low mean responses to these statements indicate the learners in this study may perceive scientific investigations to follow a single scientific method in which experiments generate surprising results, as more facts are uncovered.

The view of scientific investigations as a blend of scientists' beliefs and empirical results shared by the scientific community (Collins et al., 2001) does not appear to be shared by the learners in this study and is evident in that 62% of the learners agree that the purpose of scientific investigations is to reveal the world as it really is (mean response 1.50). These findings support those of Bady (1979) who claimed learners tended to have simplistic and naïve absolute views of the nature of science and Duveen, Scott and Solomon (1993) who claimed learners regard science as a fact collecting process in which the purpose of experiments is to reveal more facts, leaving little room for speculation or explanation. Whilst 65% of the learners agree a scientific investigation involves collecting evidence, logical reasoning and imagination, the mean response to this statement was low (0.85) and only 51% of the learners in this study perceive science knowledge to be influenced by scientists' opinions (mean response 0.30). However, in contradiction to these responses, 67% of the learners agreed scientists' explanations come partly from what they observe and partly from what they think and 79% of the learners agree there are certain events science will never be able to explain (mean response 1.62). The questionnaire responses revealed 91% of the learners agree that theories and anomalies can co-exist and 77% of the learners in this study agree science knowledge changes gradually. However, 44% of the learners agree that a carefully repeated scientific investigation produces exactly same results. This finding suggests the learners may not perceive it possible for scientists to legitimately come to different interpretations of the same data and therefore to disagree.

The scientific community (Collins et al., 2001) and the learners in this study share the view that scientific developments are collaborative and new scientific knowledge claims are subject to peer scrutiny. The questionnaire responses revealed 85% of the learners in this study agree that scientific contributions have been made by people from all different cultures, 91% of the learners agree that what makes science different is that any new information is carefully examined and debated before being made available to the public and 86% of the learners agree that all new science information must be verified by others before it is accepted.

According to the scientific community (Collins et al., 2001) science affects and is affected by society. The questionnaire responses revealed 44% of the learners in this study agree money and politics determine what scientists investigate, 49% of the learners agree historical events are closely linked to science and 71% of the learners agree science can provide solutions to the problems faced by society and the environment.

The questionnaire responses revealed Grade 10 learners appeared to hold perceptions of science different to those of the other grades. Whilst these findings were surprising and warrant further exploration, the primary purpose of this study was simply to provide a snapshot in time of some South African learners' perceptions of science. Consequently further investigation of these differences was deemed beyond the bounds of this study.

4.3.7 Learners' perceptions of the nature of science – a brief summary

The questionnaire responses revealed some inadequacies in learners' perceptions of the nature of science. The learners in this study tend to support an empirical view and have inadequate perceptions of the role creativity plays in the development of scientific knowledge. This is evident in that 62% of the learners agreed that the purpose of scientific investigations is to reveal the world as it really is (mean response 1.50). Although the learners in this study do agree scientists have an idea of the possible outcome of an investigation and decide what data to collect prior to conducting an investigation, the mean response to these statements was less than 1. Furthermore, although the learners in this study agree scientific knowledge is influenced by scientists' opinions, scientific explanations are a blend of observation and thought, and scientific investigations involve collecting evidence, reasoning and imagination the mean response to these statements was also less than 1. The learners in this study also appear to have inadequate perceptions of the interaction between science and society and do not adequately perceive science to affect and be affected by the supportive community. This is evident in that although 44% of the learners in this study agree that money and politics affect what scientists investigate and 49% of learners agree history and science are closely related, the mean responses to these statements were -0.18 and 0.27 respectively. These findings lend support to the claims of Wilson (1954), Mead and Metraux (1957), Miller (1963), Mackay (1971) and Lederman (1992) that learners' understanding of the nature of science is inadequate.

The learners in this study do however share some of the views shared by the scientific community (Collins et al, 2001). The learners in this study agree science proceeds through the systematic testing of ideas and acknowledge that science knowledge changes slowly. The learners in this study acknowledge that new theories do not simply replace existing theories and scientific knowledge claims are subject to peer scrutiny. The learners in this study also acknowledge that different cultures make scientific contributions. The mean responses to these statements were all greater than 1.

4.4 PHOTOGRAPHS OF SCIENCE

After a brief discussion of the response rates of the disposable cameras, photographic prints and report sheets, the photographic images of science captured by the learners are presented within the contexts of three broad categories developed inductively. An interpretation of the photographic images of science is then outlined within the context of existing literature.

4.4.1 Response rates of disposable cameras, photographic prints and report sheets

Ideally this sample (120 learners) should have produced 360 photographic prints for analysis. However, eight learners did not participate and of the 20 disposable cameras used in this research, one was stolen and one was misplaced. When the remaining 18 cameras were processed, 321 photographs were generated for analysis, but 151 of these photographs were not of print quality and a further 10 photographic prints had to be discarded because they were (by the learners' admission) photographs of friends and family and not of science. Consequently only 160 quality photographic prints were available for analysis – a response rate of 44%. Most learners (96%) did however return the report sheets outlining what they had photographed and why they had taken the photograph. Table 4-6 illustrates the response rates for the report sheets.

Table 4-6 Response rate of report sheets

	Grade 8	Grade 9	Grade 10	Grade 11	Total
Number of learners in the study	34	27	29	30	120
Number of learners that took photographs	34	27	25	26	112
Number of report sheets returned	34	24	25	24	107
Response rate	100%	89%	100%	92%	96%

4.4.2 <u>Data used in analysis</u>

The data generated from the photograph taking activity was used to facilitate an analysis of the learners' perceptions of science within the context of their daily lives. Table 4-7 compares the maximum number of photographs of science that could have been generated in this study with the number of photographs of science that were adequately described on the report sheet and therefore available for analysis.

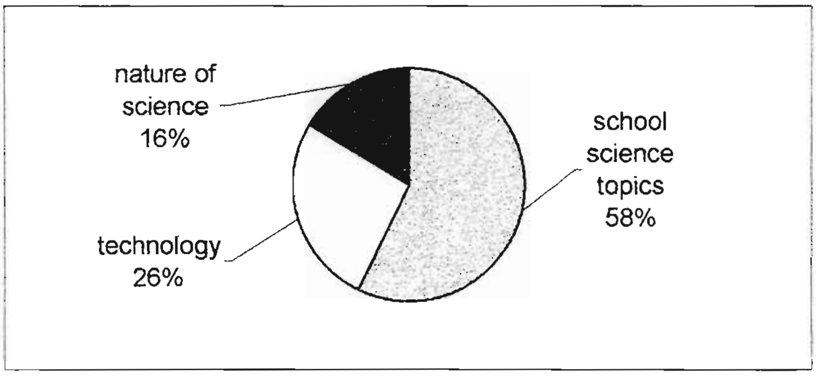
Table 4-7 Photographs of science available for analysis

	Grade 8	Grade 9	Grade 10	Grade 11	Total
Maximum number of photographs of science that could have been generated by the learners in this study	102	81	87	90	360
Number of photographs that were actually taken by the learners in this study	102	72	75	72	321
Number of photographs not of science and excluded from analysis	5	0	1	4	10
Number of photographs of science available for analysis because clear description and explanation provided on report sheet.	97	72	74	68	311
Response rate	95%	89%	85%	76%	86%

4.4.3 <u>Categories of photographs of science</u>

Through a process of systematic network analysis, three broad categories emerged: photographs of school science topics, photographs of technology and photographs of the nature of science. For a photograph to be placed in the category of school science topics, the learner needed to indicate the image depicted a content-based topic that had been studied either during the 2002 academic year or in previous high school years. For a photograph to be placed in the category of technology, the learner needed to indicate the image depicted technology. For a photograph to be placed in the category nature of science, the learner needed to indicate the image depicted some aspect of the nature of scientific inquiry, the nature of science knowledge or the interaction between science and society. The distribution of the photographs of science within these three broad categories is illustrated in Table 4-8.

Table 4-8 Categories of photographs of science



4.4.4 Photographs of school science topics

Grade 8 learners had studied Biology in the first semester of the 2002 academic year and had studied the following Physical Science content-based topics during the second semester of the 2002 academic year: particle model of matter, phase change, elements and compounds, density, separating mixtures and electricity.

Grade 9 learners had studied the following Physical Science content-based topics during the first semester of the 2002 academic year: force, work, energy, power, pressure, elements, compounds, chemical reactions, static electricity and current electricity. The Grade 9 learners had studied Biology during the second semester of the 2002 academic year.

Grade 10 learners had studied the following Physical Science content-based topics during the 2002 academic year: current electricity, effects of electricity, atomic structure, chemical bonding, writing formulae, naming compounds, balancing equations, metal reactions, non-metal reactions, acids and bases, electrochemical cells, ionic reactions, the mole, chemical calculations, waves, light and sound. Grade 10 learners did not study Biology during the 2002 academic year.

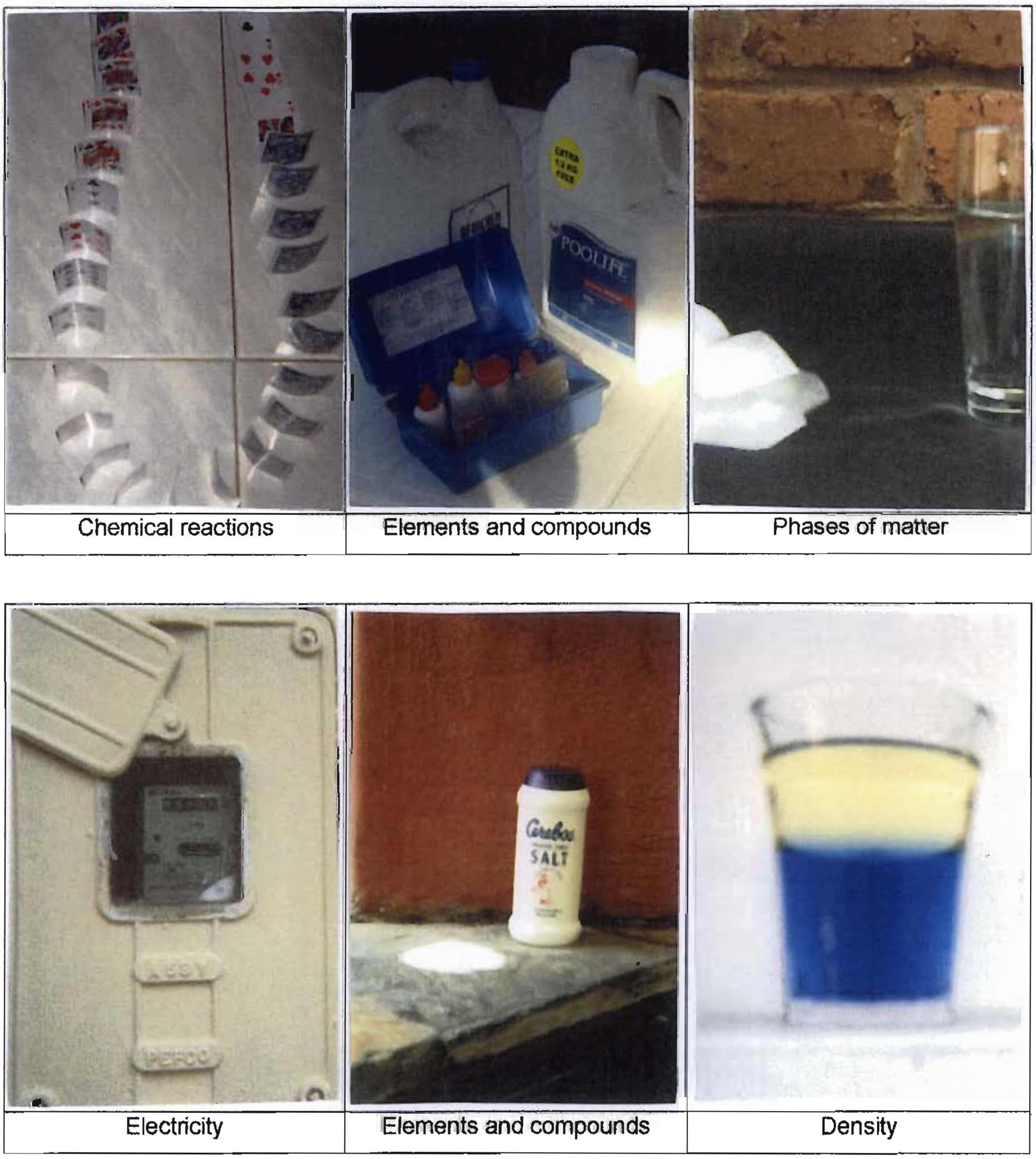
Grade 11 learners had studied the following Physical Science content-based topics during the 2002 academic year: waves, light, writing formulae, naming compounds, balancing equations, the periodic table, the mole, chemical calculations, chemical bonding, intermolecular forces, kinetic theory (solids, liquids and gases), solutions, redox reactions, sulphur, nitrogen, halogens, vectors, graphs of motion and equations of motion. Grade 11 learners did not study Biology during the 2002 academic year.

A summary of the images depicting school science topics learners elected to photograph is presented in Table 4-9.

Table 4-9 Photographs of school science topics

Sub-categories within the broad category of school science topics	Grade 8			Grade 9			Grade 10			Grade 11			TOTAL
	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	
Elements & compounds	10	7	17	4	7	11	5	3	8	6	7	13	49
Chemical Reactions	8	10	18	2	2	4	6	4	10	3	2	5	37
Electricity	2	3	5	5	3	8	7	7	14	0	4	4	31
Phases of matter	4	5	9	3	1	4	0	1	1	2	0	2	16
Waves, light & sound							4	1	5	3	2	5	10
Energy				4	2	6	1	0	1	2	0	2	9
Force				2	0	2	0	1	1	2	3	5	8
Plants	4	2	6										6
Animals	4	0	4										4
Density	0	3	3							0	2	2	5
Chemical bonding							2	0	2				2
Static electricity				1	0	1							1
TOTAL	32	30	62	21	15	36	25	17	42	18	20	38	178

Grade 8 photographs of school science topics. Although Biology comprised half of the Natural Science course, Grade 8 learners only produced 10 photographs directly related to Biology, whilst 52 photographs related directly to Physical Science topics. Grade 8 learners produced the most photographs of school science topics (64% of Grade 8 photographs of science). These learners captured images of chemical reactions, elements and compounds and phase change most frequently. Figure 4-1 depicts some Grade 8 photographs.



Chemical reactions | Elements and compounds | Phases of matter

Electricity | Elements and compounds | Density

Figure 4-1 Grade 8 photographs of school science topics

Grade 9 photographs of school science topics. At the time of data collection this class was learning Biology. Grade 9 learners did not take any photographs directly related to Biology topics. Grade 9 photographs directly related to Physical Science topics accounted for 50% of their photographs of science. These learners generated the fewest photographs in this category, with images of elements and compounds, electricity and energy captured most frequently. Figure 4-2 illustrates some of the photographs taken by Grade 9 learners.

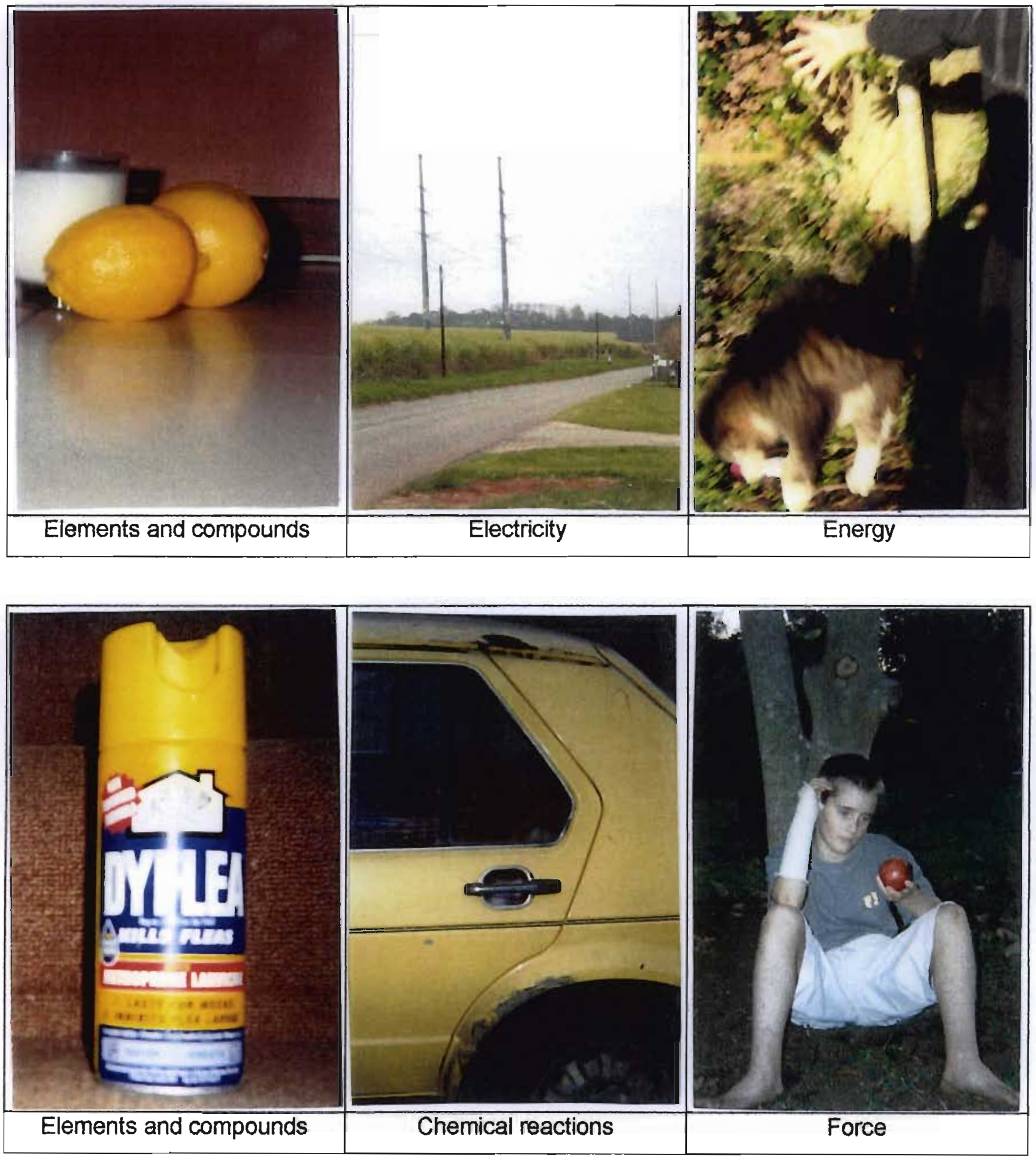


Figure 4-2 Grade 9 photographs of school science topics

Grade 10 photographs of school science topics. Photographs of school science topics comprised 57% of Grade 10 photographs. The images captured most frequently were of electricity, chemical reactions and elements and compounds. Figure 4-3 depicts some of the Grade 10 photographs.

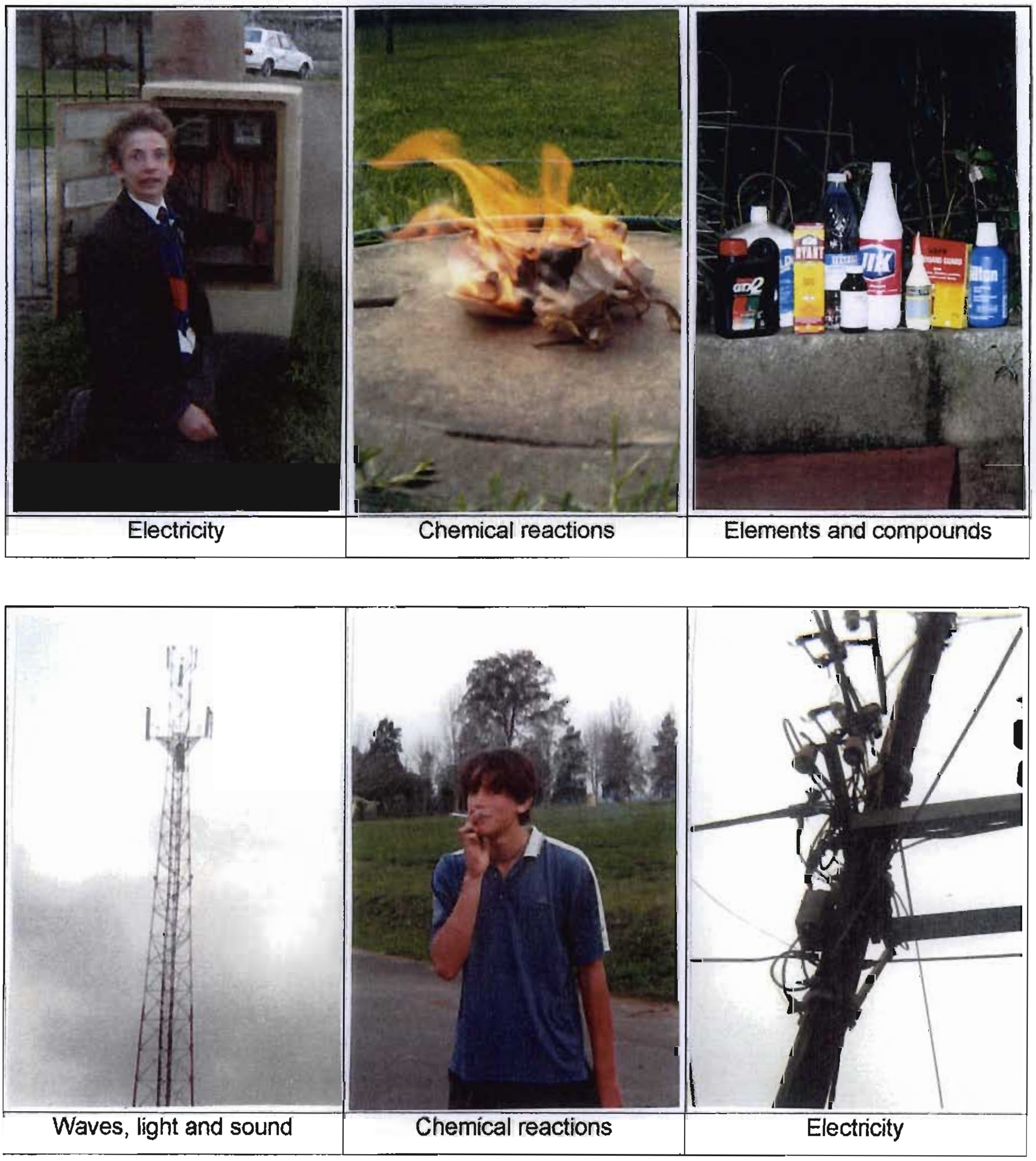


Figure 4-3 Grade 10 photographs of school science topics

Grade 11 photographs of science. Photographs of school science topics comprised 56% of Grade 11 photographs. The images mostly depicted elements and compounds, chemical reactions, waves, light and sound and force. Figure 4-4 illustrates some of their photographs.

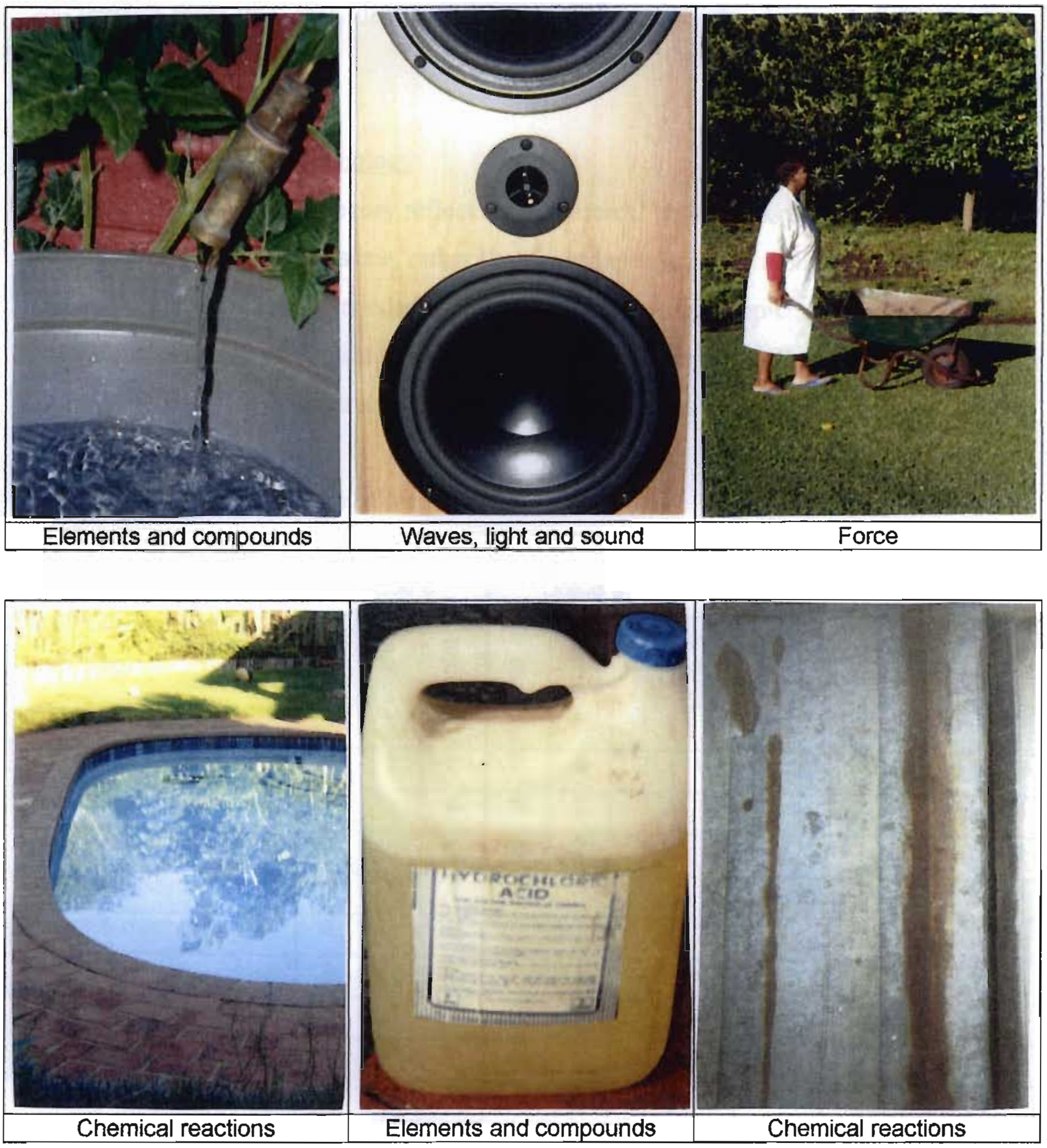


Figure 4-4 Grade 11 photographs of school science topics

Photographs of school science topics – gender differences. The photographs of school science topics appeared to have been marginally influenced by the photographer's gender. Of all the photographs of science taken by males, 59% depicted school science topics, whilst

55% of the photographs of science taken by females depicted school science topics. There was a marginal gender difference in the topics learners chose to photograph, but both males and females most frequently depicted elements and compounds, chemical reactions and electricity.

4.4.5 <u>Photographs of technology</u>

The photographs in this category reflect some learners' perceptions that science and technology are one and the same, rather than interdependent. For a photograph to be placed in this category, the learner needed to indicate the photograph depicts technology, and (erroneously) therefore depicts science. The photographs of technology are summarized in Table 4-10. Figure 4-5 illustrates a selection of photographs that typify this category.

Table 4-10 Photographs of technology

Sub-categories within the broad category of technology	Grade 8			Grade 9			Grade 10			Grade 11			TOT. L
	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	
Cars and motorbikes	4	2	6	2	0	2	6	1	7	3	5	8	23
Computers	3	3	6	6	2	8	3	0	3	3	1	4	21
Cellphones & telephone				2	2	4	1	3	4	0	1	1	9
Hi-fi & speakers	0	1	1				1	0	1	3	2	5	7
Motors & machines	2	3	5				1	0	1				6
Television	1	0	1				2	0	2	1	0	1	4
CD and LP				0	1	1	0	2	2				3
Meters	0	3	3										3
Bicycle	0	1	1				1	0	1				2
Manufactured materials				1	0	1	1	0	1				2
Remote control				0	1	1							1
Microwave	0	1	1										1
TOTAL	10	14	24	11	6	17	16	6	22	10	9	19	82

Figure 4-5 Photographs of technology learners claimed depicted science

Photographs of technology. Photographs of technology made up 25% of Grade 8 photographs of science. Cars, car engines, computers and motors or machines were photographed most frequently. Grade 9 learners captured images of technology in 24% of their photographs of science. They photographed computers, cellphones and telephones most frequently. Photographs of technology made up 30% of Grade 10 photographs of science. These learners photographed cars, car engines, cellphones and computers most frequently. Grade 11 learners depicted images of technology in 28% of their photographs of science. They frequently photographed cars, motorbikes, car engines, hi-fi's and computers.

Photographs of technology – gender differences. Males generated more photographs of technology than females. In this study, 29% of the photographs of science taken by males were images of technology, whilst 23% of the photographs of science taken by females depicted technology.

4.4.6 Photographs of the nature of science

For a photograph to be placed within this category, the learner needed to explicitly mention an aspect of the nature of scientific inquiry, the nature of science knowledge or the interaction between science and society. A summary of the photographs of the nature of science is presented in Table 4-11.

Table 4-11 Photographs of the nature of science

Sub-categories within the broad category of nature of science	Grade 8			Grade 9			Grade 10			Grade 11			TOTAL
	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	Male	Female	Subtotal	
Scientific inquiry													
Science proceeds through controlled testing of ideas	2	1	3	0	3	3	2	0	2	1	0	1	9
Science is an ongoing investigative process	1	0	1	0	4	4							5
Scientific knowledge													
Science is a way of understanding the natural world	1	5	6	2	4	6	2	4	6	1	5	6	24
Science is a body of knowledge							1	0	1	2	1	3	4
Science knowledge changes over time				0	1	1	1	0	1				2
Science proceeds slowly										1	0	1	1
The interaction between science and society													
Science is both helpful and harmful				2	2	4							4
Science is a human activity				0	1	1							1
Science is cultural heritage	1	0	1										1
TOTAL	4	7	11	4	15	19	6	4	10	5	6	11	51

Due to the abstractness of this category, most photographs of the nature of science were simply pieces of photographic art if not viewed within the context of the explanation provided in the report sheet. The discussion that follows therefore includes descriptions of each photograph together with the explanation of why the photograph represented science.

The nature of scientific inquiry. In this study 14 photographs depicted the nature of scientific inquiry. Some of these photographs are illustrated in Figure 4-6.

Burning candle	Microchemistry kit	Experiment

Sky	Medicines	Experiment

Figure 4-6 Photographs of the nature of scientific inquiry

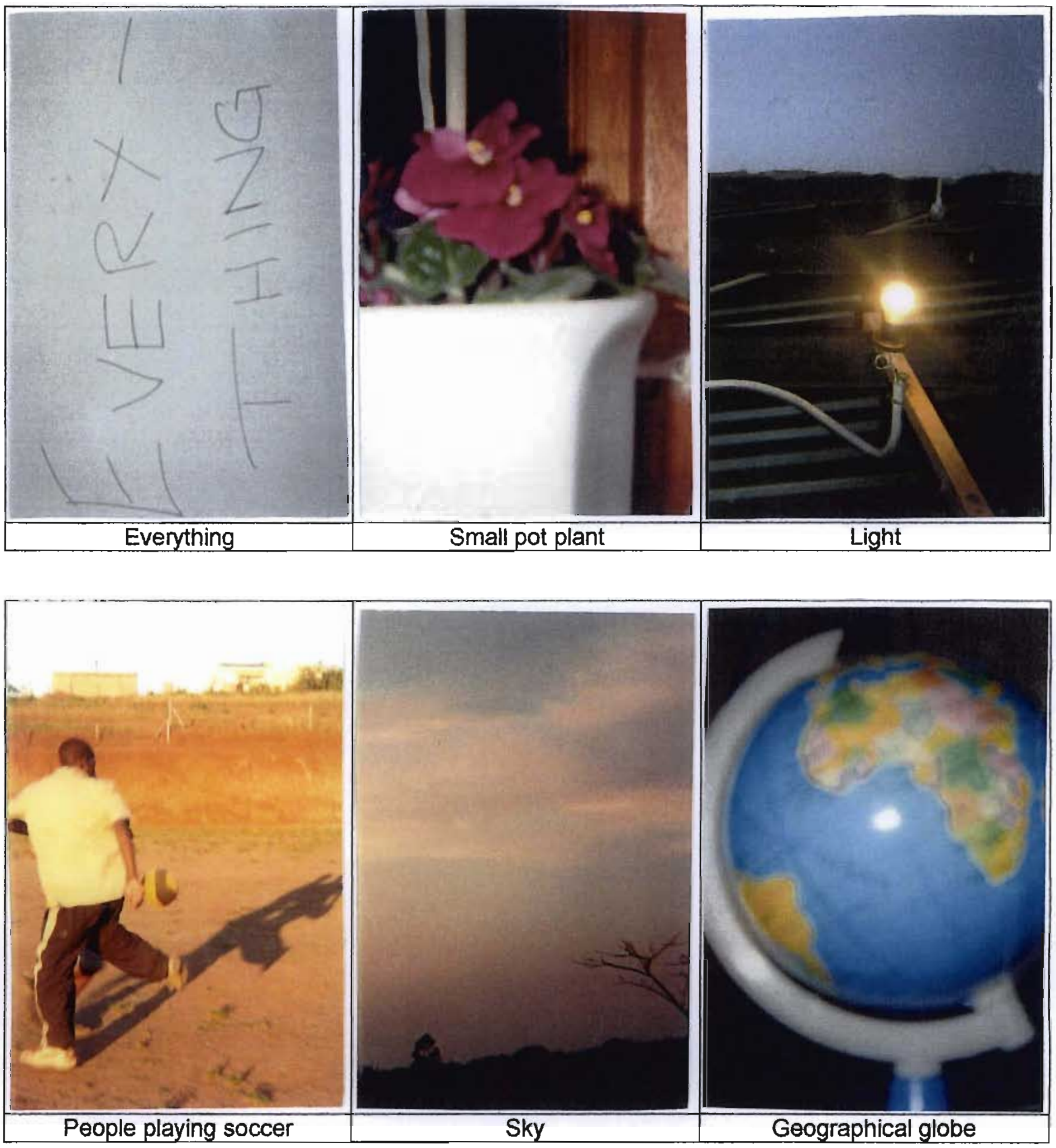
Grade 8 learners took four photographs that depicted the nature of scientific inquiry. One photograph was of tools, another was of household items set up in such a way as to collect a gas using the downward displacement of water and a third photograph was of a dead pot plant surrounded by lush green grass. The explanation for each of these photographs was that science used "controlled experiments" to "test ideas". The fourth photograph was of a collection of medicines. This image was explained as: "Scientists are continually developing new medicines by performing lots of experiments and scientific calculations. Science is a continual process of finding out new things".

Seven Grade 9 learners took photographs depicting the nature of scientific inquiry. Two learners photographed items arranged to look like an experiment, whilst one learner photographed a burning candle. The explanations for these photographs were given as science is about "experimenting" and "controlling variables in experiments". Two learners captured images of medicines and the explanations for these photographs were: "Science continuously seeks answers" and "Science is about scientists trying to find new solutions to old problems". One learner photographed the sky and offered this explanation: "Science is about trying to find out some of the many things we don't understand about our Universe". One learner photographed the report sheet (Appendix B) used in this study and provided the following explanation: "Science is about continually finding out some of the answers to the many questions we have about life and daily living".

One Grade 10 learner photographed a large mouth bass that he had caught and preserved. He claimed he took the photograph because in his open-ended investigation he had tested the strength of rubbers used to make artificial lures: "Science is about using controlled experiments to test ideas". Another Grade 10 learner photographed a microscope. The accompanying explanation was: "Science is about experimenting and finding answers to questions. This is an example of apparatus used to help find answers".

One Grade 11 learner photographed a microchemistry kit. The explanation of the photograph was: "Science is about theories. The purpose of an experiment is to test a theory".

The nature of science knowledge. In this study, 31 photographs depicted the nature of science knowledge. Some of these photographs are presented in Figure 4-7



Everything | Small pot plant | Light

People playing soccer | Sky | Geographical globe

Figure 4-7 Photographs of the nature of science knowledge

Grade 8 learners contributed six photographs to this category. Two learners took photographs of people talking and claimed this represented things in nature "getting along" or "interacting". They claimed science helps us understand how things in nature get along. Two learners photographed gardens and a further two learners photographed the sky. The explanation for these photographs was that these were representations of "the natural world" or "the world around us", and science is about "understanding our natural world".

Grade 9 learners captured seven images of the nature of science knowledge. These photographs varied considerably. Two learners photographed a garden, one learner photographed a geographical globe of Earth and one learner photographed a tableaux of a bird, flowers and a sign with 'the world around us' written on it. Each learner claimed that the image represented either "the natural world" or the "world around us". Each photograph was explained using the phrase: "Science is one way of understanding our natural world". One learner photographed a light bulb hanging from the ceiling. The explanation of the photograph was: "Science is the study of our surroundings, and light surrounds". When the learner was interviewed he explained that the image of light was an analogy for the term 'surroundings'. One learner photographed two boys playing soccer and described this as "representing the way things interact". The explanation was given as: "Science is about finding out how things in the world work". One learner photographed an electricity pylon. The explanation was given as: "This shows how our understanding of electricity has developed from the days of Thomas Edison".

Grade 10 learners took eight photographs that depicted the nature of science knowledge. One learner described the photographs as: "The view from my bedroom window" and claimed: "This represents our environment and there is not one thing in our environment that is not governed by some scientists' law". During the interview, this learner maintained the view that nature obeyed scientific laws. Another learner photographed the view across the Valley of 1000 hills and claimed the photograph represented the natural world. The explanation for this photograph was: "Science helps us to understand our natural world". Two learners photographed their gardens. They explained science as: "One way of studying the natural world" and "One way of understanding our surroundings". Two learners photographed larva lamps. They claimed: "Science is able to provide explanations for why the colours don't mix" and "Somewhere in some science book will be the explanation for why the lamp bubbles and the substances don't mix". One learner photographed a science book and wrote: "Science is made up of lots of facts about our world". One learner photographed a clock and provided the following explanation: "Science slowly changes over time".

Grade 11 learners provided ten photographs in this category. Three learners photographed gardens and one learner photographed a sunrise. Each of these photographs were described as photographs of: "the world", "the world around us" or "the Universe". The accompanying explanations claimed science provides a way of understanding the natural world. Two learners photographed signs they had made. One learner had written the word "Everything" and claimed: "Science can find out everything". When this learner was interviewed the view that science could and would provide the solutions to all problems was maintained. Another learner had written the word "Anything" on cardboard and claimed: "Anything in the Universe can be traced back to science". During the interview, this learner maintained the Universe obeys the laws of science, so all phenomena could be traced back to some science law or theory". Two learners photographed their science files and explained science was a "huge collection" of "facts, laws and theories". One Grade 11 learner photographed a large green tree. The description read: "A large and fully developed tree". During the interview, the learner explained that this photograph was an analogy: Science knowledge was vast (hence the large tree) and most of what there was to know, science had already found out (hence the fully developed tree). Another Grade 11 learner photographed a small pot plant. This learner described the photograph as: "A small plant in the process of growing". The accompanying reason was: "It is symbolic of the way science grows – very slowly".

The interaction between science and society. In this study six photographs depicted the interaction between science and society. There were no Grade 10 or Grade 11 photographs in this category and only one Grade 8 learner provided a photograph for this category. This photograph depicted science as a non-western cultural heritage and was described as: "A rural version of a lightning conductor – a rubber car tyre on the roof". This explanation was given as: "The lightning will not strike the house because of the rubber tyre. This has been going on for a very, very long time". During the interview, this learner was adamant that the 'African lightning conductor' was a more tested and far superior lightning conductor to 'the tall poles used by Whites'. The other five images of the interaction between science and society were provided by Grade 9 learners: Two photographs depicted medicines and the photographers claimed science was 'helpful' when drugs were used to heal, but 'harmful' when scientists develop recreational drugs. One photograph was of an electricity meter and another of a light bulb. The explanation for these photographs was that science is 'able to make a difference' in the way people live their lives. One Grade 9 learner described science as a human activity. This learner photographed her mother. She claimed: "Humans created science . . . and if you think about it, science might create humans. I don't think this [cloning] is such a good idea". A selection of these photographs is provided in Figure 4-8.

Lightning conductor	Drugs	Human

Figure 4-8 Photographs of the interaction between science and society

Photographs of the nature of science – gender differences. Photographs representing the nature of science made up 12% of the photographs of science taken by males, whereas 21% of the photographs taken by females depicted the nature of science. Females captured 57% of the photographs of the nature of scientific inquiry generated in this study, whilst males captured 43% of these images. Females generated 65% of the photographs depicting the nature of science knowledge, whilst males captured 35% of these images. There was no gender difference in the photographs representing the interaction between science and society, with males and females each generating 50% of the images.

4.4.7 Learners' photographs of science – a discussion of the findings

Recognition of science concepts learned at school within the context of daily lives. The findings of this study indicate that the science knowledge learned in science lessons held significance for learners within the context of their daily lives. This is evident in that 58% of the photographs of science depicted images of school science topics learned during science lessons. These findings support the findings of Settlage (2000): "The science learned within the classroom held significance for the children in their daily lives. Several of the students revealed in their photographs a recognition of science concepts as they occurred in and around their homes" (p.10).

Blur between science and technology. The findings of this study also point towards a blur between learners' perceptions of science and their perceptions of technology. In this study, 26% of the photographs of science were photographs of technology and not of science, as claimed by learners. Settlage also notes similar findings. He comments: "Half of the student photographers included an electronic device as an example of science" (p.10). The findings of this study confirm the findings of Carey et al,(1989) who notes students perceive the product of scientific inquiry to be inventions, rather than knowledge and Duveen, Scott and Solomon (1993) who indicate that learners may well perceive scientific knowledge progress is attributed entirely to technological improvements.

Learners' perceptions of the nature of science. Settlage writes of his research: "There were almost no pictures representing science as a process" (p.10). He writes: "This population seems to perceive science as something to be studied and not something that they themselves do" (p.5). Although the same could be said of this study, as there were no photographs of learners doing science themselves, the findings of this study do indicate some learners perceived science to be more than just the science concepts making up the content of school science topics. Attempts to depict the nature of science were evident in 16% of the 311 photographs of science. An interpretation of the 14 images of the nature scientific inquiry captured by learners in this study, revealed learners perceived science to be a continual process of inquiry that proceeds through the testing of ideas by means of controlled experiments. Learners' perceptions of the nature of science knowledge were evident in 31 photographic images. An interpretation of these images revealed these learners perceived science knowledge to change slowly over time, a way of explaining natural phenomena and a way of understanding the natural world. However, the empirical views of learners surfaced in that some learners perceived science knowledge to be a vast collection of facts uncovered through scientific inquiry, and scientific laws and principles were so absolute that even nature was compelled to obey them! These findings concur with those of Wilson (1954) and Mead and Metraux (1957), who claimed learners believed the primary purpose of scientific activity was to uncover natural laws and truths, and support those of

Duveen, Scott and Solomon (1993), who claim many learners regard science to be a fact collecting process and the purpose of experiments is to uncover yet more facts, leaving little room for either speculation or explanation – the most naive form of empiricism.

In this study six photographs depicted the interaction between science and society. These photographs provided some indication that some learners in this study acknowledged that science is a human activity in which all cultures participate. These images also revealed some learners perceive science to affect and be affected by society and some scientific developments can conflict with moral and ethical values.

4.4.8 Learners' photographs of science – a brief summary

The photographs of science revealed the science knowledge learned in science lessons held significance for learners within the context of their daily lives. The numerous photographs of technology revealed the learners in this study perceive technological inventions (rather than science knowledge) to be the product of scientific inquiry and point towards a blur between learners' perceptions of science and their perceptions of technology. Learners' perceptions of the nature of science as revealed by the images captured photographically include: Science is a continual process of inquiry that proceeds through the systematic testing of ideas. The body of science knowledge changes slowly. Science is a human activity in which all cultures participate. Science affects and is affected by society, and some scientific developments may conflict with moral and ethical values of groups within society. These views are reflective of the scientific community. However, the photographs of science also revealed some learners held empirical views of science and regard the purpose of scientific activity as a process of uncovering facts, laws and truths, with little room for speculation.

4.5 SCIENCE THROUGH THE CAMERA LENS – SOME LEARNERS' PERCEPTIONS OF SCIENCE - A SUMMARY OF THE FINDINGS OF THIS STUDY

4.5.1 What are learners' perceptions of the nature of science ?

Based on the questionnaire findings and the learners' photographs of science, the learners in this study share the following perceptions of the nature of science with the scientific community: Science proceeds slowly. Scientific inquiry involves the cyclic, systematic testing of ideas by means of controlled experiments. The questionnaire findings revealed the learners in this study acknowledge new theories do not simply replace existing theories and new science knowledge claims are subject to peer scrutiny. The photographs of science revealed the learners in this study perceive science to be a human activity in which all cultures participate and science affects and is affected by society. The photographs of science also revealed the learners in this study acknowledge that some scientific developments may conflict with moral and ethical values of groups within society.

However, the questionnaire findings and photographs of science also revealed inadequacies in the learners' perceptions of the nature of science. The questionnaire findings revealed the learners in this study have inadequate perceptions of the role creativity plays in the development of scientific knowledge. These findings are reflected in the photographs of science that revealed learners upheld empirical views of science and perceive the purpose of scientific activity is to uncover facts, leaving little room for imagination and creativity. The questionnaire findings also reveal the learners in this study do not adequately perceive science to be reflective of the supportive community and located within a historical context.

4.5.2 What are learners' perceptions of science within the context of their daily lives?

The photographs of science revealed the science knowledge learned in school held significance for learners within the context of their daily lives and some learners perceived science to be more than just the science concepts making up the content of school science topics. However, the learners in this study do not perceive science and technology as separate entities that pull and push each other in a complex relationship. The photographs of science revealed the learners in this study do not view science knowledge as the product of scientific inquiry. Rather, the learners in this study view the technology they encounter in their daily lives as the product of scientific inquiry.

CHAPTER 5
CONCLUSIONS AND IMPLICATIONS

5.1 SCIENCE THROUGH THE CAMERA LENS – SOME LEARNERS' PERCEPTIONS OF SCIENCE: KEY QUESTIONS FRAMING THIS STUDY

The purpose of this interpretive case study was to determine some South African learners' perceptions of the nature of science and to consider how they might choose to represent their perceptions of science within the context of their daily lives, photographically. Two key questions framed this study: What are learners' perceptions of the nature of science? and What are learners' perceptions of science within the context of their daily lives?

5.2 LIMITATIONS OF THIS STUDY

This interpretative case study is simply an account of attempts to include the nature of science construct within learning programmes and is a snapshot of what has happened in one South African school, a collection of some learners' perceptions of science captured on photographic film and an insight into some learners' perceptions of the nature of science. The findings of this study are therefore not generalizable beyond the boundaries of this case.

5.3 METHODS USED TO PROBE LEARNERS' PERCEPTIONS

To probe learners' perceptions of the nature of science, learners were asked to complete a cartoon-style questionnaire by marking a rating on a seven-point semantic differential rating scale. To map out more fully learners' perceptions of the nature of science and probe learners' perceptions of science within the context of their daily lives, learners were asked to take photographs of what they perceived as science beyond the boundaries of the classroom. Each photograph of science was examined within the context of why it represented science. Similar photographs of science were grouped together and by means of a process of systematic network analysis, three broad categories emerged: photographs of school science topics, photographs of technology and photographs of the nature of science. The questionnaire responses and photographs of the nature of science were analyzed and interpreted using a framework of analysis based on three groupings: learners' perceptions of the nature of scientific inquiry, learners' perceptions of the nature of science knowledge and learners' perceptions of the interaction between science and society.

5.4 LEARNERS' PERCPETIONS OF THE NATURE OF SCIENCE

The learners' mean response to the questionnaire statements, when viewed co-jointly with the photographs of the nature of science, provided a useful means of comparing the views of science common to the scientific community (Collins et al., 2001) with the views held by the learners in this study. The findings of this study indicate views of science common to the scientific community, and shared by the learners in this study (evident in learners' questionnaire responses and photographs) include: Science proceeds slowly; Scientific inquiry involves the cyclic, systematic testing of ideas by means of controlled experiments; New science knowledge claims are subject to peer scrutiny and; new theories do not simply replace existing theories. The views of science common to the scientific community and partly shared by the learners (evident in either the photographs of science or the questionnaire responses) include: Science is a human activity in which all cultures participate; Science affects and is affected by society and; scientific developments may conflict with moral and ethical values of groups within society. However, the findings of this study also revealed some dissonance between the learners' perceptions of the nature of science and the views common to the scientific community (evident in both the questionnaire responses and photographs). Learners have inadequate perceptions of the role creativity plays in the development of scientific knowledge. The learners in this study tend to uphold empirical views of science and perceive the purpose of scientific activity is to uncover facts, leaving little room for imagination or speculation. The findings also indicate that learners in this study do not adequately perceive science to be reflective of the supportive community and located within a historical context.

5.5 LEARNERS' PERCEPTIONS OF SCIENCE IN THE CONTEXT OF THEIR DAILY LIVES

The findings of this study indicate that science knowledge learned within the classroom held significance for learners within the context of their daily lives. Whilst the findings of this study seem to indicate learners perceive science as something to be studied, rather than something that they themselves do, there is some evidence that suggests some learners perceive science to be more than just science concepts making up school science topics. The findings of this study point towards a blur between learners' perceptions of science and their perceptions of technology and suggest that learners perceive technology, rather than science knowledge to be the outcome of scientific inquiry.

5.6 HOW DOES THIS STUDY CONTRIBUTE TO THE EXISTING LITERATURE?

The findings of this study lend some support to the claims of Wilson (1954), Mead and Metraux (1957), Miller (1963), Mackay (1971), Bady (1979), Lederman (1992), Duveen, Scott and Solomon (1993) and Settlage (2000) that learners' understanding of the nature of science is inadequate. Further research of South African learners' perceptions of the nature of science would provide an indication of whether the findings of this study are only true of the learners at this school.

This study lends some support to the claims of Reddy (1998), Solomon (1999), and Rogan (2003) that putting curriculum theory into classroom practice always proves more difficult than it sounds. Despite attempts to include the study of the nature of science, the views of the nature of science underpinning the Natural Sciences as shared by the scientific community and outlined by Curriculum 2005, are only partially reflected in Grade 8 and 9 learners' photographs and questionnaire responses. Furthermore, whilst some attempts were made to implement Curriculum 2005 at this school, the content laden previous curriculum still prevailed and this study is a grassroots account of attempts to implement Curriculum 2005 in a school that resisted curriculum change. I suspect that this school is one of many that are not implementing Curriculum 2005 as intended.

Hodson (1992) claims that an individual educator's views about science and scientific inquiry constitute a major factor in determining the hidden curriculum, which in turn impacts substantially on learners' views. This study, whilst not challenging Hodson's claims, casts a different hue on his statement. The findings of this study indicate the learners in Grade 10 appeared to hold perceptions of the nature of science different to those of the other grades. The common factor in this study was the educator – I taught each class and to the best of my knowledge my views of the nature of science had similar impacts on the hidden curriculum experienced by each grade. The inclusion of a lengthy Grade 9 unit of learning that explicitly dealt with the nature of science did appear to positively impact on learners' perceptions of science as these learners produced the most photographs depicting the nature of science. These findings lend support to the claims of Driver (1989) and Sutton (1989) that learning science should involve an explicit initiation into the culture of science. The findings of this study also support the claims of Driver (1983), that it is as important to consider and understand learners' own ideas as it is to present new ideas and Driver (1989) that although educators may intend to introduce learners to certain ideas, it is in the end the learners who have to think through and make sense of the experience themselves. The findings of this study provide some evidence to suggest that activities designed for the study of the nature of science need to be formally and thoughtfully planned. The study of the nature of science is a new focus for South African science education and further research of suitable learning activities aimed at enhancing South African learners' views of the nature of science is needed.

Settlage (2000) and Carey et al. (1989) claim learners consider scientific inquiry and technological activity to be equivalent. The findings of this study also point towards a blur between learners' perceptions of science and their perceptions of technology. The findings of this study provide some evidence that a unit of learning that explicitly deals with the relationship between science and technology should be included in learning programs. However, this needs further research, as the focus of this study was learners' perceptions of science and learners' perceptions of technology were not explored in this study.

5.8 CONCLUSION

Majara and Raubenheimer (1997) claim when educators conduct research in their own schools and document their experiences, they grow professionally and improve their practice. This study bears testament to their claim. Whilst the primary purpose of this study was to probe learners' perceptions of science, I have also had to re-examine my own perceptions of the nature of science and re-consider the type of activities I use in learning programs that include the study of the nature of science.

The value of this study is therefore twofold: Firstly, this study provides a snapshot in time of learners' perceptions of science at the cusp of curriculum change and is a grassroots account of what actually happened in one South African school, thereby contributing to an archive of South African nature of science literature. Secondly, this study has prompted me to reflect upon my classroom practice and bring about change both in myself and in my classroom.

Apologizing for the obvious metaphor, this study supplied a unique lens for viewing some learners' perceptions of the nature of science, some learners' perceptions of science within the context of their daily lives and some attempts to include the study of the nature of science in learning programs at a time of curriculum change.

REFERENCES

Ausubel, D. (1968). *Educational Psychology: A cognitive view.* London: Holt.

Bady, R.A. (1979). Students' understanding of the logic of hypothesis testing. *Journal of Research in Science Teaching*, 16(1), 61-65.

Bowtell, E. (1996). Educational stereotyping: Children's perceptions of scientists: 1990's style. *Investigating: Australian Primary and Junior Science Journal*, 12(1), 34-37.

Carey, S., Evans, R., Honda, M., Jay, E. and Unger, C. (1989). An experiment is when you try it and see if it works. *International Journal of Science Education*, 11(2), 514-529.

Chalmers, A.J. (1982). *What is this thing called Science?* (2nd ed.). Cambridge: Open University.

Chambers, D.W. (1983). Stereotypic images of the scientist: The Draw-A-Scientist test. *Science Education*, 67, 255-256.

Cobern, W.W. (1995). Constructivism for science teachers. *Science Education International*, 6(3), 8-12.

Cohen, L. and Manion, L. (2000). *Research Methods in Education* (5th ed.). London: Falmer Press.

Collins, S., Osborne, J., Ratcliffe, M., Millar, R. and Duschl, R. (2001). *What 'ideas about science' should be taught in school science? A Delphi study of the expert community.* Paper presented at the Annual Conference of the American Educational Research Association, Seattle.

Department of Education, (1997a). *Curriculum 2005 – Lifelong learning for the 21st Century.* Pretoria: Author.

Department of Education, (2002b). *Revised National Curriculum (Draft) Statement.* Pretoria: Author.

Department of Education, (2002c). *Revised National Curriculum Statement Grades R-9 (Schools) Policy.* Pretoria: Author.

Department of Education, (2002d). *Curriculum 2005 Assessment Guidelines: Natural Sciences, Senior Phase.* Pretoria: Author.

Dlamini, B. (1997). *Why do science as a school subject. High school student's views.* In Saunders, M. (Ed.), Proceedings of the Fifth Annual Meeting of the Southern African Association for Research in Mathematics and Science Education, University of Witwatersrand. (pp99-105). Johannesburg: SAARMSTE

Driver, R. (1983). *The Pupil as scientist?* Milton Keynes: The Open University Press.

Driver, R. (1989). The construction of scientific knowledge in school classrooms. In Millar, R. (Ed.) *Doing Science* (pp.83-105). London: The Falmer Press.

Driver, R., Leach, J., Millar, R. and Scott, P. (1996). *Young peoples' Images of science*. Buckingham: Open University Press.

Duveen, J., Scott, L and Solomon, J. (1993). Pupils' understanding of science: description of experiments or 'a passion to explain'. *School Science Review*, 75(271), 19-27.

Edwards, B. (1980). *The Readable Maths and Statistics Book*. London: Allen and Unwin.

Hannagan, T.J. (1982). *Mastering Statistics*. London: Macmillan Press.

Hitchcock, G. and Hughes, D. (1995). *Research and the Teacher*, (2nd ed.). London: Routledge.

Hodson, D. (1982). Is there a scientific method? *Education in Chemistry*, 7(5), 113-116.

Hodson, D. (1993a). Teaching and learning about science: consideration in the philosophy and sociology of science. In D. Edwards, E. Scanian & D. West (Eds.), *Teaching, Learning and Assessment in science education* (pp5-32). London: Open University.

Hodson, D. (1993b). In search of a Rationale for Multicultural Science Education. *Science Education*, 77(6), 685-711.

Hodson, D. (1999). Critical Multiculturalism in Science and Technology Education. In May, S. (Ed.) *Critical Multiculturalism: Rethinking Multicultural and Antiracist Education* (pp217-238). London: Falmer Press.

Hopkins, K.D., Hopkins, B.R. and Glass, G.V. (1996). *Basic Statistics for the Behavioral Sciences*, (3rd ed.). Boston: Allyn and Bacon.

Jansen, J. (1999). The school curriculum since apartheid: intersections of politics and policy in the South African transition. *Curriculum Studies*, 31(1), 57-67.

Lederman, N.G. (1992). Students' and Teachers' Conceptions of the nature of science: A Review of the research. *Journal of Research in Science Teaching*, 29(4), 331-359.

Lederman, N.G., Abd-El-Khalick, Bell, R.L. and Schwartz, R.S. (2002). Views of Nature of Science questionnaire: Towards valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(1), 497-521.

Mackay, L. (1971). Development of understanding about the nature of science. *Journal of Research in Science teaching*, 8(1), 57-66.

Majara, K and Raubenheimer, D. (1997). *Reflections on teachers as researchers.* In Saunders, M. (Ed.), Focus on the learner, Proceedings of the Fifth Annual Meeting of the Southern African Association for Research in Mathematics and Science Education, University of the Witwatersrand. Johannesburg: SAARMSTE.

Mead, M. and Metraux, R. (1957). Image of the scientist among high school students. *Science*, 126(1), 384-390.

Merriam, S.B.(1988). *Case Study Research in Education*. San Francisco: Jossey Bass.

Millar, R. (1989). Introduction: Science Education and Science Studies. In Millar, R. (Ed.) *Doing Science* (pp.1-9). London: The Falmer Press

Millar, R. (1996). Towards a science curriculum for public understanding. *School Science Review*, 77(280), 7-18.

Miller, P.E. (1963). A comparison of the abilities of secondary teachers and students of biology to understand science. *Iowa Academy of Science*, 70(8), 510-513.

Mouly, G. (1978). *Educational Research: the Art and Science of Investigation*. Boston: Allyn and Bacon.

National Department of Education (1997). *Curriculum 2005 – Lifelong learning for the 21st centiury.* Pretoria: Author.

Nisbet, J. and Watt, J. (1984). *Conducting Small-scale investigations in Educational Management*. London: Harper & Row.

Nordwall, S. (1980). What is science? Some viewpoints form the perspective of the theory of science. *The Nordic Journal for Anthrosophic Medicine*. 1(27), 1-14.

Oppenheim, A. N. (1996). *Questionnaire design and Attitude Measurement.* London: Heinemann.

Osgood, C.E., Suci, G.S. and Tannenbaum, P.H. (1957). *The Measurement of Meaning*. Urbana: University of Illinois.

Reddy, V. (1998). *Relevance and the promotion of equity. African science and technology education into the new millennium: Practice, Policy and Priorities.* South Africa: Juta.

Richardson, M. and Boyle, C. (1979). *What is science? An introduction to aspects of the philosophy and sociology of science*. Hatfield: Association for Science Education.

Roberts, D. (1982). Developing the concept of 'Curriculum emphases' in science education. *Science Education* 66(2), 243-260.

Rogan, J. (2003). *Out of the frying pan ... ? The implementation of Curriculum 2005.* Proceedings of the Eleventh Annual Meeting of the Southern African Association for Research in Mathematics and Science Education. Swaziland: SAARMSTE

Salleh, K. (1997). *Culturalisation of science and technology and its relationship to Islamic thought.* Johannesburg: University of the Witwatersrand.

Schibeci, R.A. (1986). Images of science and scientists and science education. *Science Education*, 70(34), 139-149.

Schofield, J. W. (1993). Increasing the generalizability of qualitative research. In Hammersley, M. (Ed.), *Social Research: Philosophy, Politics and Practice* (pp.200-225). London: Sage.

Settlage, J. (2000). Views of science as represented in urban schoolchildren's photographs. *Electronic Journal of Science Education*, 5(2)

Siraj-Blatchford, J. (1990). What is an antiracist atom? *School Science Review*, 71(257), 127-130.

Solomon, J. (1999). Meta-scientific criticisms, curriculum innovation and the propagation of scientific culture. *Curriculum studies*, 31(1), 1-15.

Sutton, C. (1989). Writing and reading in science: the hidden messages. In Millar, R. (Ed.) *Doing Science* (pp.138-159). London: The Falmer Press.

Swift, D. (1992). Indigenous Knowledge in the service of science and technology in developing countries. *Studies in Science Education*, 21(3), 1-28.

Webb, P, Webb, L, Kurup,R and Cross, D. (2003). *Investigating South African teachers' views of the nature of science: Towards developing appropriate assessment instruments.* Paper presented at TIMSTE Conference, East London.

Wellington, J. (1994). *Secondary science: Contemporary issues and practical approaches*. London: Routeledge.

Wilson, L. (1954). A study of opinions related to the nature of science and its purpose in society. *Science Education*, 38(2), 159-164.

APPENDICES

APPENDIX A QUESTIONNAIRE – VIEWS OF SCIENCE

Name:			
Age in years today:		Date:	

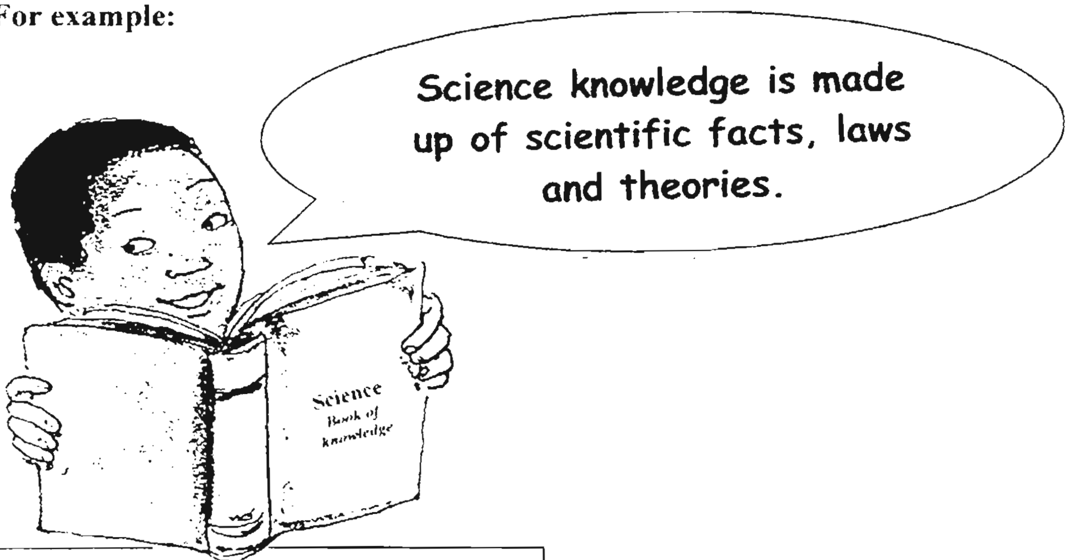
VIEWS OF SCIENCE

- The purpose of this questionnaire is to find out your views of science.
- There are no 'right' or 'wrong' answers.
- Please indicate if you agree or disagree with the views that are expressed by the cartoon figures by using the rating scale given below.

	Agree	Neither agree nor disagree		Disagree
+3	Agree very strongly with the statement		-3	Disagree very strongly with the statement
+2	Agree strongly with the statement	0	-2	Disagree strongly with the statement
+1	Agree with the statement		-1	Disagree with the statement

- Please draw a circle around one of the numbers that are given in the rating scale for each cartoon drawing to indicate your view.

For example:



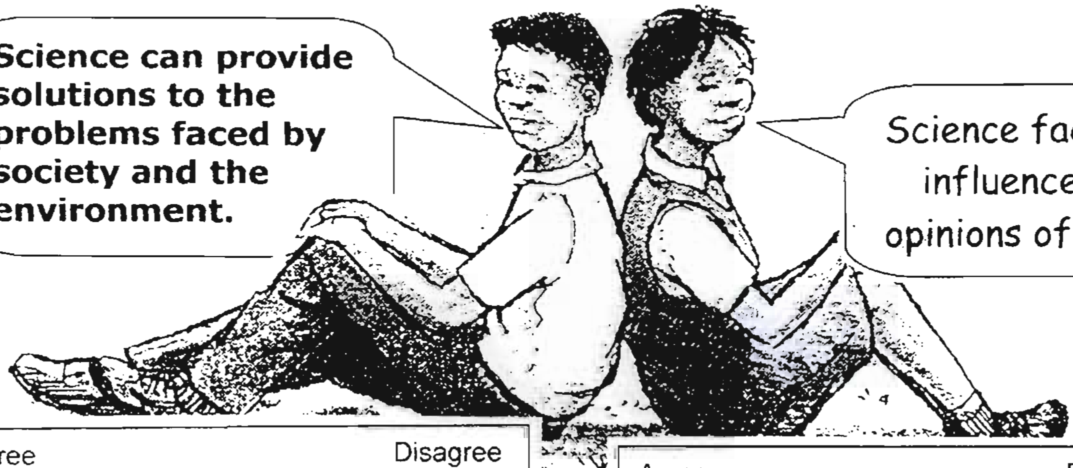
Agree						Disagree
+3	+2	+1	0	1	2	3

Agree						Disagree
+3	+2	+1	0	-1	-2	-3

Agree						Disagree
+3	+2	+1	0	-1	-2	-3

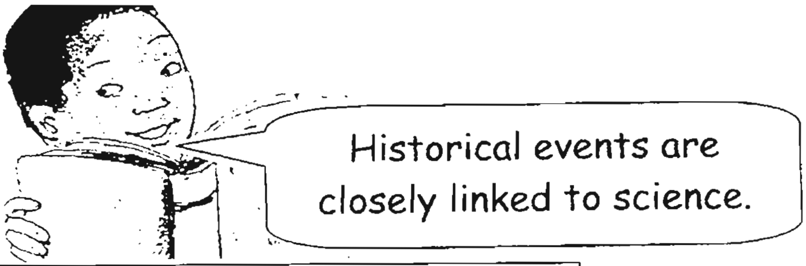
Agree						Disagree
+3	+2	+1	0	-1	-2	-3

Agree						Disagree
+3	+2	+1	0	-1	-2	-3

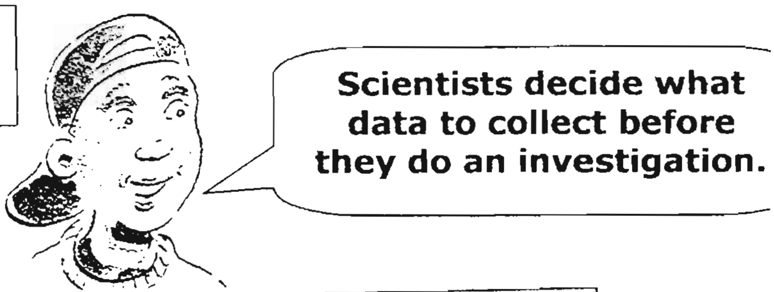


Agree						Disagree
+3	+2	+1	0	-1	-2	-3

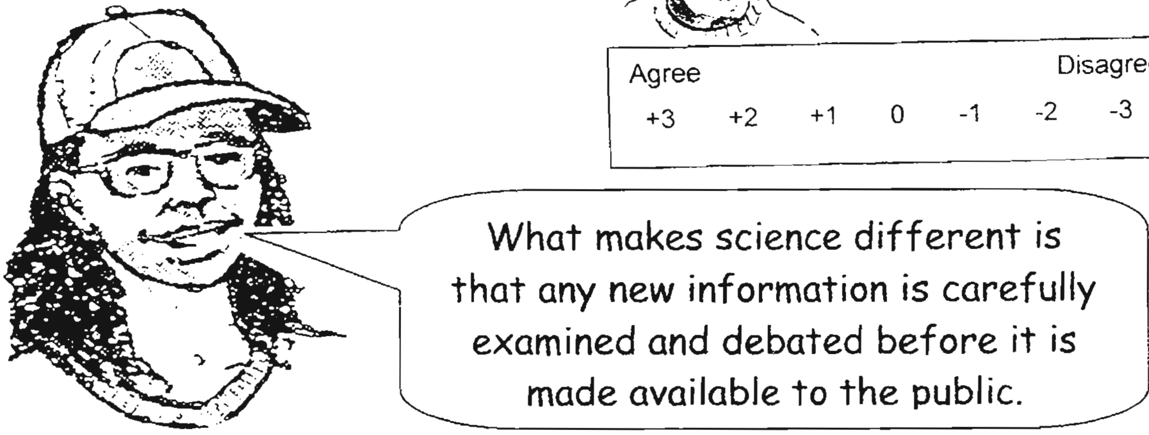
Agree						Disagree
+3	+2	+1	0	-1	-2	-3



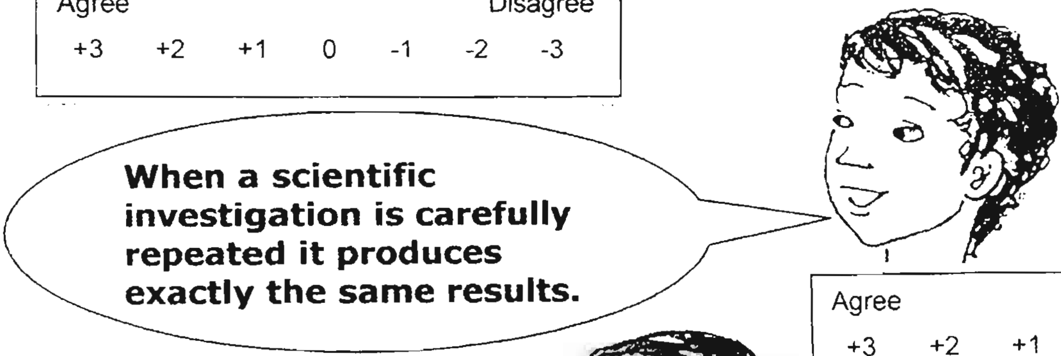
Agree						Disagree
+3	+2	+1	0	-1	-2	-3



Agree						Disagree
+3	+2	+1	0	-1	-2	-3

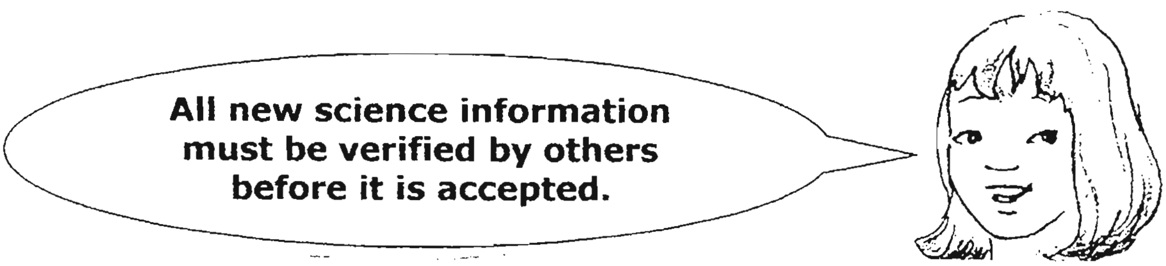


Agree						Disagree
+3	+2	+1	0	-1	-2	-3



Agree						Disagree
+3	+2	+1	0	-1	-2	-3

Agree						Disagree
+3	+2	+1	0	-1	-2	-3



Agree						Disagree
+3	+2	+1	0	-1	-2	-3

Scientist's explanations come partly from what they observe and partly from what they think.

Agree						Disagree
+3	+2	+1	0	-1	-2	-3

There are certain events science will never be able to explain.

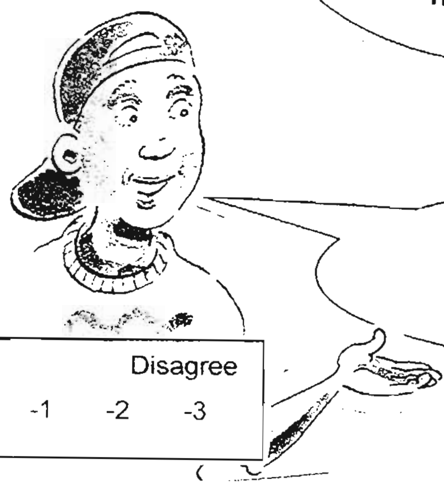
Agree						Disagree
+3	+2	+1	0	-1	-2	-3

Scientists have no idea what will happen in an experiment before they actually do the experiment.

e					Disagree
+2	+1	0	-1	-2	-3

Money and politics do not determine what scientists investigate.

Agree						Disagr
+3	+2	+1	0	-1	-2	-3



When a new theory is proposed, the old theory is quickly 'thrown out'.

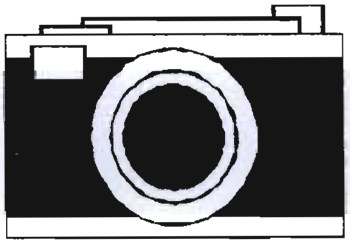
ree						Disagree
3	+2	+1	0	-1	-2	-3

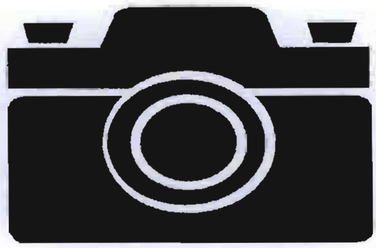
A scientific investigation involves collecting evidence, logical reasoning and imagination.

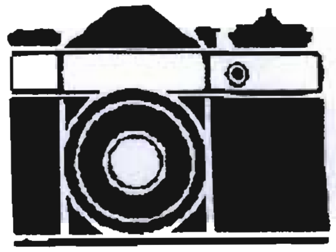
Agree						Disagree
+3	+2	+1	0	-1	-2	-3

APPENDIX B INSTRUCTION SHEET AND REPORT SHEET

SCIENCE THROUGH THE CAMERA LENS







ABOUT THE CAMERA

- You have been given a camera to use. It is NOT WATERPROOF and is not an underwater camera.
- PLEASE LOOK AFTER THE CAMERA. Do not leave it in a desk or bag where it could be stolen.
- If you think there is something wrong with the camera, please bring it back as soon as possible – DON'T OPEN IT!!
- You may only take 4 photographs, so think carefully about what you want to photograph and take your time to take the photograph.
- Once you have taken your 4 photographs, please return the camera.

WHAT TO DO

- The first photograph taken must be a photograph of yourself. When the spool is developed, you will be given this photograph to keep.
- The next 3 photographs you take will be photographs of what you think are good representations of SCIENCE.
- Before you take these photographs stop and think about what you think science is.
- Please take a little time after taking each photograph, to fill in the Report Sheet attached to this page. Try to fill in the report Sheet as soon as you have taken the photograph or you might forget what you photographed!
- PLEASE RETURN THE CAMERA AS SOON AS POSSIBLE AFTER YOU HAVE TAKEN YOUR PHOTOGRPAHS.

REPORT SHEET

PHOTOGRAPH 1

Name: ____

Age in years on day photographs were taken: ______________

PHOTOGRAPH 2

This is a photograph of ....

____
____
____
____
____

I took this photograph because ...

____
____
____
____
____

PHOTOGRAPH 3

This is a photograph of ....

____
____
____
____
____

I took this photograph because ...

____
____
____
____
____

PHOTOGRAPH 4

This is a photograph of . . . .

I took this photograph because . . .

REFLECTION

Did you enjoy this activity ? ______________

Explain your answer.

APPENDIX C QUESTIONNAIRE – VIEWS OF NATURE OF SCIENCE, ELEMENTARY/MIDDLE SCHOOL VERSION

VIEWS OF NATURE OF SCIENCE
ELEMENTARY/MIDDLE SCHOOL VERSION

Name: ______________________________

Date: / / 2002

Instructions:

- **Please answer each of the following questions. You can use all the space provided and the backs of the pages to answer a question.**
- **Some questions have more than one part. Please make sure you write answers for each part.**
- **This is not a test and will not be graded. There are no "right" or "wrong" answers to the following questions. I am only interested in you ideas relating to the following questions.**

1. What is science ?

2. How is science different from the other subjects you are studying?

3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. (a) How do scientists know that dinosaurs really existed?

(b) How certain are scientists about the way dinosaurs looked?

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about these weather patterns?

(b) Why or why not?

6. What do you think a scientific model is?

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?

(a) If NO, explain why.

(b) If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc) do you think they use their imagination and creativity? Give examples if you can.

APPENDIX D ANNOTATED SCORING GUIDE – VIEWS OF NATURE OF SCIENCE, ELEMENTARY/MIDDLE SCHOOL VERSION

VIEWS OF NATURE OF SCIENCE ELEMENTARY/MIDDLE SCHOOL VERSION (ANNOTATED SCORING GUIDE)

EACH QUESTION ON THE FOLLOWING PAGES IS FOLLOWED BY A DESCRIPTION OF WHAT IS BEING ASSESSED AND WHAT IS CONSIDERED TO BE AN ANSWER CONSISTENT WITH REFORM DOCUMENTS AND CONTEMPORARY VIEWS ABOUT SCIENCE. "SCORING' OF ANSWERS IS NOT MEANT TO YIELD A NUMERICAL VALUE, BUT RATHER A DESCRIPTION OF WHETHER THE RESPONDENT HAS THE DESIRED VIEW.

GENERALLY SPEAKING, THE QUESTIONS THAT FOLLOW ARE DESIGNED TO ASSESS STUDENT'S UNDERSTANDING THAT SCIENCE IS TENTATIVE, INVOLVES HUMAN CREATIVITY AND SUBJECTIVITY, NECESSARILY INVOLVES BOTH OBSERVATION AND INFERENCE, IS NOT LIMITED TO A SINGLE APPROACH, AND IS AT SOME POINT EMPIRICALLY-BASED. THE STUDENT IS NOT EXPECTED TO USE THESE WORDS, BUT THEY WILL USE WORDS THAT ARE CONSISTENT OR NOT CONSISTENT WITH THESE IDEAS.

WE FULLY REALIZE THE LIMITATIONS OF INTERPRETING THE WRITTEN WORD, ESPECIALLY WITH YOUNGER STUDENTS. IT IS FOR THIS REASON THAT WE INTERVIEW RESPONDENTS AS WELL AND THAT WE CAUTION YOU AGAINST BASING YOUR RESEARCH FINDINGS JUST ON THE SCORING OF A PAPER AND PENCIL QUESTIONNAIRE.

1. What is science ?

RESPONSE SHOULD INCLUDE REFERENCES TO A BODY OF KNOWLEDGE (OFTEN THE SCIENCE CONTENT STUDENTSA RE CURRENTLY STUYING0 AND PROCESSES (OBSERVING, EXPERIMENTING,ETC) FOR THE DEVELOPMENT OF THIS KNOWLEDGE.

STUDENTS WILL MOST LIKELY NOT REFER TO ANYTHING RELATED TO EPISTEMOLOGY OR CHARACTERISTICS OF THE KNOWLEDGE THAT RESULTS FROM THE PROCESSES.

RARELY DO YOUNG CHILDREN REFER TO SCIENCE AS A "WAY OF KNOWING".

2. How is science different from the other subjects you are studying?

THE DESIRED RESPONSE SHOULD REFER TO RELIANCE ON DATA FROM THE NATURAL WORLS (EMPIRICAL BASIS). SYSTEMATIC OR ORGANIZED APPROACH TO COLLECTION OF DATA. IT IS ALSO COMMON FOR STUDENTS TO FOCUS ON THE SPECIFICSUBJECT MATTER OR OBJECTS OF SCIENCE'S ATTENTION (THIS IS WHERE AN INTERVIEW CAN HELP GET ANSWERS TO WHAT YOU REALLY WANT TO KNOW ABOUT HERE).

STUDENTS ARE LIKELY TO INCORRECTLY STATE THAT SCIENCE FOLLOWS A SINGLE METHOD (THE SCIENTIFIC METHOD) AND THAT SCIENCE IS A TOTALLY OBJECTIVE ENDEAVOR. THEY MOST LIKELY WILL NOT INCLUDE THE ALTERNATIVE TO THESE VIEWS, BUT THE INCORRECT VIEWS ARE COMMONLY INCLUDED.

3. Scientists produce scientific knowledge. Some of this knowledge is found in your science books. Do you think this knowledge may change in the future? Explain your answer and give an example.

THIS QUESTION FOCUSES ON THE IDEA THAT ALL SCIENTIFIC KNOWLEDGE IS TENTATIVE OR SUBJECT TO CHANGE. SO, YOU ARE LOOKING FOR THE STUDENT TO AGREE THAT THE KNOWLEDGE IN THE TEXT WILL PROBABLY CHANGE.

ON A SUPERFICIAL LEVEL, MOST STUDENTS WILL RECOGNIZE THAT KNOWLEDGE CHANGES ECASUE WE NOW KNOW MORE DUE TO ADDITIONAL EXPERIMENTS / INVESTIGATIONS, NEW EVIDENCE OR AVAILABILITY OF NEW TECHNOLOGY. A MORE IN-DPTH, BUT NOT COMMON, ANSWER WOULD INCLUDE THE IDEA THAT KNOWLEDGE CHANGES BECAUSE SCIENTISTS VIEW THE SAME DATA IN A DIFFERENT WAY THAN BEFORE.

4. (a) How do scientists know that dinosaurs really existed?

THE FOCUS HERE IS ON OBSERVATION AND INFERENCE AND THE EMPHERICAL NATURE OF SCIENCE. A SOPHISTICATED, BUT UNCOMMON ANSWER WOULD INCLUDE THAT SCIENTISTS HAVE SOME DATA ABOUT DINOSAURS AND HAVE INFERRED FROM THIS DATA THAT CREATURES DEFINED AS 'DINOSAURS' EXISTED.

(b) How certain are scientists about the way dinosaurs looked?

THE ANSWER TO THIS QUESTION WILL OVERLAP WITH WHAT YOU MAY GET FOR PART (a). AGAIN, THIS QUESTION FOCUSSES ON THE ROLES OF ANSWERS. PART (a) AND (b) MAY ALLOW YOU TO DETERMINE WHETHER A STUDENT UNDERSTANDS THAT THE DEVELOPMENT OF SCIENTIFIC KNOWLEDGE (VIA INFERENCES) INVOLVES HUMAN CREATIVITY AND SUBJECTIVITY.

OCCASSIONALLY, STUDENTS GIVE A PERCENTAGE FOR HOW CERTAIN THEY THINK SCIENTISTS ARE (E.G. "SCIENTISTS ARE 80% SURE OF HOW DINOSAURS LOOK") REFLECTING THEIR VIEWS OF THE TENTATIVENESS OF SCIENCE.

(c) Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

THIS QUESTION REFLECTS STUDENT'S VIEWS ABOUT THE SUBJECTIVE AND TENTAIVE NATURE OF SCIENCE. THE DESIRED RESPONSE WOULD BE THAT DIFFERENT SCIENTISTS BRING DIFFERENT BACKGROUNDS AND DIFFERENT BIASES TO THE INTERPRETATION OF DATA.

IT IS IMPORTANT TO DISCERN WHETHER THE STUDENT UNDERSTANDS THAT DIFFERENT INTERPRETATIONS DO NOT NECESSARILY MEAN THAT SOMEONE IS RIGHT AND SOMEONE IS WRONG. THIS IS A DIFFICULT IDEA FR YOUNG STUDENTS.

5. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about these weather patterns?

THIS QUESTION IS LOOKING FOR IDEAS ABOUT OBSERVATION AND INFERENCE AND TENTATIVENESS. AGAIN YOU WOULD BE LOOKING FRO ANSWERS SIMILAR TO THOSE IN QUESTION 4, ONLY THE CONTEXT OF THE QUESTION IS DIFFERENT.

(b) Why or why not?

JUST ADDITIONAL INFORMATION TO SUPPORT STUDENT'S IDEAS IS BEING ASKED FOR HERE.

6. What do you think a scientific model is?

THIS QUESTION FOCUSES ON THE ROLE OF OBSERVATION AND INFERENCE, BUT ALSO MAY PERMIT YOU TO GATHER DATA ON STUDENT'S UNDERSTANDING THAT A MODEL IS AN INFERENCE THAT IS NOT "REAL" OR NOT AN EXACT COPY OF NATURE.

AT A DEEPER LEVEL. YOU MAY ALSO HAVE DATA CONCERNING STUDENT'S UNDERSTANDING THAT THE CREATION OF MODELS INVOLVES THE SUBJECTIVITY AND CREATIVITY OF SCIENCE, AND IT IS FOR THIS REASON THAT MODELS ARE TENTATIVE. FOR THIS AGE STUDENT, THE SIMPLER IDEAS IN THE FIRST PARAGRAPH ARE MORE LIKELY.

7. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?

(a) If NO, explain why.

THE DESIRED ANSWER HERE IS "YES" ANDMOST STUDENTS WILL ANSWER THIS WAY. HOWEVER, PART B WILL GIVE YOU MORE INFORMATION ABOUT THE ADEQUACY OF STUDENTS' BELIEFS.

(b) If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc) do you think they use their imagination and creativity? Give examples if you can.

MOST STUDENTS WILL ONLY UNDERSTAND, OR AT LEAST SAY, THAT SCIENTISTS USE THEIR CREATIVITY AND IMAGINATAION IN THE PLANNING OF INVESTIGATIONS. FEW WILL TELL YOU THAT SCIENTISTS USE CREATIVITY AND IMAGINATION DURING AN EXPERIMENT / INVESTIGATION AND IN THE INTERPRETATION OF DATA AND REPORTING OF RESULTS. THIS QUESTION RELATES BACK TO STUDENT'S UNDERSTANDING OF WHY SCIENCE IS TENTATIVE AND HOW CREATIVITY, SUBJECTIVITY, AND INFERENCE PERMEATE ALL OF SCIENCE.

VIEWS OF SCIENCE

Name:			
Age in years today:		**Date:**	

- Please answer each of the following questions.
- This is not a test and is not for marks. There are no "right" or "wrong" answers to the questions. I am only interested in your ideas relating to the questions.

1. **What is science ?**

2. **How is science different from the other subjects you are studying?**

3. **Do you think the knowledge in science books may change in the future?**

____

Explain your answer.

Give an example to help explain your answer.

4. **How do scientists know that dinosaurs really existed?**

How certain are scientists about the way dinosaurs looked?

Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However, scientists disagree about what had caused this to happen. Why do you think they disagree even though they all have the same information?

5. What do you think a scientific model is?

6. Scientists try to find answers to their questions by doing investigations / experiments. Do you think that scientists use their imaginations and creativity when they do these investigations / experiments?

If NO, explain why.

If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc) do you think they use their imagination and creativity?
Give examples if you can.

7. **Draw a picture of a scientist in the space below.**

Give the scientist you have drawn a title, first name and surname.

____

Where is the scientist you have drawn, working?

____

8. What kind of people do you think scientists are ?

____

____

____

____

____

____

Do you think scientists like sport? ____________________

Do you think scientists like art? ____________________

Do you think scientists like music? ____________________

Do you think scientists prefer to work on their own? ____________

9. Do you want to be a scientist when you leave school? ____________

If not, what do you want to be ?

____

APPENDIX F SUMMARY OF LEARNERS' RESPONSES TO VIEWS OF SCIENCE QUESTIONNAIRE STATEMENTS

	Questionnaire statements																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Grade 8																		
Agree	97	86	72	83	100	36	28	69	86	52	93	86	61	72	21	48	7	76
Disagree	0	11	21	14	0	50	38	21	3	41	3	3	32	14	66	38	93	14
Undecided	3	3	7	3	0	14	34	10	11	7	4	11	7	14	14	14	0	10
Grade 9																		
Agree	92	0	4	92	8	48	60	68	96	36	100	80	72	80	12	48	0	32
Disagree	8	20	88	0	92	40	8	24	0	56	0	8	24	16	68	24	96	48
Undecided	0	0	8	8	0	12	32	8	4	8	0	12	4	4	20	28	4	20
Grade 10																		
Agree	68	64	86	93	89	39	64	50	89	57	96	96	68	82	79	29	4	71
Disagree	25	36	14	7	7	54	18	39	7	43	4	0	32	18	14	68	93	29
Undecided	7	0	0	0	4	7	18	11	4	0	0	4	0	0	7	3	3	0
Grade 11																		
Agree	93	79	79	71	79	29	46	71	93	29	93	82	68	82	36	46	7	79
Disagree	4	21	14	18	11	57	29	18	0	68	7	7	25	7	46	43	82	14
Undecided	3	0	7	11	10	14	25	11	7	3	0	11	7	11	18	11	11	7
Total																		
Agree	87	77	62	85	71	37	49	65	91	44	95	86	67	79	37	43	5	65
Disagree	9	22	33	10	25	51	24	25	3	52	4	5	28	14	48	44	91	25
Undecided	4	1	5	5	4	12	27	10	6	4	1	9	5	7	15	13	4	10

APPENDIX G LEARNERS' MEAN RESPONSE TO VIEWS OF SCIENCE QUESTIONNAIRE STATEMENTS

Grade response to statements	No	Mean	Std Deviation	Std Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Statement 1								
8	29	2.14	0.915	0.170	1.79	2.49	0	3
9	27	2.26	1.163	0.224	1.80	2.72	-1	3
10	28	0.57	1.574	0.297	-0.04	1.18	-3	2
11	28	2.14	1.325	0.250	1.63	2.66	-3	3
School	112	1.78	1.431	0.135	1.51	2.04	-3	3
Statement 8								
8	29	1.03	2.044	0.380	0.26	1.81	-3	3
9	27	1.07	2.165	0.417	0.22	1.93	-3	3
10	28	0.25	1.917	0.362	-0.49	0.99	-3	3
11	28	1.39	1.571	0.297	0.78	2.00	-2	3
School	112	0.94	1.956	0.185	0.57	1.30	-3	3
Statement 10								
8	29	-0.17	2.156	0.400	-0.99	0.65	-3	3
9	27	-0.59	2.062	0.397	-1.41	0.22	-3	3
10	28	0.29	1.843	0.348	-0.43	1.00	-3	3
11	28	-0.61	2.166	0.409	-1.45	0.23	-3	3
School	112	-0.27	2.066	0.195	-0.65	0.12	-3	3
Statement 11								
8	29	2.17	1.284	0.238	1.68	2.66	-3	3
9	27	2.89	0.32	0.062	2.76	3.02	2	3
10	28	1.82	0.945	0.179	1.46	2.19	-1	3
11	28	2.00	1.305	0.247	1.49	2.51	-2	3
School	112	2.21	1.11	0.105	2.01	2.42	-3	3
Statement 15								
8	29	1.07	1.689	0.314	1.71	0.43	-3	2
9	27	0.96	1.480	0.285	1.55	0.38	-3	3
10	28	1.15	1.379	0.265	1.69	0.60	-3	2
11	28	0.32	1.744	0.330	1.00	-0.35	-3	3
School	112	0.87	1.596	0.151	1.17	0.57	-3	3
Statement 18								
8	29	1.00	1.604	0.298	0.39	1.61	-3	3
9	27	-0.19	1.861	0.358	-0.92	0.55	-3	3
10	28	1.04	1.644	0.311	0.40	1.67	-2	3
11	28	1.50	1.667	0.315	0.85	2.15	-3	3
School	112	0.85	1.782	0.168	0.51	1.18	-3	3

Grade response to statements	No	Mean	Std Deviation	Std Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Statement 2								
8	29	1.62	1.635	0.304	1.00	2.24	-3	3
9	27	1.19	1.733	0.333	0.50	1.87	-3	3
10	28	0.71	1.922	0.363	-0.03	1.46	-3	3
11	28	1.21	2.132	0.403	0.39	2.04	-3	3
School	112	1.19	1.867	0.176	0.84	1.54	-3	3
Statement 3								
8	29	1.17	2.106	0.391	0.37	1.97	-3	3
9	27	2.15	1.231	0.237	1.66	2.64	-2	3
10	28	1.39	1.449	0.274	0.83	1.95	-3	3
11	28	1.32	1.786	0.337	0.63	2.01	-3	3
School	112	1.50	1.703	0.161	1.18	1.82	-3	3
Statement 6								
8	29	0.45	2.131	0.396	-0.36	1.26	-3	3
9	27	-0.37	2.060	0.396	-1.19	0.44	-3	3
10	28	0.29	1.823	0.344	-0.42	0.99	-3	3
11	28	0.82	1.982	0.375	0.05	1.59	-3	3
School	112	0.30	2.022	0.191	-0.07	0.68	-3	3
Statement 13								
8	29	0.48	1.825	0.339	-0.21	1.18	-3	3
9	27	1.07	1.591	0.306	0.44	1.70	-3	3
10	28	0.36	1.66	0.314	-0.29	1.00	-3	3
11	28	1.07	1.741	0.329	0.40	1.75	-3	3
School	112	0.74	1.718	0.162	0.42	1.06	-3	3
Statement 14								
8	29	1.34	1.778	0.330	0.67	2.02	-3	3
9	27	1.67	1.732	0.333	0.98	2.35	-3	3
10	28	1.54	1.875	0.354	0.81	2.26	-3	3
11	28	1.93	1.412	0.267	1.38	2.48	-2	3
School	112	1.62	1.699	0.161	1.30	1.93	-3	3
Statement 17								
8	29	-2.24	1.354	0.251	-2.76	-1.73	-3	3
9	27	-2.30	0.869	0.167	-2.64	-1.95	-3	0
10	28	-1.57	1.034	0.195	-1.97	-1.17	-3	1
11	28	-1.50	1.478	0.279	-2.07	-0.93	-3	3
School	112	-1.90	1.252	0.118	-2.14	-1.67	-3	3

Grade response to statements	No	Mean	Std Deviation	Std Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Statement 4								
8	29	1.76	1.806	0.335	1.07	2.45	-3	3
9	27	2.52	0.849	0.163	2.18	2.85	0	3
10	28	1.96	1.170	0.221	1.51	2.42	-1	3
11	28	1.43	1.709	0.323	0.77	2.09	-3	3
School	112	1.91	1.480	0.140	1.63	2.19	-3	3
Statement 5								
8	29	2.34	0.814	0.151	2.04	2.65	1	3
9	27	2.26	1.259	0.242	1.76	2.76	-2	3
10	28	1.75	1.404	0.265	1.21	2.29	-3	3
11	28	1.68	1.517	0.267	1.09	2.27	-2	3
School	112	2.01	1.291	0.122	1.77	2.25	-3	3
Statement 7								
8	29	-0.45	1.682	0.312	-1.09	0.19	-3	3
9	27	0.59	1.118	0.215	0.15	1.03	-3	3
10	28	0.93	1.274	0.241	0.43	1.42	-1	3
11	28	0.04	1.835	0.347	-0.68	0.75	-3	3
School	112	0.27	1.582	0.150	-0.03	0.56	-3	3
Statement 9								
8	29	2.28	1.162	0.216	1.83	2.72	-1	3
9	27	2.33	0.877	0.169	1.99	2.68	0	3
10	28	1.75	1.430	0.270	1.20	2.30	-3	3
11	28	2.07	0.979	0.185	1.69	2.45	0	3
School	112	2.11	1.142	0.108	1.89	2.32	-3	3
Statement 12								
8	29	2.14	1.302	0.242	1.64	2.63	-2	3
9	27	1.67	1.494	0.287	1.08	2.26	-2	3
10	28	2.04	0.922	0.174	1.68	2.39	0	3
11	28	1.75	1.602	0.303	1.13	2.37	-3	3
School	112	1.90	1.349	0.127	1.65	2.15	-3	3
Statement 16								
8	29	0.10	2.193	0.407	-0.73	0.94	-3	3
9	27	0.41	2.005	0.386	-0.39	1.20	-3	3
10	28	-1.14	2.172	0.411	-1.99	-0.30	-3	3
11	28	-0.07	2.387	0.451	-1.00	0.85	-3	3
School	112	-0.18	2.243	0.212	-0.60	0.24	-3	3