EXPLORING TEACHER'S BELIEFS ABOUT THE NATURE OF SCIENCE AND THEIR RELATIONSHIP TO CLASSROOM PRACTICES : A CASE STUDY WITH SPECIAL REFERENCE TO PHYSICAL SCIENCE TEACHERS IN THE EMPANGENI / RICHARDS BAY AREA.

by

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ABSTRACT

This research explored the complex issue of the nature of science. The purpose of the study was to explore the relationship between teachers's beliefs about the nature of science and their classroom practices. Limited literature exists on the nature of science in South Africa. However, findings from the study concurs with the abundant international literature on the nature of science. This research has shown that textbooks, the curriculum, and teacher training are three of the primary factors that shape teachers' beliefs about the nature of science. The under-emphasis of the nature of science in textbooks, the curriculum and in teaching training contributes to the misrepresentation of the nature of science by teachers in their classroom practices.

This research was conducted as a case study using quantitative and qualitative methods of data collection such as questionnaires, interviews, and classroom observations. Findings from the study have shown that teachers' instructional strategies are consistent with their personal educational philosophies, that is, teachers' teach science according to a belief system. For teachers operating in the analytical paradigm, the products of science such as the laws and theories were emphasized in their teaching and lessons were teacher dominated. Teachers operating in the hermeneutic and critical paradigms present science as dynamic and changing and they emphasized the products and processes of science with the teacher acting as a facilitator.

Recommendations from the research include the development of new textbooks, curricula, teaching techniques and approaches to science. The research also calls for the inclusion of history and philosophy of science in the science curriculum.

DEDICATION

This research is dedicated to my ***family*** : Jesika, Kimara and Kyra.

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I acknowledge that this research was time consuming. However, it was a truly enriching and rewarding experience.

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- *Finally, I would like to thank God for granting me wisdom, strength and diligence to complete this research report.*

DECLARATION

I, SURESH KAMAR SINGH, DECLARE THAT THE RESEARCH INVOLVED IN MY HALF - DISSERTATION, SUBMITTED IN PARTIAL FULFILMENT OF THE M. ED. DEGREE IN SCIENCE EDUCATION, ENTITLED :

Exploring teachers' beliefs about the nature of science and their relationship to classroom practices : a case study with special reference to Physical Science teachers in the Empangeni / Richards Bay area.

REPRESENTS MY OWN AND ORIGINAL WORK, AND HAS NOT BEEN SUBMITTED PREVIOUSLY FOR ANY DEGREE IN ANY OTHER UNIVERSITY.

Singh

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Science permeates every facet of our lives. Science enables people to obtain explanations for everyday phenomena and how things work. Science empowers people to improve things and make progress. There are two broad views of science, namely, a static view and a dynamic view. The static view regards science as an accumulated body of knowledge or findings. The emphasis in this view of science is on the present body of knowledge and merely adding to this body of knowledge. In the dynamic view, science is considered to be a human activity, something that scientists do, and the body of knowledge is always changing.

The way science is taught in school affects how pupils build on their scientific knowledge and relate theory to practice. The teacher, therefore, plays a pivotal role in pupils' understanding and interest in science. The teaching strategies implemented by the teacher in the classroom impact directly on pupils' enthusiasm for science. Furthermore this affects the pupil's view and understanding of science. The researcher is of the view that the teacher's beliefs about the nature of science are influenced by a number of factors which have a direct bearing on how the teacher teaches science. This research will focus on the relationship between teachers' beliefs about the nature of science and their classroom practices.

This research will attempt to establish whether a teacher, who believes that science is merely a body of knowledge that accumulates daily, acts as a transmitter of knowledge and a teacher who, believes that science is constantly changing and improving, will act as a facilitator of knowledge. Hence, this research will attempt to establish whether teachers subscribing to different views of science, use different teaching strategies in the classroom.

This research will focus on :

a) teachers views and beliefs about the nature of science.
b) factors that influence their views and beliefs about the nature of science.
c) teaching strategies implemented by teachers
d) the influence of teachers' beliefs about the nature of science on their teaching strategies.

1. 2 STATEMENT OF PURPOSE

Teachers differ in age, experience, social and cultural backgrounds, gender, marital status, knowledge of the subject matter and ability. The uniqueness of each teacher ensures that the belief system of teachers will be varied.

The purpose of this study is to explore the relationship (if any) between teachers' declared beliefs about the nature of science and their classroom practices.

1.3. CRITICAL QUESTIONS

In exploring the relationship, this research study will attempt to provide answers to the following critical questions :

1.3.1 What declared beliefs do teachers have about the nature of science?

1.3.2 What factors influence teachers' beliefs about the nature of science ?

1.3.3 What is the relationship between teachers' declared beliefs about the nature of science and their classroom practices?

1.4. THE IMPORTANCE OF THE TOPIC

> **"If the teacher's understanding and philosophy of science is not congruent with the current interpretation of the nature of science; if the objectives that he establishes are not congruent with the dynamic nature of science, then the instructional outcome will not be representative of science ...."**
>
> (Carey and Stauss quoted in Billeh and Malik)

My interest in the topic was fuelled by the above quotation which can be found in an article written by Billeh and Malik in SCIENCE EDUCATION JOURNAL (1977 : 61 , 4). I support the idea that to understand science, one needs to understand its basic assumptions and characteristics; underlying philosophy and the processes through which scientific knowledge is acquired and developed. A teacher's understanding of science impacts directly on how he or she teaches. Previously, teachers accepted the syllabi ' handed down ' to them unquestioningly and taught their contents without challenging them. The researcher is of the view that this research is important as it allows science teachers to be reflective. I find that I need to constantly reflect on my classroom practices. This process of reflection requires me to constantly evaluate my belief system about the nature of science and factors that influence my classroom practices.

In South Africa, textbooks, the curriculum, large classes, multicultural classes, severe cutbacks in education, examinations and other factors place an increasing strain on teachers' instructional skills in the classroom. However, teachers' beliefs about the nature of science will ensure that teachers implement teaching strategies consistent with their philosophies.

I believe that this research will be useful to :

1. all science teachers.
2. curriculum developers and textbook writers because of the way science is reflected in the curriculum and textbooks.
3. supervisors of teachers, by informing them about practices in the classroom.

1.5. A BRIEF REVIEW OF LITERATURE IN THE FIELD

Literature on teachers' beliefs about the nature of science is varied, with different authors and researchers focusing on different aspects that influence teachers' beliefs about the nature of science. Some of the aspects that influence teachers' beliefs are textbooks, the curriculum, philosophies of science, technology, teacher training, examinations and the ethos of the school.

Articles by Brickhouse (1991); Fraser, Fahle and Tobin (1990); Briscoe (1991); King (1991); Koballa, Jr (1988); Stevens and Wenner (1996) ; Davis and Helly (1995) focus on teachers' beliefs. The study by Koballa is a theoretical study that explains concepts important to this study, namely, beliefs and attitudes. The other studies concentrate on teachers' classroom practices and the teacher's belief systems.

Studies involving the nature of science have been conducted by McComas (1996); Griffiths and Barman (1995); Billeh and Malik (1977); Ogunniyi and Pella (1980). These studies examine issues relating to the nature of science. The latter two studies are quantitative studies. Authors Bentley and Garrison (1990); Stinner (1992) and Groves (1995) evaluate textbooks being used in the USA. These studies focus on how science is reflected in textbooks, the impact of textbooks on teachers' beliefs about the nature of science and the influence of textbooks on the way in which science is taught.

The call for a valid science curriculum in the USA and UK has been made by many authors. Research conducted by Gruender and Tobin (1991); Bybee, et al (1991) and Kelly (1983) reveal that the present science curriculum ignores the processes of science and focuses on the products of science. According to this research, the daily experiences of pupils and the nature of science are ignored in the curriculum.

A review of the literature identifies textbooks and the curriculum as two prime factors that shape teachers' beliefs about the nature of science. Gaps in the literature reveal that there is little information about cultural influences on teachers' beliefs about the nature of science. Also, most of the literature in the field is based outside South Africa. My research will contribute to the literature in South Africa and give a South African perspective to the topic.

1.6 METHODOLOGY

This research was conducted as a case study. Questionnaires were sent to different schools in the Richards Bay and Empangeni areas. Three secondary school science teachers, with similar or different strands of thought were chosen from questionnaires received. The questionnaires were sent to schools from the three (3) ex-Education Departments; Ex - House of Assembly, Ex - House of Delegates and Ex - Department of Education and Training. There are no Ex - House of Representatives schools in this area. The sample of teachers was taken from the Empangeni and Richards Bay area, who teach General Science, Biology or Physical Science.

Initially, the teachers in the study were required to complete a questionnaire. The purpose of the questionnaire was to obtain background information relating to teachers' beliefs, the nature of science and classroom practices from the sample of teachers. The questionnaire was followed by an informal, semi - structured interview which was audiotaped. The purpose of the interview was for further elaboration and clarification of responses to the questionnaire. The interview also focuses on the ethos of the school, that is, the school governance, structure, management and teachers. In doing so, it looked into the kind of school the teachers function in, their attitude towards examinations, the freedom that they have to engaged in individual projects, and the support that they get from teachers and management.

Textbooks and the curriculum are the teacher's main source of information and 'guide' in school. An evaluation of textbooks and the curriculum is essential to understand the impact that these have on shaping teachers beliefs and classroom practices. The critical evaluation will focus on how the nature of science is portrayed in textbooks used in schools and how it is emphasised in the curriculum. Teachers were observed in their classroom once a week for a period of one month. The classroom observations enabled the researcher to study each teacher's classroom practices.

1.7 DATA ANALYSIS STRATEGY

The information from audiotapes was transcribed and returned to the teachers for verification. The data obtained from the questionnaires were tabulated and analysed. Information from interviews and responses in questionnaires will be compared and analysed.

1.8 VALIDATION

The questionnaires were given to teachers outside Richards Bay for their comments and responses. The validity of this study was enhanced by comparing teacher responses in the interview and questionnaire. The researcher believes that the reliability of the data obtained from the questionnaire would have been in jeopardy if the teachers' responses in interviews differ substantially from the responses in the questionnaires. Triangulation was used as a validation strategy by analysing teachers' responses in questionnaires, interviews and observation of their classroom practices.

1.9 LIMITATIONS OF THE STUDY

This study is limited in that all factors that influence teachers' beliefs about the nature of science cannot be explored. Time constraints ensure that only certain factors can be explored in depth. It is not the intention of this study to draw generalisations but to give valuable insight into some science teachers' practices in the classrooms. As the sample of teachers is too small, no generalisations can be made.

1.10 THE RESEARCH PLAN

The second chapter of this research study will focus on some of the relevant literature in this field. The literature review will examine the nature of science, factors influencing teachers' views or beliefs about the nature of science and other similar case studies done in the field.

Chapter three provides a description of the research methodology. In this chapter, the researcher outlines reasons for the type of research being conducted, the sample chosen, the site for the study, methods of data collection and other relevant details with respect to the study.

In chapter four, the questionnaires, interviews and classroom observations are analysed and interpreted. Also, examined in this chapter are the teachers' beliefs about the nature of science.

The final chapter of the research study will identify findings and conclusions to the study. The critical questions are examined in light of the conclusions and findings. Possible reasons for the findings are suggested together with recommendations and implications for future research.

CHAPTER 2

REVIEW OF LITERATURE

Literature about the nature of science in South Africa is limited and has been difficult to locate. As far as the researcher is aware, no research has explored teachers' perceptions and views about the nature of science in South Africa. A notable exception, however, is the research conducted by Ayayee and McCarthy (1996). Abundant literature on the nature of science can be located in research conducted in the United States, United Kingdom and other countries. Literature from these countries will form the backbone of the literature being reviewed. The literature review will focus on the following aspects :

a) the nature of science.
b) teachers' beliefs or views about the nature of science.
c) teachers' classroom practices or strategies.
d) factors influencing teachers' beliefs about the nature science such as textbooks, curriculum, science philosophies and philosophers. and teacher training.

2.1 THE NATURE OF SCIENCE

As this study involves the nature of science, the researcher believes that it is essential to clearly identify what the nature of science is to create a theoretical backdrop for this study. The researcher has identified different strands of thought about the nature of science and these are summarised in the literature review below.

According to Baker (1992) an understanding the of the nature of science by teachers is important as it influences how teachers teach. The nature of science plays a crucial role in bringing about conceptual change in pupils. An understanding of the nature of science by students helps enhance their understanding of scientific concepts or helps students relinquish their misconceptions. In the USA, the National Assessment of Educational Progress Tests have included items about the nature of science. Baker (1992) contends that research has shown that understanding the nature of science has been a goal of science education for many years but little time or space in the curriculum has been allocated to the nature of science.

Teaching about the nature of science is more difficult than teaching facts or concepts. According to Baker (1992) an understanding of the history, philosophy and sociology of science is essential to teach about the nature of science. Teachers, however, lack a background in the history, philosophy and sociology of science. He adds that textbooks contribute to this lack of understanding as little space is allocated to the history and development of scientific ideas. Also textbooks ignore ideas in the history of science and applications of science to students lives. According to Lederman cited in Baker (1992) :

> ***"Teachers who understand the nature of science encourage the more higher level thinking and frequently use problem solving, inquiry oriented instruction and higher level questioning in a risk - free environment."***
>
> (Baker, 1992 : 14)

From the above discussion, it is clear that teaching and learning in a science classroom involve the constructing and reconstructing of scientific knowledge and is dependent on teachers' and pupils' understanding of the nature of science.

According to Carr (1994), the constructivist view of science has important implications for classroom teaching and learning. The authors contend that many teachers hold a traditional view of science rather than a constructivist view of science. Hence, there is a need for teachers to reconceptualize their views about the nature of science. The authors add that teaching pupils about the nature of science will contribute towards better learning in the classroom. This equips learners to re-evaluate concepts they have learnt.

According to Carr (1994) a number of issues arise naturally in the classroom which will enable teachers to explore the nature of science. Some of these include :

"a) building up experiences and trying to make better sense of these experiences;

b) how scientists construct concepts - which are not 'out there' in the world waiting to be uncovered;

c) how science takes the richly complex world of experience and reduces it to a more manageable one in order to make more powerful statements;

d) how science often focuses on a defined system as it is at the moment and ignores previous history or possible futures unless these are clearly stated;

e) that there are a number of apparently simple questions about the world that may be difficult for science to answer." (Carr, 1994:158)

Hence according to Carr (1994) the nature of science has to take into consideration the experiences that pupils bring into the classroom and the history of science. Therefore, when a teacher teaches science, he / she must take this into consideration.

This view is supported in the National Science Curriculum in the UK which has the following aim with respect to the nature of science :

"Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the contexts in which they are developed; in doing so they should begin to recognise that while science is an important way of thinking about experience it is not the only way."

(Watts, 1991 :89)

According to Watts (1991), both the nature of science presented to pupils and the way in which that science is presented are of paramount importance. He states that it is important for science to be presented as just one way of explaining the world around us. He adds :

> ***"School science needs to show that science and scientists are not neutral but that their observations, theories and explanations are bound by all the aspects of society that surrounds them : by social mores, economic and political understanding, religious and moral convictions."*** (Watts, 1991 :132)

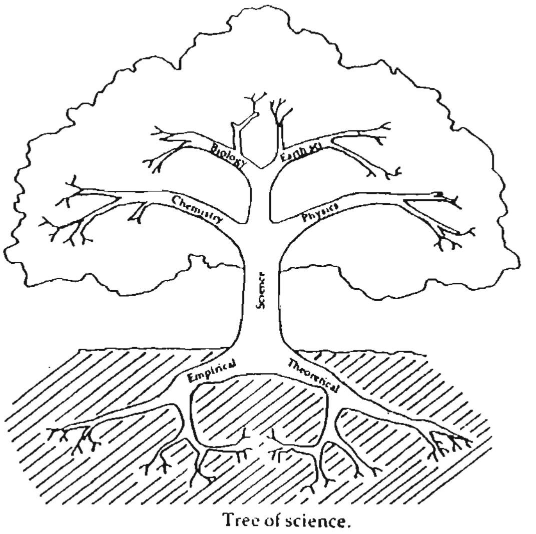
The author believes that the way science is presented in any national curriculum is vital in establishing equality of approach. An approach that works towards equality and justice would involve the pupils in investigation and experimentation, often starting from their own questions and ideas and working towards pupils' developing their own understanding of the issues. This may result in pupils and teachers having different ways of explaining the world around them, as pupils and teachers differ in cultural or ethnic backgrounds or in their levels of understanding. If science is presented to pupils as a 'body of knowledge' that needs to be learnt and regurgitated, with the occasional need to be creative and solve a few problems, it is unlikely that students will gain equality of access. This gives pupils a false picture of science.

Stevenson and Palmer (1994) support the view that science enables us to explore and to question observations in the universe, to find hidden order, and to analyse and interpret findings. However, pupils' and teachers' understanding of the world will differ. According to Stevenson and Palmer (1994) the common view of science embodied in most curricula is that :

> ***"...it should be an essential part of a whole curriculum that is broad, balanced, relevant and differentiated. It should be directed towards effective learning by ensuring that pupils are eager to participate in science, are stimulated by interest and curiosity, and can see relevance in what they are learning for their own lives."***
>
> (Stevenson & Palmer,1994 : 48)

For this to be achieved pupils must acquire scientific knowledge and understanding, develop skills of investigation and experimentation and must be able to talk about science. There should be a parallel between what scientists do and what happens in the classrooms. John Rigden cited in Stevenson and Palmer (1994) emphasized that there are two key characteristics in the nature of science : its empirical character and its analytical nature. Students' need to observe, explore, investigate and describe objects and situations contributes to the empirical nature of science whilst experimentation and investigatory procedures that lead to the discovery of hidden patterns or laws, meanings and explanations contribute to the analytical nature of science. Hence, science involves two key processes, namely investigation and analysis. Some of the scientific processes or enquiry skills that are fundamental to the learning of science in school programmes are "classifying, creating models, formulating hypotheses, inferring, interpreting data, making decisions, manipulating materials, measuring, observing, predicting, and recording data"

Farmer and Farrell (1980) analyse the nature of science and its implications for science teachers in their book *Systematic Instruction in Science for the Middle and High School Years*. They contend that science has its roots in both the 'idea world and the physical world'. The illustration below clearly indicates that science has a theoretical nature and an empirical nature.



Tree of science.

ILLUSTRATION 1

that teaching the history of science will enhance pupils understanding of the nature of science.

Billeh and Malik (1977) used different quantitative instruments to test practising and prospective teachers' understanding of the nature of science. The teachers used in this study were enrolled at a university. The instruments used were: Nature of Scale; Science Process Inventory; Wisconsin Inventory of Science Processes; and Test on Understanding Science. Conclusions, important to this research, arrived at by the authors revealed that prospective teachers did not adequately understand some elements of the nature of science since training programmes for teachers include very little formal instruction in the nature of science. Also, teaching experience as such does not contribute to a teacher's understanding of the nature of science.

A similar quantitative study was conducted by Ogunniyi and Pella (1980) to poll science teachers views on terms frequently encountered in the nature of science such as concepts, laws and theories. The researchers used a questionnaire consisting of 68 statements about the nature of science to test teachers' understanding about the nature of science. The research showed that more than 75% of the teachers polled used their personal conceptualization of concepts, laws and theories when they teach science. Also, more than 67% of science teachers expressed the belief that scientific laws are true and verifiable statements about natural phenomena.

In one of the few South African studies on the nature of science, Ayayee and McCarthy (1996) conducted a study, in Johannesburg, to investigate pupils, student teachers and practising teachers views about the nature of science. In the study the nature of science is considered to be :

> ***"..the nature of scientific knowledge (its generation, characteristics and limitations), values in science, and how science is practised"***
>
> (Ayayee and McCarthy, 1996:1)

According to the researchers :

> ***".. the broad goal of the study was to describe the views held by a group of pupils and teachers about the nature of science.."***
>
> (Ayayee and McCarthy, 1996:1)

The researchers found that science was considered to be facts and processes by the majority of the teachers and pupils. A small percentage of pupils and teachers considered science to be a human activity. Another finding of the research was that the majority of the persons in the sample were of the view that hypotheses lead to theories which in turn lead to laws. Possible reasons for these misconceptions are :

> ***"...poor textbook writing and poorly taught science courses"***
>
> (Ayayee and McCarthy, 1996:4)

The following conclusion was reached :

> ***"...this study confirmed findings of research in other countries that pupils and teachers have inadequate conceptions about the nature of science."*** (Ayayee and McCarthy, 1996:7)

The researchers believe that the science curriculum must be used to develop authentic conceptions of the nature of science. This true representation of the nature of science conveyed to pupils will ensure that pupils are scientifically literate.

In another piece of South African research Clitheroe (1994) examines gender issues in science and provides possible reasons why women are generally not in the laboratory. Some of the reasons suggested are biological differences between boys and girls, socialization (especially at home), subject choices offered to girls, classroom interactions with teachers and the structure and nature of science. The author contends that the structure of science has been influenced by white western males and is considered to be objective and rational. Also, a scientist is portrayed as a man in a white coat, wearing spectacles, and is eccentric (the image of the 'mad scientist'). The masculine image of science is reinforced by the teachers who teach the subject as most science teachers are male. Also, teachers tend to encourage boys rather than girls in their science classes. The author found that male domination in science is reinforced in most South African textbooks. These textbooks make few references to women or women are shown in illustrations in a passive role. The author calls on teachers to examine their role in the classroom and to address the entrenched prejudices and gender bias in science education.

Another study on the nature of science was conducted by Barman and Griffiths (1995). They, however, used pupils from three different countries, namely USA, Canada and Australia, in their study. The study focused on pupils' views about the nature of science. The researchers did note that whilst there were many differences, when comparing the results from different countries, there were many similarities. Some of the findings of the research were :

a) pupils presented a general and environmental view of science.
b) most pupils believe that science changes due to changes in technology.
c) Canadian pupils believe that science changes because of new ideas. The researchers found that the nature of science was emphasized in the teacher education programme and encouraged in a recent report on science education in Canada.
d) American pupils maintained that scientific laws are not meant to be broken and followed 'mechanistic traditional scientific methods'.

Concluding comments by the researchers are :

> ***"The results of the study are potentially useful to a wide range of science educators and curriculum developers, in that the usefulness of an education in science is restricted when the nature of science itself is not understood."*** (Barman and Griffith, 1995:253)

A theoretical study by McComas (1996) examines ten myths or misconceptions about the nature of science held by students and teachers. These ten myths contribute towards incorrect perceptions about the enterprise of science.

The ten myths identified by the author are listed in the table below :

no	myth
1	hypotheses become theories which become laws
2	a hypothesis is an educated guess
3	a general and universal scientific method exists
4	evidence accumulated carefully will result in sure knowledge
5	science and its methods provide absolute proof
6	science is procedural more than creative
7	science and its methods can answer all questions
8	scientists are particularly objective
9	experiments are the principle route to scientific knowledge
10	all work in science is reviewed to keep the process honest

TABLE 1 : Myths about the nature of science

McComas states that two new science education projects in the USA have called for a review of the nature of science being portrayed in schools. He makes a plea that instruction in and opportunties to experience the nature of science are vital in preservice and inservice teacher education programmes to help unseat the myths of science.

The author concludes his article by stating :

> *"There must be increased opportunity for both pre-service and in-service teachers to learn about and apply the real rules of the game of science accompanied by careful review of textbooks to remove the 'creeping fox terriers' that helped provide an inaccurate view of the nature of science."* (McComas, 1996:15)

2.2 TEACHERS' BELIEFS

Another aspect that this research focuses on is that of teachers' beliefs about the nature of science. When looking at factors that influence teachers' beliefs about the nature of science, I ignored cultural and religious influences on beliefs due to time constraints and the length of the report. I believe that a study of beliefs is important to gain insight and understanding into the choices that teachers' make in the classroom. Further, I contend that understanding why and how teachers think and practice in classrooms is essential to understanding teaching.

In the review of the literature, possible definitions to the concept belief are provided and possible factors that influence teachers' beliefs about the nature of science are identified.

An article by Hamilton (1993), in the book *Research on Teacher Thinking: Understanding Professional Development*, explores the concept of beliefs in depth. According to Hamilton beliefs can be categorised in three ways :

a) *private beliefs* - these are unique to the individual and are always true irrespective of the beliefs of others;

b) *declared beliefs* - are beliefs voiced in public by an individual and are cited in an argument to justify action;

c) *public beliefs* - are beliefs shared by a group of individuals as their common declared beliefs.

In the context of her research, Hamilton identified beliefs as 'sets of assertions held by informants and spoken as declarative sentences'.

The image of science and scientists is examined in an article by Rampal (1992). This research was conducted in India and its primary purpose was to qualitatively explore teachers' beliefs and views about issues relating to science, technology and society.

Interesting findings of the research revealed that :

> ***"Teachers tend to view scientists as those unfamiliar yet extraordinary beings who, though not necessarily trained through the formal education system, display a keen sense of commitment in their pursuit for 'truth'. Scientists are also seen as stereotypically preoccupied personages with a distinct 'lost' look......"***
>
> (Rampal, 1992 : 432)

Rampal found that many teachers (85% - 90% in the study) have never met a scientist but had an 'authoritative' image of a scientist, that is, someone who is unemotional, rational and objective. Rampal points out that :

> ***"...the projection of science in school as a collection of 'facts' results in the popular belief that scientists are not person-centred and are not normally concerned with human problems."***
>
> (Rampal, 1992 : 426)

Rampal calls for a 'holistic' account of scientists' works to be included in textbooks such as their failures, errors and beliefs.

Pomeroy (1993) investigated the implications of teachers' beliefs about the nature of science by comparing the beliefs of scientists with that of secondary and elementary teachers. This research was conducted as an empirical study and examined the differences between how scientists and teachers view the nature of science and scientific methods. The researcher found that elementary teachers had less traditional views of science due to their growing awareness and commitment to constructivism whilst scientists and science teachers held a traditional positivistic view of science. The researcher suggests that teacher education programmes that are heavy on the content of science and tradition - driven science textbooks are possible reasons for teachers displaying a positivistic notion of science.

Research conducted by Davis and Helly (1995) address the issue of conflicting beliefs of an individual teacher. The case study examined the conflicting beliefs a teacher has about her role as a teacher and her professional responsibilities. The research explored the teacher's struggle to change herself, her teaching and develop an understanding of the teacher's construction of meaning. In this case study the teacher looked within herself and at her practices to clarify her beliefs.

The three primary conflicts that emerged from data collected over a two year period include :

"a) conflicts between state curriculum mandates and individual student understanding;

b) conflicts between theoretical and applicable chemistry content knowledge;

c) conflicts between students' goals and teachers' goals."

(Davis and Helly, 1995 : 345)

She defined her position as a teacher primarily through the guidelines set down by the state. She felt pulled between the obligations she felt to the state and to her students. She also lacked confidence in her knowledge of chemistry. She did not consider herself a scientist. She looked up to the 'real' scientist, and believed that she was only able translate the scientific knowledge of the experts to her students. She wanted to match the expectations of the 'scientific world' of which she was not a member, with the 'teaching world' in which she operated. Her perception of what would be expected of students at higher level science education influenced her decisions of what to teach.

Through her involvement in the research, the teacher was able to develop confidence in her ideals and goals. The research enabled her to take control of her actions and decide which beliefs are more important to her, thus empowering her.

2.3 TEACHERS' CLASSROOM STRATEGIES

The third aspect of this research deals with teachers' classroom practices, that is, how and what they teach. I contend that there is a relationship between how teachers' teach and their view of science. I believe that the teacher is the key to educational change and transformation in any school. In terms of the curriculum, the teacher does not merely deliver the curriculum but helps to develop, define and interpret it. It is what the teacher thinks, what the teacher believes and what the teacher does at the level of the classroom that ultimately shapes the kind of learning that young people get. In the literature reviewed below, the effect of teachers' beliefs about the nature of science on their classroom practice was examined.

One of the key articles that influenced this research was conducted by Brickhouse (1991). She conducted an ethnographic study and explored how belief and knowledge shaped classroom instruction in a case study of three high school science teachers. The author used interviews and classroom observations over a four month period to determine the teachers' knowledge of the nature of science, their role as teachers and their students role as learners. Brickhouse found that the teachers' understandings of what science is and how students learn science in school formed a consistent system of beliefs for guiding classroom instruction. Two of the three teachers in the study had personal philosophies that were congruent with their actions in the classroom although they had differing views on the nature of science. One teacher considers scientific theories as "tools to solve problems" (Brickhouse, 1991). This view is consistent with philosophers of science such as Kuhn and Lakatos. The other teacher believed that scientific theories are truths that have been uncovered through rigorous experimentation. This perspective is consistent with earlier philosophies of science such as positivism and empiricism. These divergent views resulted in the teachers setting different educational goals for their students. One teacher required his students to use scientific theories to solve problems whilst the other simply required his students to know what the theories are. The third teacher in the study had unpredictable classroom instruction as he had not reconciled his own conflicting beliefs about the nature of science.

A similar ethnographic study was conducted by Fraser, Kahle and Tobin (1990) and is compiled in the book Windows into Science Classrooms. Actual occurrences in the science classrooms of two teachers from an urban high school in Australia are recorded, interpreted and analysed in this book. Data was collected using participatory observation strategies with different researchers focusing on specific aspects in the classroom. The book makes a detailed study of teacher beliefs, teaching styles, frameworks within which teachers operate and other related teaching and learning issues.

The two teachers in the study differed in their views about their role as the teacher. They also differed in their views about the nature of science. One teacher considered herself to be a facilitator of student learning whilst the other regarded himself as an educational leader whose actions are crucial to student learning. The teacher who believed that she must facilitate student learning viewed science as a process and she felt that scientific knowledge changed with time. The other teacher, however, ignored science as a process and presented his students with facts only.

Briscoe (1991) describes the findings from a case study of a chemistry teacher who participated as co-researcher in investigating the process of change. This research differs from the previous ethnographic study and focuses on individual change from a social psychological perspective. The teacher's conceptualizations of his roles and the beliefs which supported them are reported in this research. From the article, it is clear that the teacher's understanding of the nature of science impacted heavily on the way he taught science to his pupils. Initially the teacher held an objectivist view about science and learning was considered a process of knowledge transfer.

As his understanding of the nature of science changed, his approach to teaching science changed and he later described science as :

> ***"an approach to gaining knowledge rather than an accumulated body of knowledge"*** (Briscoe, 1991 : 193)

The teacher attributed his lack of understanding of how scientific knowledge is acquired to the inability of science teachers to implement a process approach to teaching. This research emphasizes the need for teachers to reflect on their understandings, beliefs and classroom practices. The call for teachers to be reflective and introspective are reflected in the concluding comments in this research :

> ***"Teachers must be given the opportunity to reflect on their own images of teachers and learners."*** (Briscoe, 1991: 199)

This research clearly indicates that teachers' understanding of the nature of science is enhanced when they reflect on their daily practices. It is also clear that their understanding of both the nature of science and the nature of teaching and learning are intertwined.

Osborne and Freyberg (1994), in their book *Learning in Science*, examine the role of the teacher in a constructivist approach to science. A teacher implementing constructivist principles uses flexible teaching and learning strategies that emhasize the processes of science rather than the products of science. The role of the teacher, in the classroom, changes from the traditional role of 'TEACHER TALK' to one of diagnosing, mediating and facilitating. Some of the roles that the teacher will be engaged in will be those of enabler, manager, presenter, adviser, observer, challenger, respondent and evaluator. The teacher ensures that pupils take responsibility for their own learning. Furthermore, the authors state that the teacher needs to create an atmosphere in which pupils are happy to contribute to discussions and listen to one another. Learners must be active participants in their own learning. A classroom ethos that supports pupils developing their independence is vital. Co-operative learning, role - playing, discussion, debate are some of the teaching strategies that teachers must implement in a constructivist's classroom.

Gallagher (1991) used two data sources, namely, textbooks used by teachers and studies of classroom practice to determine how science is portrayed to to students in secondary schools. An ethnographic study was conducted to gain insight and understanding of what science teachers do when they teach science. An evaluation of textbooks used by the teachers revealed that :

> ***"secondary school textbooks devote nearly all of the print and illustrations to presentation of concepts and principles of science, with little attention given to the nature of science, or to how the knowledge of science is formulated or validated, ... or to the utility of the science in the daily lives of the students"***
>
> (Gallagher, 1991 : 123-124)

A critical analysis of the teachers' classroom practices showed that all teachers in the study placed most emphasis on the body of knowledge of science. The terminology of science was foremost in classwork, homework and tests. The understanding of scientific principles and relationships was neglected. The research revealed that majority of the teachers' in the study devoted no time to :

> ***"discussion of matters related to the nature of science such as how the knowledge included in the curriculum was formulated or the processes by which scientists validate knowledge ...... Teachers' frequently fail to point out obvious connections between classwork and the world outside of school."***
>
> (Gallagher, 1991 : 125-126)

Gallagher (1991) contends that the teachers' lack of understanding of the origins and applications of the scientific knowledge and their strong emphasis on the content knowledge of science in their teaching is reinforced by the textbooks that are available for their use. The issue of textbooks as a factor influencing teachers' beliefs is dealt with more fully in section 2.5.

2.4 HISTORY and PHILOSOPHY OF SCIENCE

A review of the literature has revealed an underemphasis of history and philosophy of science in school science curriculums and teacher training programmes in the USA and UK. This has resulted in a distorted perception of the nature of science. Listed below is literature that calls for the inclusion of history and philosophy into science curricula to enhance the image of the nature of science.

MATTHEWS (1994) in his book, *Science Teaching*, believes that science teaching can be improved if it is 'infused with the historical and philosophical dimensions of science' (Matthews, 1994). He maintains that the learning *of* science must be accompanied by the learning *about* science. A knowledge *of* science entails a knowledge of the products of science such as scientific facts, laws, theories whilst a knowledge *about* science involves the processes of science. The processes of science take into consideration the way science develops and is tested. Matthews states that the history and philosophy of science are essential to understand the processes of science. Furthermore, he believes that an inclusion of history and philosophy into the school science curriculum will improve science teaching and learning and will 'humanize' the sciences. The history and philosophy of science will give teachers a richer and more authentic understanding of science.

King (1991) highlighted the knowledge, beliefs and attitudes towards history and philosophy of science that student teachers bring with them to the classroom. The study involved thirteen (13) students who had been accepted in Stanford University's Teacher Education Program in Science. The student teachers had to complete a questionnaire prior to practice teaching and were interviewed after they had been practice teaching for at least one week. The majority of the student teachers, in the study, stressed the social construction of knowledge and that science is neither neutral nor objective. They, however, rejected the notion that science is merely a collection of facts that need to be imparted to students in a classroom.

These student teachers had little or no knowledge of the history or philosophy of science. A major finding of the study was that these student teachers' ignorance of history or philosophy of science influenced their teaching. The student teachers found it difficult to :

> ***"incorporate ideas such as inquiry; relevance; critical and creative thought into their teaching"*** (King, 1991 : 140)

The student teachers acknowledged that a knowledge of the history of science together with the grounding on the nature, purpose and value of science would help them in their classrooms.

2.5 FACTORS INFLUENCING TEACHERS' BELIEFS ABOUT THE NATURE OF SCIENCE

A review of the literature revealed that the following factors influence teachers' beliefs, attitudes and views about the nature of science. The false representation of science in textbooks and the curriculum; teachers' exposure to the philosophies of science and teacher training programmes at Universities and Colleges of Education were the prominent factors that impacted on teachers' beliefs about the nature of science. These factors are closely examined in the literature reviewed below.

2.5.1 Textbooks

Garrison and Bentley (1990 : 188) believe that :

> ***"...current teaching practices and instructional materials frequently misrepresent science and promote faulty reasoning "***

They, therefore, contend that science teachers need to be more thoroughly versed in the nature of science so that they make correct instructional choices in the classroom. The authors further contend that science textbooks, as instructional aids, ensure that the teacher functions in a positivistic frame. In textbooks, the introduction or chapter one, where the nature of science is discussed generally has a positivistic orientation. The following example is quoted from an American chemistry textbook in the research :

> ***"Someday you may decide to pursue a career as a scientist and seek facts about the world. As a scientist you will make observations. You will also hypothesize .... and then experiment to test your hypotheses. In this way you will add to the collection facts that scientists have already recorded."***
>
> Garrison and Bentley (1990 : 190)

The researchers found a common pattern in student activities in all textbooks that they examined. Textbooks followed a 'cookbook' method of doing experiments by encouraging students to arrive at conclusions through a process of induction. The following example is quoted from an American Physical Science textbook in the research article :

> ***"Students test the effect of various concentrations of salt on the boiling pointing of water. Under the section titled 'Analysis', the student is asked, "What conclusion can you draw from this experiment ? Explain why you think it is correct". "***
>
> Garrison and Bentley (1990 : 191)

The authors add that premises aren't listed or discussed and the results are assumed to confirm the hypothesis or predictions, without question.
The researchers concluded by stating that :

> ***"..an understanding of the issues and principles that are at the core of the nature of science would help teachers make wise choices with regard to teaching aids and methods."***
>
> (Garrison and Bentley, 1990:196)

The influence of science textbooks on science teaching is also examined by Stinner (1992). He found that :

> *"..science textbook writers as well as teachers emphasize the finished product of a 'scientific fact' and mathematical formulation in the teaching of Physical Science. Students, in turn, are trapped by the efficiency of memorizing the 'scientific fact' and the efficacy of applying the 'formulas' in solving exercise problems. The correct solution of the exercise problem then provides evidence for the teacher of the success of his / her teaching and it gives a sense of confirmation of mastery and understanding of the material.."*
>
> (Stinner,1990 : 2)

From the above quotation it is clear that students focus on mastery and memorization of 'facts' and therefore see little connection between their ideas about the world and what they learn in science textbooks. The author states that textbooks implicitly and explicitly support the empirical inductive picture of science. Stinner maintains that teachers need to examine the historical and philosophical contexts of information in textbooks since teachers fail to expose their students to situations where a law, theory, or concept may be challenged. This kind of activity and reflection would re-educate the teacher and the students and change their views and understanding of science.

Groves (1995) argues that many students consider science to be a collection of facts to be memorized. This over-emphasis on memorization of facts has resulted in a lack of understanding of science. Songer and Linn cited in the research point out that :

> *"..this method of studying science can lead to 'static beliefs' rather than 'dynamic beliefs'. Adherence to static beliefs is associated with negative attitudes towards science and the idea that science is not relevant."* (Groves,1995:231)

In this research, Groves evaluates the vocabulary and terminology used in textbooks, as textbooks form an integral part of any science lesson. Earlier research cited in the article show that 90% of teachers used the textbook

95% of the time. The researcher found that there was a heavy emphasis on terminology in the textbooks that were evaluated. The emphasis on terminology has resulted in rote learning and memorisation which has serious implications for how science is viewed.

According to Groves :

> ***"Focusing on memorization may contribute to the development of misconceptions that science is a finished body of knowledge comprising facts, proofs, and absolutes to be absorbed."***
>
> (Groves, 1995:234)

This is clearly a misrepresentation of science.

2.5.2 Curriculum

All science curricula contain views about the nature of science, that is, images of science that influence what is included in the curriculum, how material is taught and how the curriculum is assessed. Curriculum developers set the tone, for the image of science, in the curriculum. These images of science become statements about the nature and epistemology of science.

Wenham (1992) argues that the development of a broad, balanced science curriculum, relevant to the needs and interests of all pupils, is being held back and limited by narrow concepts of scientific activity adopted by educators and writers on science education. Wellington cited in the article by Wenham states that :

> ***"it cannot be doubted that, in the past, science education has overemphasised the products of science, that is, its laws, its theories, its knowledge, at the expense of its processes. But if this balance is to be redressed, it must surely be on the basis of an accurate account of the processes of science."*** (Wenham,1992 : 549)

Wenham states, in his research, that school science and science teaching has misrepresented both the nature of scientific knowledge and the process by which that knowledge is created and validated. He calls for an accurate representation of scientific activity as a whole in science teaching and science curriculums.

A theoretical report by Gruender and Tobin (1991) calls for reforms in the science curricula in the United States of America. According to the authors, science in the present curricula, is perceived to be a catalogue of truths about the universe which has to be learnt for recall in a test. They emphasize that :

> ***"..the curriculum needs to change to show science as a process - a means of gaining knowledge."*** (Gruender and Tobin, 1991:2)

The authors call for an inclusion of history and philosophy of science in the curriculum since these have been absent from all levels of curricula in the USA. The authors maintain that an inclusion of the historical and philosophical aspects of science in the curriculum will help students and teachers look at science as a human activity rather than as a body of facts or absolute truths and will help students and teachers understand what science is and what role it plays in society and civilization at large.

A similar call is made by Bybee, Ellis and Powell (1991). These researchers looked at integrating history and the nature of science into the science curriculum. They state that :

> ***"...the reason why students do not receive or understand the connections between science and society is partially due to the fact that students are not taught about these connections"***
> (Bybee, Ellis and Powell, 1991:143)

The empirical research cited in the article reveals a pattern of under-emphasis of history, the nature of science and technology in science curricula. The researchers found that teachers spend minimal time addressing material pertinent to the history and nature of science but gave primary attention to facts and methods. They found that practicals took the form of memorizing a series of steps in the method and reproducing these steps in the laboratory.

Other research cited in the article indicates that *inquiry* is not a widely implemented goal of science teaching and that teachers' lack of knowledge about the history and nature of science makes it difficult to elaborate on these topics during instruction. The authors contend that teachers should know 'what scientists do'. Possible misconceptions by teachers about 'what scientists do' results in an underemphasis of the nature of science in classroom practice.

The call for a change in science education in Britain was made by Kelly (1988). She states that :

> ***"...school science is seen as overly academic and theoretical, presenting disconnected bits of knowledge which are unrelated to pupils' lives ... Teachers emphasize these discontinuities rather than the continuities between school science and everyday knowledge, by stressing the laboratory as a different place with its own specialized apparatus and rules."*** (Kelly, 1988 : 152)

Schools neglect the social implication of science by presenting science as a collection of 'facts' unrelated to the people who discovered them, their historical contexts and reasons for needing this information. Kelly makes a plea to 'humanise' science and make it relevant to children's lives by placing it in a wider historical, sociological and philosophical context.

A similar call was made by Hodson (1988) who emphasized the need for a more philosophically valid science curriculum in the United Kingdom. He contends that teachers' inadequate views about the nature of science, together with a degree of confusion in the philosophical stance implicit in many contemporary science curricula,; has resulted in science curricula failing to achieve some of their declared goals in relation to children's understanding of science. The author maintains that many science teachers still subscribe to an inductivist view of science. This is so because :

> *"...the curriculum places emphasis on the processes of science (teaching science as inquiry) rather than using the processes of science to learn science (teaching science by inquiry)... The attainment of certain attitudes, the fostering of interest in science, the acquisition of laboratory skills, the learning of scientific knowledge, and the understanding of the nature of science by students are done inductively by teachers."*
>
> (Hodson, 1988 :22)

Inductive teaching of science by teachers causes student not to see science as a human activity shaping our lives and environment.

In an earlier article Hodson claims that :

> *"..the nature of laboratory work may be a crucial factor determining children's understanding of what scientists do and their attitudes towards science and scientists. However, teachers place a great emphasis on goals related to the acquisition of knowledge rather than to understanding the nature of science or to the development of attitudes."* (Hodson, 1986 :215)

Research cited in the article revealed that teachers subscribe to an inductivist view of science. This results in the science curricula being projected as neutral, value - free and absolute truths, functioning independent of socio - historical - economic issues. Hodson contends that, in the inductivistic view of science, :

> *"...scientists are viewed as objective, open-minded, unbiased and possessing the know - how to ascertain the truth about the universe. These myths about science and scientists are internalised by teachers during their own science education and, subsequently, are represented to children through the curriculum."* (Hodson, 1986:220)

Further, these views about science undervalue creativity, imply single solutions to problems, make no allowance for individuality and ignore differing opinions. Teachers subscribing to this perspective of science do not teach their pupils the processes of science and do not put their pupils in the situation of 'being a scientist'.

Hodson (1993) also gives a different perspective to science curricula when he proposes that science education should become society - oriented and learner - centred. Hodson proposes that a learner - centred science curriculum must take into account the experiences of all pupils and must therefore be multicultural in nature. An evaluation of curricula in the USA, UK, New Zealand, Australia and Canada reveals that the needs, experiences, interests and aspirations of ethnic minority groups are ignored because of the western orientation of the science curriculum's content and curriculum materials which are sexist and racist.

Another reason proposed by Hodson is that :

> ***"The image of the scientist as the controller, manipulator, and exploiter of the environment is in conflict with the cultural values of some children."*** (Hodson, 1993 : 687)

Hodson advocates that a multicultural science curriculum will help pupils gain a better understanding of "*their* world, *our* world, and *the* world". (Hodson, 1993 : 690) Simply, a multicultural approach will ensure that pupils will understand the historical development of scientific theories and principles and recognize the contributions of non - Europeans to science. This way will also ensure that pupils will be able to explore and develop their own ideas.

A similar call for multicultural science education in the USA is made by Murfin (1994). According to Murfin :

> ***"..The history of science as it has been taught in schools has been from an exclusively white, European, male perspective. Females and people of many of the world's cultures have been excluded from the history of science."*** (Murfin, 1994 : 96)

He contends that western science has denied the validity of other cultures' contribution to science.

2.5.3 Philosophies of science

The transmission approach to science teaching has resulted in the personal experiences of students being neglected in their construction of knowledge. Gilbert and Pope (1983) state that :

> ***"...effective teaching relies on the teacher having some understanding of students' view points..... Few science teachers pay attention to, and make use of, the personal experiences and spontaneous reasoning of their pupils"***
>
> (Gilbert and Pope, 1983:193)

The main premise advocated by the authors is that significant learning is likely to occur if the 'facts' to be learnt by the learner are construed as having personal relevance. The authors add :

> ***"...traditional teaching methods emphasize the students' role as the passive receiver of information rather than as active participant. This positivist, empiricist - inductivist conception of science is in sympathy with an absolutist view of truth and knowledge"*** (Gilbert and Pope, 1983:194)

Teachers aligned to this perception of science teach the curriculum content 'robot style', that is, with little or no emphasis on student's personal or prior knowledge and active participation. The researchers encourage teachers to foster in their students the need to question and develop their own criteria regarding the quality and relevance of ideas. They state that students should not accept unquestioningly information given by teachers. Teachers must help students establish the relevance of knowledge and develop links between their personal experiences and concepts learnt. Teaching strategies such as role - playing, simulation, group discussion, syndicate work and interactive lecturing are suggested by the authors.

Driver (1983) considers the different views of the nature of science in her book *The Pupil as a Scientist*. The first view of the nature of science discussed is the empiricist's view which regards knowledge as being based on observations only. Scientific laws are reached by a process of induction from the 'facts' of sense data. Observations are considered to be objective and facts unchangeable. This view encourages students to explore events and phenomena first hand and induce generalisations and principles for themselves. Philosophers of science and scientists recognize the limitations of induction and acknowledged the important role imagination plays in the construction of scientific theories.

In the alternate constructivist view :

> ***"...theories are constructions of the human mind whose link with the world of experience comes through the processes by which they are tested and evaluated"*** (Driver, 1983:4)

Driver suggests that teaching needs to relate what is familiar to children, not just at the level of the world of events and experiences, but also in their world of ideas. The task of educators is to give students experiences that will help develop their thinking. Teachers are to act as mediators between pupils' experiences and understandings and the scientific community.

The contributions made by great philosophers of science education are elaborated in the book by Anderson, Hughes and Sharrock (1986). Brief descriptions about the theories and contributions by some philosophers with respect to the nature of science are discussed below.

Karl Popper was primarily concerned with finding a way around the problem of induction. He contends that scientists should not be trying to verify theories by carrying out experiments expected to confirm them but should instead be trying to falsify the theories. He points out that progress in science takes place when theories are disproved and replaced by better theories. Progress in science is made when we are confronted by problems arising out of observations of the world. Popper believes that theories are formulated initially as inspired guesses or conjectures. Experimental evidence will help accept or reject the theory.

Thomas Kuhn, like Popper, concentrated on scientific theory and proposed the concept paradigm (a set of ideas or beliefs) and distinguished between normal and revolutionary science. He examined the historical process through which science is produced and pointed out the contrast between science seen historically and the image of science portrayed in textbooks. He noted that textbooks often regard out - dated theories as unscientific. Also, the problems and standards of the scientists of the past are not compared to contemporary scientists. Unlike Popper, Kuhn relates science to society and people. According to Kuhn, in normal science there is a history of stability, homogeneity and continuity whilst in revolutionary science there is conflict, disruption and change. The scientific community is held together by the sharing of basic ideas - paradigm.

Imre Lakatos examined the research programme used to formulate scientific theory. He attempted to reconstruct scientific history and divorced himself from what he considered 'meaningless scientific theorising'. He differed from Kuhn, in that he proposed that science is a rationally accumulated body of knowledge. He claimed that scientific progress was not solely by trial and error as proposed by Popper, but agrees with Kuhn that there is a relationship between scientific reasoning and historical factors. However, he does not state the degree of relationship.

2.5.4 Teacher training / preparation at a University or College of Education

Young and Kellogg (1993) studied the attitudes of prospective elementary teachers at university to science. According to the authors, their research provided great insights into undergraduate science education and the preparation of prospective elementary teachers. Their research revealed that large numbers of prospective teachers avoid courses that have laboratory work due to their lack of science background. Also, the science courses focused on the content of science rather than the application of scientific principles.

> ***"Science must be taught in a way that allows students to see the 'big picture' and be exposed to applications of scientific principles. The emphasis on one right answer or solution must be abandoned and collaborative terms utilized, rather than focusing on competitive individualism. The 'coverage' of massive volumes of content without interaction should not continue."*** (Young & Kellogg, 1993 :289)

Also, the student teachers considered themselves to be passive recipients of knowledge and did not assume responsibility for building the content knowledge in their classes. Further, they relied solely on the lecturers to make the lessons interesting. The research also showed that student teachers were strongly influenced by their teachers at elementary and secondary schools. Their early experiences at school influenced the direction they took at university.

A qualitative study conducted by Palmquist and Finley (1997) focussed on preservice science teachers' views about the nature of science and how these views change during a teacher education program. Before entering the teaching program, the participants in the study were categorised into different conceptual frameworks. Palmquist and Finley found that the participants had a contemporary (postpositivist) view of scientific theory, knowledge and the role of a scientist and a traditional (positivist) view of scientific method. The participants' views about the nature of science was determined by a survey and follow - up interviews. The interviews took place before and after they were taught the science teaching methods course. The researchers found that all preservice teachers' views of the nature of science changed during their time in the science teaching methods course as the methods courses protrayed a comtemporary view of the nature of science.

The nature of science was examined under 5 broad categories, namely, scientific knowledge, scientific method, scientific theory, scientific law and the role of the scientist. One of the critical questions examined in this research was :

> ***"What aspects of the nature of science are portrayed in the classroom actions and activities of the preservice teachers during their practium experience ?"*** (Palmquist and Finley, 1997 : 598)

The researchers found that the traditional or contemporary beliefs about the nature of science held by the preservice teachers are manifested in their classrooms, their lessons plans and in their discussions about teaching. Hence, teachers' classroom decisions are guided by their personal theories of science. Palmquist and Finely add that teachers could, therefore, make better curricular decisions with respect to the nature of science if they knew how different classroom activities portray the nature of science.

A similar study, using preservice teachers, was conducted by Kelly (1997). This research explored HDE preservice teachers beliefs about science, science teaching and their experiences of the teacher preparation programme. This study was undertaken as three case studies with data being collected through interviews, classroom observations and personal journals. Some interesting findings in the research are :

a) Student teachers easily abandon their ideals to resolve the conflicts between their own ideas of science and science teaching and the realities of the classroom.
b) For a teacher to adapt to a new curriculum, he or she should feel

confident with the content. Any insecurity in this area will lead to a reversion to chalk and talk and authoritarian teaching. Limitations to the subject matter knowledge constrains a teacher's teaching methods.

The researchers found that each teacher in the case study subscribed to their own view of science and science teaching. They found that teachers do not follow their beliefs in inquiry due to inadequate knowledge of the subject matter. Hence, the prevailing conditions at school cannot be ignored when considering the implimentation of beliefs in practice.

Czerniak and Chiarelott (1990) explore ways in which teacher education can be used for effective science instruction in the classroom. According to the authors, science education suffers because of teachers' inadequate preparation and their negative attitudes. Teachers' negative experiences in science such as "lack of time allowed for preparing for science teaching, lack of science content background needed to teach the subject effectively, lack of administrative support, and poor funding for supplies and equipment" (Czerniak and Chiarelott, 1990 : 51) impacts on the quantity and quality of science instruction.

The authors call for teacher education programmes to prepare teachers for the realities of classroom management in a science class as a science class differs from other subject classes due to the laboratory, inquiry - based nature of science. The authors also state that there is a need for teacher education curriculum to address issues of equity in science. According to the authors the science curriculum should :

> ***".extend beyond the classroom to include experiences with neighbourhoods nature centres, museums, zoos, airports, and other community resources. Integration of science into other settings and subject areas seems to have a particularly positive effect on females and minorities."***
>
> (Czerniak and Chairelott, 1990 : 54)

2.6 CONCLUSION

The literature review has shown that empiricism and induction are the cornerstones of the traditional view of science whilst constructivism and deduction are the pillars of the contemporary view of science. This chapter has focused on the nature of science, teachers' beliefs, teachers' classroom strategies, the history and philosophy of science and factors influencing the teachers' beliefs about the nature of science. The purpose of this chapter was to develop a conceptual framework for the research and highlight the nature of science.

Constraints of time, money, distance and length of report resulted in me concentrating on two aspects that influence teachers' beliefs about the nature of science, namely textbooks and the curriculum. Issues involving gender, culture, teacher education and training at universities and colleges of education, technology and other factors that influence teacher' s beliefs have been considered but not elaborated in the study.

The data collected using the different data collection strategies will be analysed in the next chapter whilst further interpretations, recommendations and conclusions will be identified in the chapter 5.

CHAPTER THREE

DESIGN OF THE STUDY : RESEARCH METHODOLOGY

3.1 INTRODUCTION / OVERVIEW

The purpose of this chapter is to provide detailed insight into the research instruments used for this study and to develop a theoretical framework for the study. This research was conducted as a case study which combined qualitative and quantitative methods of data collection. The researcher used questionnaires to obtain a combination of qualitative and quantitative information and interviews and classroom observations to gather qualitative information. The reason for combining the quantitative and qualitative approaches was to improve the validity of the study. This is supported in a book on research methodology, dealing specifically with case studies, by Merriam (1988) :

> ***"This is in fact a form of triangulation that enhances the validity of one's study."*** (Merriam, 1988:2)

3.2 CHOICE OF THE RESEARCH SITE

The research was conducted in the Richards Bay / Empangeni area. This locality was chosen because the researcher has resided and taught in Richards Bay for the last three years. Time and monetary constraints for the research also ensured that the schools chosen for the study had to be in close proximity of the researcher. Furthermore, this area was chosen as it has schools from the ex - Departments of Education such as ex-House of Delegates, ex-House of Assembly and ex-Department of Education and Training. Schools in the area comprise ex - model C schools and state schools which are now called public schools.

Also, the researcher is familiar with the environment and has developed an excellent working relationship with Physical Science teachers in the area. The researcher's involvement in extra mural work in Physical Science, such as contributions at regional and departmental meetings and tutoring disadvantaged pupils from the townships and outlying rural areas, facilitated this research investigation. Consent from the

Department of Education for access to schools was difficult to obtain. Hence, access to teachers from different schools, in this study, was through Heads of Department and teachers with whom the researcher is familiar.

3.3 RATIONALE FOR A CASE STUDY

This research was conducted as a case study which combined qualitative and quantitative methods of data collection. A detailed ethnographic study was considered ideal for this research. However, time and monetary concerns resulted in the ethnographic study being rejected. The case study method was favoured for this research as it was similar to an ethnographic study and it allowed me to examine teachers, who participated in the research, in their natural context. This allowed me to interact with teachers' in the sample in a natural and unobtrusive manner. Further, a case study allowed me to be flexible by enabling me to develop concepts, insights and understanding from patterns in the data. Also this research was conducted as a case study due to the small number of teachers in the sample. According to Merriam (1988 : 23) :

> ***"An ethnographic case study then, is more than an intense holistic description and analysis of a social unit or phenomenon. It is a sociocultural analysis of the unit of study. Concern with the cultural context is what sets this type of study apart from other qualitative research."***

My intention with this research was to establish the relationship between teachers' beliefs about the nature of science, their view about science and how they taught science to their pupils. To be able to do this I needed to get a detailed understanding of the teacher's perspective about science. This was only possible by observing teachers in the classroom and listening to them talk about science. The case study method enabled me to 'blend into the woodwork' and not be conspicuous when observing the teacher in the classroom and helped me develop an understanding of environment the teacher operated in.

A case study allows the researcher to use multiple methods of data collection. According to Merriam :

> ***"Unlike experimental, survey or historical research, case study does not claim any particular methods for data collection or analysis. Any and all methods for gathering data from testing to interviewing can be used in a case study."*** (Merriam, 1988 : 10)

For this research a questionnaire, classroom observations and interviews were the key forms of data collection. These are described in detail in section 3.5 later in the chapter.

3.4 THE SAMPLE

Prior to 1994, the provision of education was considered an ' own affair ' and came under the control of the racially divided houses of the tricameral parliament. Education in the black homelands was provided by the homelands themselves. The Department of E ducation and Training catered for black South Africans not living in the homelands. Although no homeland existed in Natal, education for blacks was catered for by the Department of Education and Training (controlled and manipulated by white South Africans for their own apartheid purposes) and the KwaZulu Education Department.

In 1994 segregated education was abolished with the election of a new democratic government. Nine provincial education departments were established to cater for the the educational needs of the people residing in each province regardless of race. Although the dissolution of the different education departments in Kwazulu Natal has been an extremely slow process, eight(8) regional education departments have been established. Whilst the regions control and administer many aspects of education within their region, some aspects such as monetary allocations, salaries, leave taken by educators, and other similar matters continue to be monitored and administered by the various ex-departments of education of the different racial groups. This research was conducted in one of the eight regions demarcated by the provincial education department, namely the Lower North Coast Region of which Empangeni and Richards Bay are part.

Multiple data collection methods were used in this research. The data for this research was collected by means of questionnaires, interviews and classroom observations. Initially, the teachers in the study were required to complete a questionnaire. Twenty five (25) questionnaires were distributed personally by the researcher to six (6) different schools the Empangeni / Richards Bay area. The questionnaires were sent to schools from the four (4) ex-Education Departments, Ex - House of Assembly, Ex - House of Delegates, Ex - Department of Education and Training and Ex - KwaZulu Education Department. There are no Ex - House of Representatives schools in this area. The schools chosen were representative of the different kinds of schools in the area and were chosen because of access and locality of the schools. The six schools were two (2) English medium ex - model C schools from the ex - House of Assembly ; one (1) Afrikaans medium ex - model C school from the ex - House of Assembly; one(1) ex - House of Delegates School; one (1) school from the ex - Department of Education and Training and one (1) from the ex - KwaZulu Education Department.

Access to teachers in these schools was extremely difficult and had to be done via persons with whom the researcher was familiar at the different institutions, such as the teachers, Heads of Departments, Deputy Principals or Principals. The questionnaire was administered to teachers from the Empangeni / Richards Bay areas teaching General Science, Biology or Physical Science. The questionnaires were used to choose three secondary school science teachers, with similar or different strands of thought. All teachers in this study are employed by the Provincial Education Department and teach at public schools as classified by the South African Schools Act No. 84, 1996.

The questionnaires were given to teachers in the different schools by the representative chosen by the researcher. The questionnaires were self - administered by the teachers during their own time. All teachers who returned the questionnaire were given an equal chance of becoming members of the sample of three teachers. By ensuring that teachers from different schools filled in the questionnaire the researcher was able to obtain, if any, differences in teachers' classroom practices depending on scientific background, beliefs, educational resources being used, and qualifications. Also, this ensured that no discrimination was made because of gender, race or qualification.

3.5 DEVELOPMENT OF THE RESEARCH INSTRUMENTS

Time, distance and monetary constraints rule out a detailed ethnographic study although this would have been the most effective way to conduct this research. Hence, other appropriate research instruments had to be developed to obtain as much information as possible in a short space of time. The following research instruments were developed and used in this study, namely questionnaire, interview, classroom observation and document analysis. These research instruments are closely examined below.

3.5.1 Questionnaire

Information from questionnaires formed an important source of data in this research. The purpose of the questionnaire was to obtain background information relating to teachers' beliefs; the nature of science and classroom practices from the teachers used in the study. The initial questionnaire was designed by the researcher with inputs and suggestions from his supervisor.

The initial questionnaire was piloted with four (4) science colleagues in the Masters Programme. The persons involved in piloting the questionnaire are experienced and well respected science educators. Two of the educators are Heads of Departments in their respective schools; one is a senior lecturer at a College of Education in Durban and the last person is a senior Physical Science teacher (17 years teaching experience) in Phoenix, outside Durban. Their invaluable contributions revealed that some of the statements were unclear and ambiguous. Also, they expressed the concern that the questionnaire ignored second language speakers. They were of the view that the questionnaire should take into consideration second language speakers as the questionnaire would be administered to teachers in previously disadvantaged schools. Another concern was the confusion of the terms syllabus and curriculum. They believed that from the questionnaire the use of syllabus and curriculum were used in the same context and, therefore, had the same meaning. They suggested that the term syllabus be used instead of curriculum. Another difficulty they encountered with the questionnaire was the limited space provided in the questionnaire to respond to certain questions. They requested that more lines be allocated for answers to the questions in sections A and C of the questionnaire.

The researcher implemented these suggestions and contributions with the additional comments from the his supervisor. The questionnaire was then piloted a second time by five (5) teachers of the Sadtu North Coast Regional Physical Science Committee. The researcher is a member of this committee. The teachers that participated in this pilot were all senior Physical Science teachers at their schools. The teachers felt the questionnaire was too long as it required detailed and careful reflection of their classroom practices. The teachers also felt that the questionnaire was too detailed and philosophically inclined.

To verify the length of the questionnaire and inputs from the teachers on the North Coast, the researcher piloted his second draft questionnaire with three (3) teachers that belong to the Empangeni / Richards Bay Mathematics and Science Project. This project was run by a group of concerned Mathematics and Physical Science teachers, on a voluntary basis, for pupils from the disadvantaged communities around Richards Bay and Empangeni. The researcher is one of the teachers' in this programme. The three teachers found the questionnaire was long and time consuming. However, they had little difficulty answering the questionnaire. After discussions with the teachers, the researcher eliminated some questions from the second draft questionnaire to ensure that the questionnaire was not too long.

The third draft questionnaire was developed with the specific intention of ensuring that the questionnaire was not time consuming. Also the table of statements were subdivided into three tables. Statements in relation to each critical question was placed on the same page. Once the questionnaire was constructed, it was discussed with the supervisor. With the assistance of the supervisor, the language used in the questionnaire was further simplified. The supervisor offered suggestions on how to improve on the image of the questionnaire. The questionnaire was then finalised taking into considerations suggestions and inputs from the supervisor. The final questionnaire (refer to Appendix No. I) was divided into three (3) sections. Section A required the teachers to provide biographic data about themselves, the subjects they teach, their exposure to history and philosophy of science and matters discussed at science meetings.

Section B of the questionnaire required teachers to indicate the degree to which they agree or disagree with statements listed (based on the Likert Scale). The statements were linked to the three critical questions with the intention of providing the researcher insights into teachers' beliefs and classroom practices. The statements in this section of the questionnaire focus on the following aspects :

a) the knowledge, beliefs, and attitudes about the nature of science that teachers' bring with them into the classroom.
b) the influence of textbooks and the curriculum on classroom practice.
c) philosophies of science.
d) evaluation and testing.

Section C in the questionnaire has open - ended questions of a philosophical nature. These open ended questions allowed teachers, in the study, to verify and justify, in detail, responses to statements made earlier in the questionnaire (Section B). Some open - ended questions asked by the researcher were : What is Science ? ; How is scientific knowledge produced ?; What are your goals as a science teacher ?; Why is an understanding of the nature of science important ?; and How should science be taught in schools ?. Teachers responses to the open - ended questions enabled the researcher to get sufficient elaboration of teachers insights and understandings on the nature of science and allowed the researcher an opportunity to check and compare responses of teachers within a questionnaire.

3.5.2 Interview

The researcher decided that an interview would be an appropriate research instrument as it would allow him to personally interact with the teachers, in the study, on a one - on - one basis. Also, the interview provided the researcher with an opportunity to obtain detailed explanations, from teachers, for the purpose of the research. Although the questionnaire was the major instrument used in this research, the researcher is of the view that interviewing the three (3) teachers selected for the study was essential to corroborate findings and provide greater insight into the way teachers think. Furthermore, the researcher was able to get an understanding of teachers' responses in the questionnaire through an interview.

Using the responses of teachers in the questionnaire as a guide, an interview schedule for teachers' was constructed. Time constraints ensured that the interview schedule could only be piloted with teachers within a close locality of the researcher. Hence, the researcher used the responses of teachers, in the second draft questionnaire, from the Empangeni / Richards Bay Mathematics and Science Project to trial his first interview schedule. The teachers were asked to further elaborate on their responses in the questionnaire. The researcher found that, during the piloting process and the actual interviews, the teachers were uneasy and nervous about their responses in the questionnaire being scrutinised in their presence. Also, they considered their responses as being incorrect and the researcher had all the 'right' answers. The researcher had to explain to the teachers that there were no 'right' answers and that their responses are strictly confidential. The researcher found that talking to teachers about their school, pupils, family and sport help to 'distract' teachers from their responses in the questionnaires and set them at ease. The researcher, therefore, engaged in a discussion with the teachers before the interview explaining to them the need for the interview, and answered any questions that they posed.

The piloting of the interview schedule showed that some teachers displayed strong dislike for being audiotaped. The researcher had to take notes in his research diary when a teacher refused to be audiotaped. Another problem the researcher encountered was the time allocated for the interviews. If the interview exceeded thirty (30) minutes, then teachers begin to give short and untruthful responses to get the interview over; in the words of one teacher; "over and done with". The time factor was also a problem in the actual interviews where teachers complained about a lack of time for preparation for the next day's work, family chores, administrative work at school, and other similar reasons. Hence, teachers requested for the interviews to be as short as possible. Another problem encountered by the researcher was the over - eagerness of some respondents to want to please the interviewer by trying to provide the 'right' answers. The researcher found that having a fixed set of questions was problematic and teachers generally deviated from the questions to other issues. Hence, the decision to use prompts, from teachers' responses in the questionnaire, when conducting the interview.

Before developing the final interview schedule the researcher also piloted the interview schedule with one teacher from the Sadtu North Regional Physical Science Committee. The teacher had little difficulty with the interview. However, the one problem encounter by the researcher was his personal bias. In the second pilot interview, he attempted to seek answers that supported his theoretical framework. Using the information gained during the piloting process the researcher decided that an informal, semi - structured interview was to be conducted with the teachers of similar or different strands of thoughts. The interview was to be of thirty (30) minutes duration and audiotaped and took place at a time and place agreed to between the researcher and the teacher.

As the interview was a follow-up of teachers' responses to statements and questions in the questionnaire, the interviews were conducted within a week of completion of the questionnaire. This time gap allowed the researcher to analyse the responses in the questionnaire and select the teachers he wanted to use in the study. Also, the short time gap ensured that the teachers' responses in the questionnaire were still 'fresh' in their minds and this would facilitate the interview.

The purpose of the interview was for further elaboration and clarification of responses in the questionnaire. Also, the interview focused on the ethos of the school, that is, the school governance, structure, management and teachers. The interview focused on the kind of school the teachers operate in, their attitude to examinations, the freedom that they have to engage in individual projects, the support that they get from colleagues and the management, and questions that are a follow - up from individual responses relating to science in the questionnaires.

3.5.3 Classroom Observations

The purpose of this study is to evaluate teachers' classroom practices taking into consideration teachers' views of the nature of science. The classroom observations were used by the researcher to study the teachers' classroom practices. These observations gave the researcher first hand information about what's happening in the classroom. One of the areas classroom observations focussed on, was the teaching strategies adopted by the teacher such as co-operative learning using group work, question and answer, discussion, practical work (individual and group) and other techniques. The classroom observations, therefore, helped the researcher to establish the additional information about :

a) textbooks (their use in the classroom by teachers and pupils) ;
b) syllabus (Do teachers adhere strictly to, or are flexible with the syllabus ?);
c) teaching strategies (the teaching methodologies used by the teachers);
d) tests and examinations (their importance as a means of assessment);
e) other factors that impact on teachers' view of the nature of science.

The researcher decided, after negotiation with the teachers in the study, that teachers would be observed in their classroom four (4) times. They were observed, as they taught, at least once a week for a period of one month.

3.5.4 Document Analysis

A review of the literature in the field clearly indicates that teachers' beliefs about the nature science is influenced by the curriculum (Bybee, et al, 1991) and textbooks (Stinner, 1992) and this impacts on teachers' educational practices (Brickhouse, 1991). As all the teachers are employed by a state controlled education department all the teachers in the study teach the same prescribed core national science syllabus and use the same prescribed textbooks.

Textbooks and the curriculum are the teachers' main source of information and 'guide' in school. An evaluation of textbooks and the curriculum was essential, for the researcher, to understand the impact that these have on shaping teachers' beliefs and classroom practices. The analysis of these documents focussed on how the nature of science was portrayed in textbooks used in schools and its emphasis in the curriculum. To determine whether a change in thinking among curriculum developers is taking place, the researcher will compare how the nature of science is portrayed in the old syllabus with the new curriculum in an outcomes - based educational environment.

3.6 DATA ANALYSIS STRATEGY

The information from the interviews, on the audiotapes, was transcribed and returned to the teachers for verification. The responses of interviewees was divided into two categories, namely, the teachers' beliefs about the nature of science and secondly, their classroom practice. The data obtained from the questionnaires was manually coded, with teachers having similar trends of thought, being grouped together. Teachers' responses to statements in the questionnaire were tabulated and analysed. Information obtained from the interviews and responses in questionnaires will be compared and analysed.

I am of the opinion that the validity of this study was enhanced by comparing and validating responses in the interview and questionnaire. With the aid of classroom observations the researcher was able to triangulate the data. This further enhanced the validity of the study. In the next chapter the data obtained from the questionnaires, interviews, classroom observations and document analysis will be analysed.

CHAPTER 4

INTERPRETATION AND ANALYSIS OF RESULTS

4.1 INTRODUCTION

According to Hurd who is quoted by Carey and Stauss (1970 : 368) :

> ***"It is undoubtedly true that a teacher's concept of what science is influences not only what he teaches but how he teaches"***

The teacher's concept of what science is and how it influences his / her classroom practices are explored and analysed in detail in this chapter. The researcher will outline the findings of the research from the questionnaires, interviews and classroom observations. The findings from the research will be analysed and interpreted to establish a relationship (if any) between teachers' beliefs about the nature of science and their classroom practices.

4.2 BACKGROUND TO DATA COLLECTION

4.2.1 Questionnaires

Twenty five (25) questionnaires were handed out to science teachers in the Richards Bay / Empangeni area and twenty four (24) were returned to the researcher. This represents a return of 96 %. The one questionnaire that was not returned was issued to a teacher who was subsequently promoted in the last round of promotions in the province. Numerous efforts by the researcher to locate this teacher and obtain the questionnaire were futile. Although a 96% return was obtained, two (2) questionnaires were returned with only the first page completed and in another two (2) questionnaires the open - ended questions were not answered.

One of the teachers who did not complete the questionnaire wrote the following note on the questionnaire :

> ***" After reading through the questions I found that my feelings and reasoning being considered. The questionnaire is misleading and supports their point of view."***

A brief discussion with the teacher revealed that she had made no effort to complete the questionnaire due to work commitments but, more importantly, she refused to be reflective about her teaching practices. She did acknowledge, however, that the many questions in the questionnaire differed from her own beliefs, hence her statement *"...the questionnaire is misleading and supports their point of view."*

The other teachers that did not complete the questionnaires were unable to do so due to time constraints and work commitments. Although the rest of the questionnaires were completed, some teachers did leave a few blanks when responding to individual items in the different tables.

4.2.2 The sample of teachers

The questionnaires were used to select three (3) teachers for the research. The researcher intended to use three (3) teachers, each with differing points of view on science irrespective of race, language or gender considerations. However, on analysis of the responses in the questionnaire, the researcher was able to isolate two distinct trends of thought about science. The researcher found that majority of the teachers that completed the questionnaire operated in a positivistic framework whilst other teachers operate in a hermeneutic framework. None of the twenty (24) teachers who completed the questionnaire operated in the emancipatory (critical) or a postmodernist framework. The researcher chose two (2) teachers with similar beliefs about science. The other teacher that was chosen operated in a different theoretical framework from the first two (2) teachers. Hence, all three teachers did not have the same theoretical framework. This would enabled the researcher to establish a link between teacher's views about the nature of science and their classroom practices. The two teachers with similar beliefs operated in the empirical / positivistic framework whilst the other teacher operated in the interpretive / hermeneutic framework. The questionnaire was the only instrument used initially to categorise the teachers.

To do this, ten statements of a positivistic nature about the nature of science, from the different tables in the questionnaire, were used. The table below identifies these ten statements which are also found in the research questionnaire (appendix 1).

no	statement
1.	*Science is objective and value free.*
2.	*All scientific knowledge is true.*
3.	*Science has a core body of knowledge that never changes.*
4.	*All scientists follow a common routine when doing research.*
5.	*Scientists are particularly objective people.*
6.	*Scientific laws are unchangeable and absolute truths.*
7.	*Textbook drawings and pictorial illustrations are a true representation of science.*
8.	*The main task of a teacher, when teaching science, is to disseminate scientific information.*
9.	*Pupil inquiry is restricted to classroom experiments from the syllabus.*
10.	*Pupils learn the processes of science through induction, that is, doing an experiment by following a worksheet.*

Table 9 : Statements used to categorise teachers

Teachers agreeing with the above statements were placed in the positivistic framework. Teachers disagreeing with the above statements were placed in the interpretative framework.

4.2.3 Research bias

The researcher endeavoured to ensure that the research was not biased in any way. The questionnaires were handed out to science teachers at the different schools and was not aimed at a particular race, gender or language group. The twenty (24) questionnaires returned were completed by 11 males and 13 females. There was no gender bias in this research as the questionnaires were completed by an equitable number of males and females. The questionnaires were completed by teachers who taught in single medium schools, either English or Afrikaans medium schools, and in dual medium schools where Zulu and English were used as the mediums of instruction. Hence, the research was not biased towards a particular language group.

No concerted effort was made by the researcher to target a particular racial group for this research. 'White', 'Indian' and 'Black' teachers, as previously classified, completed the questionnaires. There were no 'Coloured' teachers in the research area. Teaching experience was not used as a criterion to obtain the sample of three teachers. From the questionnaires returned, teachers had between one (1) year and sixteen (16) years teaching experience.

The questionnaires were completed by teachers teaching Biology, Physical Science or General Science. The table below indicates the subjects taught by teachers who completed the questionnaires and the range of their teaching experience in years.

subjects being taught	***number of teachers***	***range of teaching experience in years***
PHYSICAL SCIENCE *only*	1	15
BIOLOGY *only*	4	2 - 16
GENERAL SCIENCE *only*	3	1 - 9
GENERAL SCIENCE & PHYSICAL SCIENCE	6	1 - 15
BIOLOGY & GENERAL SCIENCE	4	3 - 8
PHYSICAL SCIENCE & MATHEMATICS	4	1½ - 5

TABLE 2 : Subjects taught and years of teaching experience

From the table 2 it is clear that majority of the teachers in the study taught a combination of subjects and that their teaching experience in the subject was varied. As the researcher is a Physical Science teacher, he limited his sample of 3 teachers to persons who taught Physical Science irrespective of their years of teaching experience. Furthermore, all teachers who completed the questionnaire had a University degree or a teacher training qualification from a College of Education. There were no unqualified or under - qualified teachers in this research. The fact that the teachers had a qualification from a tertiary institution enhanced the research as the teachers were thoroughly familiar with science at university or college level and at school level. This ensured that the teachers had greater insight into science and science teaching.

4.2.4 Biography of the three (3) teachers in the sample

As indicated in 4.2.2, three teachers were chosen for the study. The purpose of the teacher biography is to provide a background to the teachers in this study so that information obtained from them can be seen in the context of their work situation. Also to ensure the anonymity of the teachers in the research, they will be referred to as Teacher A, Teacher B and Teacher C. These teachers readily agreed to be part of the study and access to these teachers was through their Heads of Department or Deputy Principals.

a) TEACHER A

Teacher A is a 'white' male who has been teaching Physical Science at an Afrikaans medium school for 15 years. He has a B.Sc and H.E.D qualification and teaches both Physical Science and General Science. His school is an ex - model C school and has amenities such as lights, water, photocopier, laboratories, sportfields and school hall. The school laboratory was well equipped with sufficient chemicals and apparatus for pupils to do individual or group experiments. Teacher A is a level one educator and does not belong to any professional teacher organisation related to science. His Head of Department is more inclined towards the biological aspects of science as she is a Biology teacher. He therefore controlled all aspects in relation to Physical Science.

b) TEACHER B

Teacher B is a 'black' male who recently qualified from the Esikhawini College of Education. He has been teaching Physical Science for three (3) years. He has a Secondary Teachers Diploma (STD). He teaches Physical Science and Mathematics at a school in Enseleni just outside Richards Bay. His school is a dual medium school. English and Zulu are the languages of instruction. His school does not have a laboratory and hence, he has no apparatus to do experiments. The school borrows equipment from neighbouring high schools in the area or from the Centre for Advancement of Mathematics and Science Education (CASME). Although his school lacked equipment to do experiments, teacher B showed tremendous enthusiasm and resolve to do experiments. He used the experiment kits obtained from CASME to show his pupils experiments. He does not belong to any professional teacher organisation for science and is a level one educator. He did not have a Head of Department to 'guide' him. He seeks advice from senior teachers in the area.

c) TEACHER C

Teacher C is a 'white' female who recently graduated from university with the following qualifications : B.Sc and HDE. She has been teaching both Physical Science and General Science for two (2) years. She teaches at an English medium, ex - model C school in the area. Her school does not lack any facilities or equipment. She is a member of the recently launched provincial science body called KASTE (Kwazulu Natal Association for Science and Technology Educators). Her Head of Department is a Physical Science teacher.

4.3 ANALYSIS OF THE DATA

In analysing the data the researcher will integrate the data obtained from the questionnaires, interviews and classroom observations rather than present the analysis separately for the different kinds of data. The researcher believes that integration of the data will help to establish a clearer picture of the teachers' theoretical framework. Further, combined information obtained from the different data sources such as interviews, questionnaires and classroom observations helped the researcher place the teachers in a particular theoretical framework.

From the questionnaires, interviews and classroom observations, information relating to the following aspects were obtained :

a) teacher biographies and matters discussed at science meetings

b) the nature of science
c) teachers beliefs about the nature of science
d) factors influencing teachers beliefs about the nature of science, namely:
   I) textbooks
   II) curriculum
   III) philosophies of science
   IV) teacher training
e) classroom practices

The results from the different data sources were tabulated and analysed under the above headings. The table of results represents teachers' responses to statements in the questionnaire. Teachers' responses to statements in the questionnaire is summed within each of the response choices after determining the number of teachers selecting each response. No detailed statistical analysis will be done to verify the results obtained. The teachers' responses to the open - ended questions were analysed together with the tabulated responses and the information obtained from the interviews.

4.3.1 The nature of science

Science is not only an activity of the mind; widening our horizons and sharpening our curiosity; it also has many applications. It provides possible explanations for everyday observations and phenomena. It also attempts to provide models and to theorize about how things happen. Science stimulates technologies which have vastly, on balance, improved our well being. The definite character of science is found in its attempts to find solutions and in the new questions it raises. The term science, therefore, could mean different things to different people. According to Brown (1986) the philosophy of science and the role of science in our technological society have rarely been major elements in the preparation of science teachers. This leads to an interesting question : *If teachers are not taught about the nature of science, in their teacher training programmes, where does their understanding of the* *nature of science come from ?*

As this study focuses on the nature of science, the researcher attempted to establish through the questionnaire and the interviews *what are teachers views about the nature of science ?* To gain insight and understanding into teachers' views about the nature of science, the researcher will analyse general teacher responses to the nature of science. Hence, initially, the analysis will not be specific to the three teachers in the sample but will involve inputs from all teachers who completed the questionnaire. The inputs from the three teachers in the sample, with respect to the nature of science, will be analysed and evaluated after considering responses from other teachers.

The theoretical backdrop and literature review in chapter 2 form the basis for the analysis of data obtained from teachers. An analysis of the literature in chapter 2 reveals that the nature of science involves the following two key processes :

a) The aim of science is the discovery, description and understanding of all aspects about the world.
b) The methods of scientific enquiry are based on a combination of observation, experiment and reasoning.

To develop a context of the environment within which the teachers in this study operate, the researcher initially explored some teacher responses to questions about the nature of science from all questionnaires received. This helped the researcher create a picture about the nature of science. An analysis of responses to open - ended questions are considered.

'What does doing science involve ?' was one of the open - ended questions in the questionnaire. Some of the responses to this question were:

" Learning through experience and application of theoretical knowledge gained."

" Application of scientific laws and theorems in life and to improve life."

" A desire to discover, discovering, implementation, testing"

" Experimentation, drawing conclusions, use of theories and formula, logical thought."

" Application of knowledge, connection of facts."

" Learning through having interesting / fun lessons."

" experimentation"

" Doing science involves many things. Science involves inquiry, questioning, debating, research, etc. Science is an active process, Therefore it requires participation from all involved. Science also involves hypothesizing. It does not involve doing 'things' in the laboratory, but also doing things outside. Doing science also involves questions like : How ?, What ? and Why ?."

Some people think the science is merely experimentation whilst other consider it to be a way of explaining phenonema in nature. Some people think that science is test tubes, lab coats, smelly chemicals and microscopes. Others believe that science is the solution to the world's problems and is a way of thinking about the world aound you. It is a way of finding out what you don't know by figuring out what you do know. It is a way of finding solutions to problems or answers to questions. Science, therefore, has a unique scientific method which is examined later in the chapter. From the responses on page 59, it is clear that the majority of the teachers have not grasped the notion of the scientific enterprise, that is, what does doing science entail.

Some of the responses received to the question : *'What are some ways in which scientific knowledge is produced ?'* were :

" Experiments, observing the world around us, books"

" Discovery of knowledge by experiments and self activity,

teaching facts."

" Experiments, building on previous knowledge, relating facts from seeming different sections, drawing conclusions."

" Induction / deduction."

" Experimentation, theorising, accidents due to experiments, research and linking of common occurrences."

" Observation, deduction, experimentation, validation."

"Scientific knowledge is produced through intrinsic research, deduction, observation, experiments, investigation, discovery, and critical inquiry. Scientific knowledge is also produced by mistakes and trial and error."

From the above inputs, experimentation is recognised as a key to producing scientific knowledge by the majority of the teachers. Clearly methods such as trial and error, theoretical study, research, and other methods of obtaining scientific knowledge were largely ignored by teachers in this area. This issue will be analysed later in the chapter.

To get a sense of whether teachers really understand the nature of science, teachers were required to answer the following question : *"Why is an understanding of the nature of science important ?"* Some of the responses received were:

"Understanding of the nature of science develops logical thinking."

"Scientific thought - teaches pupils how to reason, think logically, relate facts, understand the world around us."

"To conduct the most effective ways of teaching and learning."

"Man is continually trying to improve his way of life. Science is one of the few if not the only way in which that can be done. By understanding the nature of science man can improve on facts by following procedures."

"It would enable the teacher to realize where to place emphasis

when teaching (on the body of facts or the methods used to obtain the facts)."

"It provides for deductive thought process."

"The understanding of the nature of science is important because we need to know science and its background. The understanding of the nature of science is important because it forms the basis of science. In order to study science we must know what it is about."

From the above information, it is clear that the nature of science means different things to different persons and is, therefore, a complex issue. This has a serious of implications for teaching. According to Davis and Helly (1995), what you think about science influences what you choose to teach in your science programme as well as how you teach it. As teachers and pupils study science they will discover that it is not merely a body of information but also a way of investigation. Hence, implicit in the nature of science is experimentation and investigation often referred to as inquiry or discovery. If children are to understand science and become capable, active problem solvers, they must begin by actively investigating their world. Children must be allowed to learn through experimentation and reflection. Teachers need to stimulate the pupils' curiosity and establish an environment that is conducive to discovery. However, these lessons need to be carefully planned so that pupils reach their desired goals.

However, from the responses on page 61 it is clear that teachers in this area do not fully understand the implications of understanding the nature of science. A de-emphasis of the nature of science in textbooks (Stinner, 1992), the curriculum (Wenham, 1992) and teacher education training programmes (Young and Kellogg, 1993) can be seen as reasons for the lack of understanding of the nature of science by teachers. Hence, a lack of exposure to the nature of science has resulted in teachers not fully understanding the nature of science.

4.3.2 INDIVIDUAL TEACHER INPUTS - NATURE OF SCIENCE

To obtain an understanding of the nature of science as perceived by the three teachers in the sample, the researcher followed - up the teachers' responses, in the questionnaires, during interviews. Listed below are teacher responses to their view of the nature of science.

Teacher A

Teacher A did not respond to the question *"What does doing science involve"* in his questionnaire. However, he made the following comment in the interview :

> ***"Science involves observing and experimenting with the intention of discovering new information and facts."***

Teacher A was of the view that doing science involved a lot of experimentation. Further, experimentation was the key to supplement to the existing body of knowledge. He added that through experimentation new knowledge is added to the existing body of scientific knowledge enhancing our understanding of the world.

This argument is supported in his response to the question *"What are some ways in which scientific knowledge is produced ?"* :

"Verbal, practical experience"

He was of the view that scientific knowledge is produced through verbal interaction and exchange of ideas between individuals, especially scientists. Also, *"practical experience"* referred to investigations done by the scientists. These investigations would have been conducted over a long period of time before deductions and conclusions are reached. Hence, scientists contribute to the body of scientific knowledge through experiments.

Although he had not met a scientist, teacher A described a scientist as:

> ***"a gentlemen in a lab, with a lab coat, glasses, surrounded by chemicals and apparatus, having a slightly bemused look"***

He added that scientists are persons with 'a deep sense of curiosity', hence their desire to look for solutions to help man understand the world he lives in.

The view that scientists help man understand the world he lives in is supported in teacher A's response to the question : *"Why is an understanding of the nature of science important"* :

"Because science explains the energy composition of the universe"

The teacher firmly believes that the nature of science provides the answers and explanations to the phenomena of the world and the universe. In the interview, teacher A elaborated further by stating :

"Science explains and helps us understand the physical world we live in. Also, science gives explanation to the millions of questions which mark our existence. Possible answers are given whenever a new situation / object appears - one is not left in the dark."

Teacher B

Teacher B responded to the question : *"What does doing science involve ?* as follows :

" I think this involves practising science, not ending up with theory. It involves doing experiments and the discovery of other things. It involves applying what is learnt in class in everyday life"

Teacher B held similar views to teacher A about what doing science entails. Teacher B subscribed to the view that doing science involved a lot of experimentation.

He elaborated by stating that :

"Experimentation is the key when doing science, to learn more about the world."

Teacher B was also of the view that through experimentation new knowledge is added to the existing body of scientific knowledge enhancing our understanding of the world.

Teacher B presented the following flowchart in his response to the question *What are some ways in which scientific knowledge is produced?"* :

> ***"Observation of natural phenomena → Hypothesis → Test (Research) → Accept / reject hypothesis. In this way a body of knowledge deemed to be accepted 'truths' is obtained."***

Teacher B identified more about the enterprise of science than teacher A. However, from the above response, it is clear that the purpose of science is to establish the truth about natural phenomena. Furthermore, science enables people to develop an understanding of their environment.

In the interview teacher B elaborated further about how scientific knowledge is produced as follows :

> ***"Scientific knowledge is produced through investigations and research. Painstaking research, experimentation and study is carried out. The research is then methodically put together - scientific knowledge emerges."***

Unlike teacher A, teacher B states that the gain of scientific knowledge is dependent on a scientific process. Experimentation is part of the scientific process. Teacher B was of the view that scientists / researchers follow a routine when analysing problems and looking for solutions. He believes that scientists adhere to a rigid process starting with a hypothesis and ending with a conclusion. This is a naive, positivistic view of the scientific process.

The view that science helps man understand the world he lives in is supported in teacher B's response to the question : *"Why is an understanding of the nature of science important"* :

> ***"Today technology is advancing. So it is important to understand the nature of science since we live in a sophisticated community. It will be easy to understand the laws of science after one has understood the nature of science. Hence, to understand the world you need to understand the laws of science."***

Clearly, teacher B holds the view that science is essential to understanding the rapid changes taking place in the world. Simply, an understanding of the nature of science is important for an understanding of the world.

From the above information, it is clear that both teacher A and teacher B have a traditional and unproblematic image of science, that is, science has an explanation for any problem. Science is able, through experimentation, to provide *right* answers. Clearly, these teachers subscribe to the view that science is objective and truth seeking. Also, science is exact and clear - cut and provides precise solutions to problems. Also they believe that through experimentation, new knowledge is *added* to the existing body of knowledge. Hence, science is viewed as an accumulated body of right answers to be transmitted to learners in school. The fact that they subscribe to the traditional view of science is highlighted in their view of the scientific method which is considered to be an objective scrutiny of hypotheses by reference to unproblematic facts based on observations. The scientific practice follows a rigid routine and is said to be objective and clinical.

Teacher C

Teacher C responded in more holistic manner to the question : *"What does doing science involve ?* when compared with teachers A and B. She stated that doing science involves :

> ***"Playing → with a conclusion. Hypothesis. Problem solving. Experimenting the 'scientific method' way. Discovering and explaining. Chance. Trial and error. Analysis, interpretation, understanding, observing, extrapolation, recording, critical thinking "***

She identified experimentation as one facet of doing science. She considers science to involve many other processes and methods. She distinguishes the scientific method from other methods. She maintains that conclusions are flexible. Her initial statement *'playing → with a conclusion'* supports this notion.

In the interview she stated that :

"Doing science is difficult to pinpoint as it involves a whole range of activities."

However, she added that doing science must be considered a 'human activity' and that in school, pupils and teachers must be placed in situations where they can work as scientists. This will enhance their understanding of the nature of science.

Her holistic approach to the nature of science is reflected in her response to the question *"What are some ways in which scientific knowledge is produced ?"* : ***"Deduction - logical conclusions***

Experimentation - trial and error associated with an aim.

Inspiration - per chance

Necessity - problem solving

Competition eg. in manufacturing

Initiative - asking questions"

Teacher C expressed the view that science should be people orientated. She identified different ways in which scientific knowledge is produced. These ways are over and above the methods proposed by teachers A and B. She also displayed greater insight and understanding into the nature of science when compared to teachers A and B.

This train of thought is perpetuated in her response to the question : *" Why is an understanding of the nature of science important."* :

"To supply a degree of sense to the environment; Provide an awareness of the environment; A true understanding develops into a love for the subject - NB. especially for teachers. Understanding leads to the ability to be creative in the subject."

Teacher C was of the opinion that science provides some answers to phenomena observed in the environment, hence the statement '*a degree of sense to the environment.*

In her interview, she stated that :

> ***"Science is just one of many ways of explaining natural phenomena. There is no absolute or definitive way of explaining certain things, as occurrences could be explained scientifically, culturally or even in a layman explanation."***

By subscribing to this view of science, teacher C believes that it has impacted on her teaching of science as she has to take into consideration other explanations and theories when she teaches. Hence, she believes that an understanding of the nature of science is important as it enables teachers to take into consideration alternative views and perceptions when teaching. Also, the inputs from pupils cannot be ignored. The views of pupils must be taken into consideration in all science lessons.

Clearly teacher C holds an alternative position on science when compared with teachers A and B. She believes that the body of scientific knowledge is constantly changing and science teachers must take this into consideration when they teach. She holds the view that our perception of the world is seen to be subjective. Hence, observations are meshed with previous experience of, and existing theories about, the world. We construct meaning for the world around us from our prior attempts to make sense of it. Science is therefore considered to be a human and social construct. Further science is considered to be an accumulated, ever changing body of knowledge, resulting in knowledge construction being subject to continuous revision in this framework of science. Teachers operating in this framework explore alternative meanings with the pupils during their science lessons. Also science is considered to be less clinical and more human.

4.3.3 TEACHERS' BELIEFS ABOUT SCIENCE

In 4.3.2 the researcher conducted an analysis of teachers' views about the nature of science to obtain a theoretical framework within which the teachers in the study operated. The questionnaire completed by teachers in the study comprised three tables. Each table in the questionnaire focussed on a different critical question. In the discussion below, the researcher used information obtained from table B.1 (appendix I) in the questionnaire and interviews to obtain a more holistic picture with respect to teachers' beliefs about science. The individual responses of teachers A, B and C to some questions from table B.1 of the questionnaire are reflected in the table 3 below.

NO	STATEMENTS	SA	A	UN	D	SD
1.	*Science helps me understand the world around us.*	*A B*	*C*			
2.	*Only science can help me to understand nature.*	*B*	*A*		*C*	
3.	*Scientific laws and facts are always produced through experimentation.*	*A B*				*C*
4.	*Laws and theories in science help clarify phenomena in nature / world*		*A B C*			
5.	*Science is objective and value free.*	*A*		*B*		*C*
6.	*All scientific knowledge is true.*	*B*	*A*			*C*
7.	*Scientific knowledge is socially constructed.*		*C*	*B*	*A*	
8.	*Science is an accumulated, ever changing body of knowledge.*		*A B C*			
9.	*Science has a core body of knowledge that never changes.*	*A B*		*C*		
10.	*All scientists follow a common routine when doing research.*		*A B*		*C*	
11.	*Scientists are particularly objective people.*		*A B*		*C*	
12.	*Scientific laws are unchangeable and absolute truths.*	*B*	*A*			*C*
13.	*Scientific experiments provide conclusive proof about phenomena in the world.*		*A B*		*C*	

TABLE 3 : Teacher's beliefs about science

Key : SA: strongly agree; A: agree; UN: uncertain; D: disagree; SD: strongly disagree.

In table 3, teachers provided their responses to individual questions posed on the nature of science. The teachers elaborated on these responses in the follow - up questions during the interviews. The following responses were received with respect to the question "*What is science ?*" :

"***The study of life and the universe ?***" Teacher A

"***Science is a branch of knowledge involving systematized observation of and experiment with phenomena. It is a systematic and formulated knowledge. It involves reasoning skills and techniques.***" Teacher B

"***The logical and pragmatic approach to answering the questions that are posed to us by the environment we exist in. Science is therefore considered to be a human activity whereby one endeavours to exploit the unknown in an attempt to seek answers or reasons concerning natural phenomena.***" Teacher C

The idea that science is a 'human activity' and its purpose was to help man understand natural phenomena was common to all responses received. This is verified by the results in Table 3. In their respective interviews, all teachers agreed that studying science was essential to gaining knowledge. However, only Teacher C believed that knowledge is socially constructed. Teachers A and B acknowledged that science in an activity that scientists engage in hence, their view that science is a human activity.

This is emphasized in a statement made by teacher A in his interview, which states :

"***An understanding of science is important in order to interpret natural phenomena and experiences, thus improving the quality of one's life and that of those around him.***"

The interaction between science and society is clearly evident in the above response. The idea of 'humanising' science and making it more relevant to pupils lives is supported by Kelly (1988), Lucas and Wagner (1977) , Driver (1983), and Hodson (1993).

Teachers A and B construed all knowledge to be scientific. They ignored all other forms of knowledge. According to teacher B :

> ***"The core of knowledge is based on scientific facts. To understand the world, you need to understand the laws of science."***

This is an extremely deterministic notion of science. The fact that both teachers A and B believe that science finally leads to truth is contradictory to the fact that these teachers believed that science is an accumulated, ever changing body of knowledge. This indicates that teachers A and B operated within the scientific or empirical paradigm but attempted to be transformative or critical since history has shown that scientific knowledge can change with time.

All teachers were of the view that scientific knowledge is produced through a process of experimentation, that is, there is a hypothesis which is tested and then accepted or rejected. According to teacher B :

> ***"In this way a body of knowledge deemed to be accepted 'truths' is obtained."***

Surprisingly, no alternate sources of obtaining knowledge was mentioned by teachers A and B. Their stress on experimentation results in the laboratory being considered as the only place where scientific knowledge can be produced or discovered. The laboratory is regarded as a *'special place'*, as it is where science takes place. Hence, the laboratory and classroom are the only places where learning can take place. This is another indication that teachers A and B operated within the empirical analytical paradigm.

Teacher B was uncertain whether science was value free or not. However, teachers A and C opposed each other on this point. From table 3, it is clear that teacher A was certain that science is objective and value free. Teachers A and B ignored the idea that science itself is an expression of values.

According to Hodson (1986), teachers subscribing to the inductivistic view of science present the curricula as being neutral, value - free and containing absolute truths. The Educational Policies Commission quoted by Theslen (1983

: 186) list the following values which underly science,

> ***"longing to know and understand; questioning of all things; search for data and their meaning; demand for logic; consideration of premises and consideration of consequences".***

Also there is a myth that science is objective and must, therefore, be 'value free'. Teacher A and B fail to recognise that objectivity in inquiry is itself a value.

Simply, theory and values cannot entirely be separated from facts. There is an element of subjectivity in all objective statements. Teachers A and B recognised science as a human activity but failed to see the influence that people have in developing science. Teachers A and B considered science to be a body of facts that is used to explain the world we live in. They ignored the historical development of the facts, that is, who identified the facts, what experiments were done before something was known to be a fact, and other similar questions are not asked. According to teachers A and B, time constraints, syllabus requirements and preparation for examinations impacted heavily on their interpretation and analysis of 'facts'.

All teachers stated that science follows a logical, systematic process. From table 3, teachers A and B maintained that all scientists followed a common routine during their investigations. Hence, the scientific process is clinical and technical and supports the inductivistic perception of science. Teacher C, however, contends that the scientific process is not a simple straight - forward process. It is sometimes complex, messy and does not always follow a specific order. Also scientists are considered to be objective and rational persons who do not allow their personal perceptions to influence their observations and findings during an investigation or research.

The findings above reaffirm the findings in 4.3.2. The teachers in the sample operated in different paradigms. Teachers A and B held traditional views of science and operated in the empirical - analytical whilst Teacher C held more progressive views about science and operated in the hermeneutic paradigm.

In the next part of the analysis of the data, the researcher examines factors that influence teachers' views of science.

4.4 FACTORS INFLUENCING TEACHERS' BELIEFS ABOUT SCIENCE

Factors that influence teachers' beliefs about the nature of science have been identified in the literature review. These factors have been supported by the findings of this research. The researcher found that textbooks and the curriculum impacted heavily on teachers views about the nature of science. Also, teachers adhere to information in textbooks and the curriculum when teaching science.

4.4.1 Textbooks

NO	STATEMENTS	SA	A	UN	D	SD
1.	*Science textbooks correctly represent the processes of science.*		*A B*			*C*
2.	*The textbook is an important resource guide when I teach.*	*A*	*B C*			
3.	*Textbook drawings and pictorial illustrations are a true representation of science.*		*A*	*B*	*C*	
4.	*Textbook writers emphasize the finished product of a 'scientific fact'.*		*A C*	*B*		
5.	*I use references, other then the prescribed text, in my classroom practice.*		*B C*	*A*		

TABLE 4 : Textbooks

<u>Key</u> : SA: strongly agree; A: agree; UN: uncertain; D: disagree; SD: strongly disagree.

In their interviews, teachers were asked the following question :

"What methods are used to initiate pupil inquiry in your science classes ?"

The following responses were received from teachers A and B :

"My pupils do experiments every double period. However, due to the lack of facilities and chemicals, I have to demonstrate the experiments to them. The teacher only demonstrates experiments that are in the syllabus." Teacher B

"Pupil inquiry is restricted to classroom experiments from the syllabus with the aid of the textbooks or worksheet." Teacher A

Teachers A and B agreed that pupil inquiry, in their science lessons, were restricted to classroom experiments with the aid of textbooks or worksheet. This is a clear indication that science is taught as a process of induction rather than as a process of deduction. By merely verifying the laws in the textbooks, the child concentrates on the products of science and does not learn the processes of science.

Teacher C identified pupil inquiry as :

"the need for teachers to allow pupils to discover things for themselves. Pupil inquiry should not be restricted to classroom experiments only. Pupils must be given opportunities to design their own experiments and conduct their investigations independently"

Teacher C was of the view that the demands of completing a prescribed syllabus was not a major stumbling block to pupil inquiry as she taught grade 10(standard 8) Physical Science only. Hence, she did not have the pressures of preparing pupils for an external examination. She allowed her pupils to conduct investigations over and above the experiments done in the class. The pupils were allowed to formulate their own aims and hypotheses with respect to everyday occurrences. She encouraged the process of deduction rather than induction. She created avenues for her pupils to engage in the process of inquiry by entering them in Science Expos, getting them to design and build models such as bridges and electric motors, taking them to industries to meet scientists and explore the scientific processes involved. The school science club plays a vital role in encouraging pupil inquiry.

Pupils are discouraged from following the steps outlined in the textbook *'cookbook style'* when doing experiments. Furthermore, pupils are given background information, not found in the textbook, before commencing experiments. This historic background helps to create a context within which the pupils can see the law or theory. Teacher C endeavours to place pupils in situations where they can work and think as scientists do. Hence, she emphasizes the processes of science rather than the products.

The products of science consist of those rational 'beliefs' derived out of observations and experiments that have not been disproved. The knowledge obtained this way is taken as 'truth'. These 'truths' are used to explain the world around us. Hence, with the aid of a textbook or a worksheet the child is directed towards finding the 'truth', that is, the pupil merely verifies a scientific fact or theory through a process of induction. This is confirmed by Bentley and Garrison (1990), Stinner (1992), and Groves (1995).

In the process of induction there is little or no room for critical thinking. Teachers A and B acknowledged in their interviews that they simply confirm the observations and laws in the textbook when they do experiments. They completely ignore the processes of science such as hypothesizing, designing experiments, recording and analysing data, inferring and other similar processes. Hence, the pupil is not allowed to work and think like a scientist. Hodson (1986) believes that the processes of science are ignored when the pupil is not put in the situation of 'being a scientist'. Learning science through the process of induction is incomplete as it provides answers to problems without understanding the nature of the answers and the processes by which they are arrived at. All Physical Science textbooks evaluated by the researcher followed the same inductive method of doing experiments.

The textbooks evaluated by the researcher followed the following routine when dealing with experiments :

AIM → APPARATUS → METHOD → RESULTS → DISCUSSION → CONCLUSION.

MODEL B

The conclusion always reaffirmed the aim. Pupils had to adhere strictly to the procedure outlined in the textbook when doing experiments. Hence, pupils conducted experiments *recipe style* , that is, doing experiments was similar to baking a cake. The laws and experiments in the textbooks are not contested by the authors of the books. Hence, pupils are not accorded the opportunity to question the laws and observations of an experiment. These textbooks, therefore, perpetuate an inductivistic ideology. Bentley and Garrison (1990) support this stand about the textbook approach being inductive.

All three teachers in the study acknowledged that textbooks were an important resource guide when they teach.

Teacher A stated that :

> ***"The textbook is an important component of my teaching."***

Teacher B stated that :

> ***"I use the textbook to give notes, exercises, tests and to do experiments."***

Teacher C stated that :

> ***"The textbook is merely a guide. I encourage my pupils to seek alternate explanations from other resources."***

The quotes from the three teachers authenticate the fact that textbooks have a strong influence on the content of science taught in schools. The curriculum taught in schools presently has been 'handed - down' by bureaucrats and politicians. Textbooks were designed to conform with the national state science curriculum. Teachers, therefore, follow the textbook as it closely resembles the core national science syllabus.

This results in the textbooks becoming an important source of classwork, laboratory work, homework activities and sometimes tests given by the teachers. Teachers A and B adhere closely to the content in textbooks. They do not question or challenge the content in the textbooks they use on a daily basis. However, different perspectives on a topic in the syllabus are obtained from references other than the prescribed texts. This is confirmed in Table 4.

In South Africa, the same textbooks are used by all pupils and education departments. These textbooks were written by 'white male authors' and have been on the standard list (recommended texts for use in schools) for a number of years. Schools used only textbooks on the standard list. This ensured that the dominant ideology is propagated and that a privileged group of people benefitted from the sale of these textbooks.

Each textbook examined by the researcher devoted nearly all print and illustrations to represent the concepts and principles of science, with little attention given to the nature of science, or to how the knowledge of science is formulated or validated. This is supported by findings in Bentley and Garrison (1990) and Gallager (1991). Science is portrayed as a process of acquiring knowledge about the natural world. This explains why all three teachers in the study believe that science is essential to understanding nature or the environment (Table 3).

In the Physical Science textbooks analysed by the researcher, science is portrayed in a generally positivistic light. The historical development of scientific ideas, the intellectual struggle that characterises the history of science, or the use of science in the daily lives of pupils is given very little space in textbooks. A scientist's contributions to science are mentioned as part of the caption below an illustration or picture of the scientist. Furthermore, many of the textbooks convey a western image of science

(Hodson, 1993).

Teacher C has recognised that textbooks do not correctly represent the processes of science but emphasize the finished product of a 'scientific fact'. Similar findings are reported in Stinner (1992) and Groves (1995). Most science textbooks referred to by the researcher displayed a gender bias and made few references to women. However, when women are shown in illustrations, it was usually in a passive or inactive role. Also, the problems and illustrations in the textbooks appeal more to boys' interests than girls' as problems dealing with guns and rockets are highlighted in the textbooks.

Most science textbooks used by the teacher emphasize the role of the teacher as a presenter of the factual content of science. This results in the teacher being unable to convey a broad perspective of science to his / her pupils. From the above discussion, it is clear that Physical Science textbooks used by the teachers in this study mis-represent the nature of science. Textbooks convey a traditional, inductivist view of science. Textbooks influence the way teachers teach and their understanding of science. According to Hodson (1993 :703) :

> ***"It could be argued that the way in which students are required to write in science lessons and the style in which science is written in school textbooks are further examples of the western image of science. The conventional style helps create and sustain the aura that science is a body of true knowledge, founded on verifiable facts and established by rational, objective procedures."***

He states that a multicultural approach to science education would require teachers to challenge these perspectives.

4.4.2 The science curriculum

The influence that the science curriculum had on shaping teachers' views and beliefs about the nature of science was the next factor that was examined by the researcher. To place the present science curriculum in context, a brief historical development of the curriculum is provided by the researcher.

The present Physical Science curriculum in schools has been prescribed by the department of education and has remained unchanged for the last ten years. Teachers and pupils were not consulted when the curriculum was drawn. The curriculum was drawn by the 'white' education department in the House of Assembly and used by all other education departments. A 'top down' approach to curriculum development has always existed in South Africa with people at grassroots having little or no influence on what should be in the curriculum. This ensured that the curriculum could be manipulated so that the policies of the dominant ideology were maintained and perpetuated.

It is against this background that the researcher analysed the responses from teachers. The table 5 on this page represents teachers' responses to individual questions in table B.2 of the questionnaire. These responses together with additional elaboration from the interviews formed the basis of the information for analysis.

No	STATEMENTS	SA	A	UN	D	SD
1.	*The present curriculum is irrelevant to pupils everyday experiences.*		C		AB	
2.	*Teachers emphasize the finished product of science.*		BC	A		
3.	*The curriculum should emphasize the processes of science.*	C		AB		
4.	*The science syllabus and examinations dictate how I teach science.*		AC	B		
5.	*The present science syllabus does not place science in a historical context.*		C	AB		

No	STATEMENTS	SA	A	UN	D	SD
6.	*The present science syllabus ignores the history and philosophy of science.*		BC		A	
7.	*The present science syllabus has remained the same from 1985 to 1996.*		AB C			
8.	*The science syllabus has not kept up with advances in technology.*	C	AB			
9.	*History and philosophy of science should be included in the science curriculum.*	C			AB	

TABLE 5 : The science curriculum

Key : SA: strongly agree; A: agree; UN: uncertain; D: disagree; SD: strongly disagree.

All three teachers in the study acknowledged that the curriculum was their 'guide' with respect to what they teach in their science classes. The curriculum, therefore, impacted on their classroom practices as the topics or sections taught were prescribed in the curriculum.

An evaluation of the present Physical Science curriculum reveals that curriculum developers confused the teaching of science *'as inquiry'* (induction) and the teaching of science *'by inquiry'* (deduction). A case in point is Newton's Second law, which is a prescribed experiment in the present Physical Science curriculum for standard ten pupils. The pupils are taught the law in normal classwork and simply verify that the law is true in practical lessons. The pupils, following the textbook or worksheet, reach their conclusion through the process of induction. The process of deduction is completely ignored. The same situation applies to all other experiments prescribed in the present Physical Science curriculum. This lack of insight in developing the curriculum is emphasized by Abimbola who is quoted by Bentley and Garrison (1990 : 189) :

> ***"Secondary school science education lacks direction as well as a theory and philosophy which should provide guidance to curriculum development and instruction."***

The present Physical Science curriculum, in South Africa, ignores different cultural influences. This results in the daily experiences of pupils being neglected. Teacher C was of the view that :

> ***"The curriculum must take into consideration wider societal and technological issues. The curriculum must be made more society oriented and cannot be silent on culture."***

Only teacher C was of the opinion that the present science curriculum is irrelevant to the everyday experiences of pupils (Table 5). Teachers A and B believe that the science curriculum is not biased towards a particular cultural group. Hence, they believe that the science curriculum is relevant to pupils lives. They ignored cultural influences in the curriculum.

Hodson (1993), Watts (1991) and Murfin (1994) call for a multicultural perspective to science curricula. According to Hodson (1993 : 694) :

> ***"Existing curriculum material should be reviewed regularly and all out - of - date, inaccurate, racially stereotyped, and ethnically insensitive content removed."***

A multicultural science curriculum will call on pupils and teachers to closely examine the image that science is conveying to the community. The present science curriculum, in South Africa, projects the following image of a scientist : ' western, white, male, self - assured, technologically powerful manipulator and controller' (Hodson, 1993).

According to teacher C, the present science curriculum was irrelevant to pupils everyday experiences and lives. This results in the pupils being forced to learn information irrelevant to their lives. Teachers adhering strictly to the curriculum, therefore, present science as a collection of facts to be used to explain the natural world. This confirms why teachers A and B believe that the present science curriculum is relevant to pupils lives. They present the curriculum as a body of facts to be used to explain the natural world. Driver (1983), Lucas and Wagner (1977), Gilbert and Pope (1983) are just a few of many researchers who call for science to be made more relevant to pupils lives.

Teacher C strongly believed that the science curriculum needs to emphasize the process of science and not the product. She said :

> ***"Teaching the child laws and theories is boring. The interesting part is actually doing the experiments and learning why things are the way they are."***

Teachers A and B were unclear what the processes of science were. An examination of the curriculum reveals that science is presented as a body of facts, theories, laws, and concepts. Applications in the curriculum are restricted to application examples. Little or no attention is given to how scientific knowledge, which is covered in the science curriculum, is obtained and validated. Students are not allowed to do experiments of their own choice. However, teacher C, encourages independent pupil investigations over and above the syllabus requirements. The curriculum allows for little or no time to be spent on ensuring that students develop their own processes or experiments to test scientific laws and theories. As mentioned in 4.4.1, the pupils follow the inductive method to do experiments, that is, experiments conducted by pupils are through a process of guided (worksheet and textbooks) discovery. Hence, the current science curriculum merely requires pupils to verify scientific laws and theories.

Teachers B and C agree with the view that history and philosophy of science is neglected completely in the curriculum. Similar findings are reported by Gruender and Tobin (1991), Bybee, et al (1991), and Hodson (1988). This was verified when the present Physical Science curriculum was evaluated by the researcher. The nature of science is totally ignored whilst science as a collection of facts is emphasized. The history of science is restricted to the development of the atom. Other historical information about how scientific knowledge has been obtained is left to the teacher to find out using references other than prescribed textbooks. The present textbooks, used in schools, contribute to the teacher's lack of understanding of the origins and application of scientific knowledge. Hence, the overemphasis on the content knowledge of science by teachers.

Teacher A disagreed with the view that history and philosophy of science is ignored in the present curriculum. According to teacher A :

"History and philosophy of science distracts pupils from the facts. Also the facts are more important as they help explain the world we live in. Pupils are not interested in how facts were developed"

Teacher A focussed on teaching the facts and laws to his pupils. He adhered strictly to the curriculum by presenting only the facts to pupils. These facts were used to solve application examples from worksheets or textbooks.

Only teacher C was of the view that history and philosophy of science should be included in the curriculum and that it will help her understand the processes of science. Teachers, in the research by King (1991), held the same view. Teacher C recognised the importance of knowing where the scientific knowledge originated. This will help place the knowledge in a particular theoretical perspective. Also it will help teachers and pupils to understand the attitudes and thinking of scientists.

Analysis of the curriculum and inputs from teachers in the study show that the present curriculum emphasizes laws and facts but ignores the processes of science. The curriculum exists in a cultural vacuum as it ignores the the culture of pupils. The curriculum is perceived as a catalogue of truths about the universe which has to be learnt for recall in a test.

4.4.3 Teacher education and training

All three teachers in the study stated that their teacher education training emphasized the content of the curriculum and not history or philosophy of science. The following comments were made by the teachers :

"At college we were taught how teach" Teacher B

"Our content emphasized how and what to teach." Teacher A

"We concentrated on the school curriculum and looked at ways and means of teaching it. We never evaluated the curriculum and did not develop an in-depth understanding of the content in the curriculum." Teacher C

From the above quotes, it is clear that the science method courses focussed on the content of science rather than on the application of scientific principles. This coincides with the findings of Young and Kellogg (1993).

They were of the view that :

The 'coverage' of massive volumes of content without interaction should not continue." (Young & Kellogg, 1993 :289)

Czerniak and Chiarelott (1990) support the view that the content of teacher education science programmes contributes to inadequate preparation of teachers. The authors call for teacher education programmes to prepare teachers for the realities of classroom management in a science class, as a science class differs from other subject classes due to the laboratory, inquiry - based nature of science. All three teachers in the study were of the opinion that a deeper understanding of science would have enhanced their teaching. Time and monetary constraints rule out an in-depth analysis of how teacher education and training affects teachers' beliefs about about the nature of science.

4.4.4 Teacher's perceptions of scientific terms and the influence (if any) of philosophers of science.

To establish the teachers' theoretical framework and understanding of science, the researcher posed similar questions (Table 6) to all the teachers during the interviews. These questions related to teachers' perceptions about concepts, scientific laws and theories. The terms are based on the nature of science and statements were made by philosophers such as Hempel, Kemey, Popper, Nash, Kuhn, and Nagel. These statements formed the basis for the questions. However, some of the statements / questions were derived by the researcher.

Also, during the interviews, the researcher attempted to establish other factors that could have influenced teachers views about the nature of science such as philosophers of science or philosophies; other educators or belonging to a particular teacher organisation.

4.4.4.1 <u>scientific terms</u>

No	STATEMENT	AGREE	DISAGREE
1.	*I unilaterally accept all scientific knowledge.*		A B C
2.	*A concept is a summary of ideas or facts.*	A B C	
3.	*Concepts are the meanings given to names, symbols, or ideas about natural phenomena.*	A B C	
4.	*Scientific laws are unchangeable and absolute truth.*	A B	C
5.	*Scientific laws link natural phenomena or events and can change with time*	A B C	
6.	*Theories are confirmed hypothesis and unchangeable.*	A B	C
7.	*Theories are general assumptions or instruments used for conducting scientific inquiries.*	C	A B

TABLE 6 : scientific terms

The interviews helped the researcher to confirm the theoretical framework within which the teachers operated. Table 6 represented teachers' own perceptions of what a concept, law or theory is. All three teachers in the study agreed with the view that a concept is a summary of ideas or facts and that it gives meanings to names, symbols and ideas about natural phenomena. This was the contention of Popper. However, none of the teachers in the study were influenced by Popper.

Teachers A and B expressed the belief that scientific laws are unchangeable and absolute truth, and theories are confirmed hypotheses and are unchangeable. This confirms the findings in Table 3. This positivistic view is contrary to the view of many philosophers who contend that theories and laws cannot be absolute truth. This finding also contradicts the finding which shows that teachers A and B believe that scientific laws link natural phenomena or events and can change with time. The idea that knowledge in the form of theories and laws changes with time, is related to Kuhn's concept of a paradigm shift.

A paradigm shift occurs when teachers / pupils question the laws and theories that they have to teach or learn. All three teachers in the study disagreed with the statement that they unilaterally accept all scientific knowledge. This contradicts the finding that scientific laws are unchangeable and absolute truth but agrees with the finding that scientific laws link natural phenomena or events and can change with time. The extent to which scientific knowledge is questioned by the teachers is not examined in the study. Using these findings, the researcher had difficulty determining the paradigm within which the teachers operated. However, teachers A and B were consistent in their views that all scientific knowledge is true and that science has a core body of knowledge that never changes. These views place them in the empirical - analytical paradigm. Teacher C, on the other hand, maintained her view that science is an accumulated ever changing body of knowledge. She clearly operated within the interpretative or critical paradigms.

4.4.4.2 Exposure to philosophy and history of science

<table>
<tr><th>TEACHER</th><th>COURSES IN PHILOSOPHY</th><th>MATTERS DISCUSSED AT SCIENCE MEETINGS</th></tr>
<tr><td>A</td><td>no</td><td rowspan="3">how to teach Physical Science, problems in class and solving them, how to motivate pupils, using teaching aids, demonstrations, importance of practical work, latest trends in education, OBE, analysis of results, changes to the curriculum, continuous assessment, the relevance of science, maintaining standards, tests and exams, teaching strategies, lack of pupil interest in science, syllabus issues.</td></tr>
<tr><td>B</td><td>no</td></tr>
<tr><td>C</td><td>yes</td></tr>
</table>

TABLE 7 : Philosophy courses and matters discussed at science meetings

From table 7 all three teachers in the study have a qualification from a tertiary institution. However, only teacher C studied philosophy and was familiar with philosophers and philosophies in science education. Teacher C was familiar with constructivist approach to teaching and learning and attempted to adopt this philosophy in her classroom practice. Other philosophers mentioned by teachers in the study were Plato, Aristotle, Darwin, Mendell, Archimedes, Newton and Einstein. What is significant is that these philosophers have contributed more to the development of scientific knowledge than to the philosophy of science. The teachers were unfamiliar with contemporary science philosophers such as Lakatos, Popper, Kuhn, Kemey, Nash and others. Teachers A and B were unfamiliar with the constructivist theory of education.

Discussions with the teachers reveal that South African universities and colleges of education do not have studies of history or philosophy of science included in their teacher education programmes. Teachers, however, expressed an interest in learning about history and philosophy of science to improve their understanding of science. All three agreed with the view that history and philosophy of science will improve their understanding of the processes of science. These findings coincide with findings reported by King (1991) and Matthews (1994).

In the article by King (1991), 'beginning teachers complained about how difficult it was to incorporate ideas such as inquiry, discovery, relevance, critical thinking and creative thought into their teaching'. The teachers acknowledged that a familiarity with the history of science and in the nature, purpose and value of science would help them in the classroom. This is supported by Olstad who is quoted in Billeh and Malik (1977 : 559):

> ***"It is necessary for a teacher to more broadly understand science - its basic methods and processes - if he / she is to teach this kind of science to children. He / she must be scientifically literate, and this definition of scientific literacy must include a reasonably sophisticated understanding of the philosophy of science."***

Teachers A and B, however, maintained their position that they would not like history and philosophy of science to be included in the science curriculum at school (Table 5). They expressed the view that studying the history and philosophy of science at university or college will improve their understanding of science. This broader understanding will enable them to teach the laws and facts better. They expressed the view that inclusion of history and philosophy into the science curriculum will de-emphasize the laws and theories that are essential to explain how the world works.

To determine the extent to which teachers were exposed to philosophy of science, teachers were questioned about organisations to which they belong and meetings that they attend. Teacher C was a member of KASTE (Kwazulu Natal Association of Science and Technology Educators). Teachers A and B did not belong to any professional organisations. All three teachers attended science departmental meetings at school and sometimes attended workshops conducted by the provincial education department. Teacher C attended meetings arranged by KASTE.

Feedback from the teachers show that no philosophical issues are discussed at science meetings. Science meetings focussed primarily on curricula and disciplinary issues (Table 7). The discussions at meetings concentrated on how the curriculum is to be presented to pupils, that is, methodology. This lack of exposure to history or philosophy of science contributes to teachers' lack of understanding of the processes of science; its origin; and how scientific knowledge is produced . This view is supported by research conducted by King (1991) who found that student teachers ignorance of history or philosophy of science influenced their teaching.

4.5 TEACHERS' CLASSROOM PRACTICES

The classroom observations were used by the researcher to study the teachers' classroom practices. These observations enabled the researcher to obtain first hand information about what's happening in the classroom. The classroom observations focussed on the teaching strategies adopted by the teachers such as co-operative learning using group work, role playing, question and answer, discussion, practical work (individual and group), simulation and other techniques. The classroom observations also helped the researcher to establish additional information about how the teachers used textbooks and the syllabus in their teaching. The teachers in the study were observed on four different occasions, in their classrooms, for a period of one month.

Listed below is a summary of the researcher's observations of the three teachers' classroom practices. The researcher ensured that he observed the teachers in the same grade / standard so that there was a degree of continuity in his observations. The observations commenced at the beginning of a new section in the syllabus.

TEACHER A

lesson 1

Purpose / topic - to investigate the effect of concentration on the rate of a chemical reaction.

Teaching strategy - practical work in groups

Observations

Pupils were given a worksheet with the aim and method. They had to record results and draw graphs to find the relationship between concentration and reaction rate. The laboratory was set by the teacher prior to pupils coming to class. Pupils worked well in their groups but continually asked the teacher for help with respect to instructions in the worksheet.

lesson 2

Purpose / topic - factors influencing a chemical equilibrium

Teaching strategy - teacher demonstration

Observations

The teacher stated Le Chatelier's Principle and based his lesson on the principle. He demonstrated the common ion effect using concentrated HCl and a saturated solution of sodium chloride. Pupils were questioned about a saturated solution. However, the teacher ignored questions about the reversibility of the reaction. Pupils were given an opportunity to explain how Le Chatlier's principle can be used to explain observations in the demonstration. Pupils were given a worksheet, based on the experiment, to complete for their practical books. An interesting observation for the researcher was pupils' use of the textbook to answer the questions in the worksheet.

lesson 3

Purpose / topic - Application on equilibrium constant

Teaching strategy - discussion / question and answer

Observations

Pupils were given a worksheet to do as homework on the previous day. The teacher answered the questions from the worksheet on the chalkboard. Pupils were given an opportunity to provide answers to some questions and some pupils were called by the teacher to answer questions on the chalkboard.

lesson 4

Purpose / topic - Test on chemical equilibrium

Observations

The teacher gave his class a test. Questions in the test were based on the application of Le Chatelier's Principle and on the equilibrium constant.

TEACHER B

lesson 1

Purpose / topic - Introduction to the kinetic molecular theory

Teaching Strategy - Question and answer / discussion

Observations

The teacher asked the pupils questions on the phases of matter. There was little feedback from the pupils. The teacher seemed to answer all the questions himself. The characteristics of the kinetic molecular theory were written on a transparency. The teacher used these points to initiate the discussion with the pupils. The teacher played a pivotal role in this lesson by transmitting information to the pupils. At the end of the lesson the pupils copied the notes from the transparency.

lesson 2

Purpose / topic - Application exercise on gases

Teaching strategy - discussion / question and answer

Observations

Pupils were given an application from the textbook to do as homework the previous day. The teacher answered the questions from the exercise on the *chalkboard. Pupils compared their answers with the answers given by the teacher. At certain points, pupils were asked the answers to mathematical calculations at the end of a problem. Some pupils were called by the teacher to answer questions on the chalkboard.*

lesson 3

Purpose / topic - to demonstrate Boyle's Law

Teaching strategy - teacher demonstration

Observations

The teacher gave the pupils the statement of Boyle's Law. He added thereafter that "today we will prove that this law is true." The pupils were given a worksheet which they had to fill in as the teacher demonstrated the experiment. The teacher used the Boyle's law apparatus ,with mercury, to demonstrate the experiment. He explained to the pupils what he was doing and why he was doing it and occasionally asked pupils questions.

lesson 4

Purpose / topic - Test on gases

Observations

The teacher gave his class a test. Questions in the test were based on the application of Boyle's law and gas equations.

The above lessons are teacher orientated and involve the dissemination of information. Also the use of demonstrations and 'guided' experiments by the teachers clearly indicate that they support the inductive method of learning science. Teachers A and B neglected pupils previous experiences when teaching them about equilibrium and gases. Both teachers did not ask pupils questions that required them to reflect on work done previously. The teachers did not create avenues for pupils to work independently and think critically. The pupils did not ask the teacher many questions. The pupils eagerly copied notes given by the teacher rather then draw up their own notes. Statements such as *"our lesson today is based on Le Chatelier's Principle which states ....."*, *"can you see the solid NaCl crystals formed!"* and *"the kinetic molecular theory deals only with gases and has the following principles....."* clearly indicate that teachers A and B operate in the positivistic paradigm.

TEACHER C

lesson 1

Purpose / topic - Introduction to sound

Teaching strategy - discussion / group work - co-operative learning

Observations

The pupils were divided into groups of five. The teacher gave each group a worksheet on sound. Some of the questions in the worksheet were : What, in your opinion, is our reason for studying sound ?; What is sound ?; What do you believe is necessary to produce sound?; and other similar questions. The pupils were given 30 minutes to brainstorm and provide their views on different aspects of sound. The different groups could choose how they they wanted to report back to the class. They could choose to allow a representative from the group to present their responses to the class or the group collectively reports back to the class or the group presented their responses in the form of a chart. The researcher found that the pupils enjoyed their discussions. The teacher facilitated the discussions in the groups and during report-backs. The teacher indicated that the experiences of the pupils will be their starting point in the section.

lesson 2

Purpose / topic - to find the speed of sound

Teaching Strategy - group experiments

Observations

The pupils were given a task by the teacher, prior to the lesson, to find *or design an experiment to find the speed of sound. In the lesson the groups were allowed to present the method they would use to find the speed of sound to the class. Some of the methods used were : using a starter pistol and stop watch or using a tuning fork and water or using two blocks and an echo. The teacher informed the researcher that the pupils performed their experiments in the next period. Peer assessment was used to evaluate pupils experiments.*

lesson 3

Purpose / topic - Application on sound

Teaching strategy - role playing; group work; co -operative learning

Observations

The pupils were given a task by their teacher to apply whatever they learnt about sound and to develop a radio station. This task was given at the end of the section by the teacher. The task was a class project. The pupils had to divide themselves into, announcers, technicians, writers, commercial artists; and other personnel found in a radio station. The name given their radio station was ***Radio Resonance.*** *This clearly indicates that the pupils thought carefully about the task. They presented news reports, weather reports, music, commercials, jokes and interviews on their station. Group assessment was used for this project.*

lesson 4

Purpose / topic - finding the resistance of an unknown resistor

Teaching strategy - discovery through group experiments

Observations

Pupils were given all the apparatus they needed to find the resistance of an unknown resistor. Their task was to connect the apparatus in such a way that they would be able to find the resistance of the unknown resistor. No other information was given by the teacher. The pupils were allowed to discuss with each other and use the textbook if they wanted. The teacher moved around the classroom checking how the pupils were *connecting the apparatus and posing questions to help them connect the apparatus correctly.*

Teacher C's lessons were learner-centred with a strong emphasis on groupwork, co-operative learning and constructivism. The prior knowledge and experiences of the pupils were not taken for granted but fundamental to the lessons. Teacher C made a concerted effort to get her pupils involved in all lessons. She did not solely rely on her assessment to evaluate her pupils work but used peer and group assessment strategies also. She encouraged the integration of science with other subjects in her lessons. Pupils were encouraged to exchange and share ideas with one another. The avenues created by the teacher for her pupils to work independently and in groups emphasised individual and collective decision making. Teacher C clearly operated either in the critical or hermeneutic paradigm.

The table below reflects teachers' individual responses to some questions about their classroom practices from table B.3 of the questionnaire.

NO	STATEMENTS	SA	A	UN	D	SD
1.	*The main task of a teacher, when teaching science, is to disseminate scientific information.*		A B			C
2.	*I encourage my pupils to participate in classroom discussions.*	AB	C			
3.	*Pupils do not ask sufficient questions during science lessons.*	B	A C			
4.	*Pupil inquiry is restricted to classroom experiments from the syllabus.*	B	A		C	
5.	*Pupils learn the processes of science through induction, that is, doing an experiment by following a worksheet.*	A	B		C	
6.	*Large classes hamper my teaching of science.*	AB	C			
7.	*Examinations determine what I teach.*	AB	C			
8.	*I promote an interdisciplinary approach when I teach science, that is, science is integrated with other subjects.*	C		AB		
9.	*The lack of facilities at school hinder the teaching of science.*	B	C	A		
10.	*I encourage my pupils to design their own experiments.*		C	AB		

NO	STATEMENTS	SA	A	UN	D	SD
11.	*My pupils work independently and critically during science lessons.*				AB C	
12.	*I continually search for ways to improve my science teaching.*	A	BC			
13.	*I always relate work done in class to pupils everyday experiences.*	A	BC			
14.	*I encourage my pupils to become involved in investigating problems of their own selection.*	A	BC			
15.	*Tests require pupils to apply knowledge gained during science lessons.*		BC		A	
16.	*Tests encourage pupils to memorise laws and facts.*				AB	C
17.	*Science teachers are responsible for the way their pupils perform in tests and examinations.*	B	A	C		

TABLE 8 : classroom practices

<u>Key</u> : SA: strongly agree; A: agree; UN: uncertain; D: disagree; SD: strongly disagree.

From table 8, teachers A and B consider that their main task as teachers is to disseminate scientific information to their pupils; implying that pupils contribute very little to the learning process. Teacher C strongly disagreed with the view that she was the most important disseminator of information in her class.

A disturbing feature of this study was that pupils do not question enough although they are encouraged to do so by their teachers. This is a positive indication that a critical environment is not created by all three teachers in their classrooms. Pupils operating in or being taught in a critical environment will not unilaterally accept everything that the teacher has to say. All three teachers acknowledge that their pupils do not work independently and critically during science lessons. This finding will be examined in the next chapter. Gilbert and Pope (1983) maintain that different strategies must be used to create a critical environment where pupils do not unilaterally accept everything that the teacher has to say.

In this study teachers A and B relied heavily on 'guided' experiments to teach their pupils. Both teachers concurred that pupil inquiry in their science classes was restricted to classroom experiments from the syllabus. The teachers acknowledged that their pupils learn the processes of science through induction, that is, doing an experiment by following guidelines from a worksheet. However, I maintain that when pupils do an experiment following a worksheet, they learn science by induction but do not learn the processes of science. Hence, teachers adopting these teaching strategies, operate in an inductivist paradigm. Furthermore, a critical environment is not created as the pupils merely follow instructions on a worksheet or textbook and do not discover information for themselves.

Teacher C acknowledged that she also taught science through 'guided' experiments using worksheets. However, in her worksheets, she excludes the aim of the experiment and allows pupils to draw conclusions for themselves. Furthermore, pupils are accorded the opportunity to develop their own experiments to verify scientific laws such as Newton's second law of motion. Also, pupils are allowed to design experiments of their own to investigate any aspect of science that interests them. These experiments are not restricted to the syllabus and are performed by pupils during the breaks or after school. According to teacher C, she believes that science should be taught as follows :

> ***"learning by experience, allowing pupils as far as possible to assimilate their own scientific findings and discover theories by experiments."***

Furthermore, she believes that it is important to teach pupils that :

> ***"It's OK to make a mistake, or to stick your neck out, eg. Dalton's billiard ball, as long as some thought and creativity has been utilized. Pupils must question everything with the aim to provide a solution."***

She adds that her goal as a teacher is to :

> ***"develop in my students an inquiring mind and the processes in science was more important then the products."***

From the above analysis, it is clear that teachers A and B used the inductive method to teach science. This method allows pupils to work independently or in groups, but requires pupils to merely verify a law or theory. The pupil does not critically examine the law or theory, that is, the pupil is not given the opportunity to design, implement, and critique his / her own investigations. Only teacher C encouraged pupils to become involved in investigating problems of their own selection. These problems were not restricted to the curriculum. Teachers A and B, stated in their interviews, that they would like their pupils to conduct experiments of their own choice. However, various factors made this extremely difficult. Availability of equipment, time constraints, syllabus requirements, examinations and other similar factors made it difficult for them to encourage independent investigations.

Clearly, teachers A and B focussed on the observational and experimental aspects of science. Observational and experimental aspects of science are central to the theory of positivism. Positivism is the idea that universal laws or principles may be induced with certainty from empirical / experimental foundation. Evidence obtained in this study confirms that teachers A and B operated within a positivistic framework. In this theoretical framework, the problem of induction, that is, inferring laws from experiments becomes a problem of confirmation or verification. Other indications that they operated within a positivistic framework are comments such as :

> ***"Pupils must be taught how to interpret, analyse and draw logical conclusions from scientific data."*** Teacher B

> ***"Pupils must be taught how to solve problems and develop logical reasoning. Teachers need to help pupils discover things***

for themselves from guided experiments." Teacher A

These comments made by teachers A and B in the study imply that pupils need to be taught these skills rather than obtain these skills through a process of self - discovery.

The fact that teachers A and B believe that they are responsible for the achievements of their pupils in science (Table 8) implies that the teacher is an essential component to the learning process, that is, constructive learning cannot take place without a teacher. Comments such as *'getting pupils to discover theories by guided experiments'* emphasize the need for the teacher to be in the classroom. In 'guided' experiments, the pupil is directed towards a conclusion or deduction that confirms the law or theory. None of the experiments in the curriculum require the pupil to prove a law or theory false as proposed by Popper (Anderson, Hughes and Sharrock 1986).

An area completely ignored by teachers A and B in this study is the personal experiences of the pupils. Teachers A and B contend that the present curriculum is relevant to the lives of pupils (Table 5). However, in their teaching they do not pay attention to and use the personal experiences and spontaneous reasoning of their pupils. This results in a 'cultural transmission' approach to teaching which dominates their lessons. The idea that knowledge is transmitted from the teacher to the pupil and that the pupil is a passive recipient is a characteristic of the empirical - scientific paradigm. The approach neglects the role of the pupil's personal experiences in constructing knowledge.

Teacher C maintains that the present science curriculum is irrelevant to the lives of pupils (Table 5). However, she recognises the importance of prior learning and experiences. In the first lesson observed by the researcher, the lesson was designed so that pupils had an opportunity discuss and debate their points of view without interference from the teacher. As the lesson was an introductory lesson, the pupils had to rely on their personal experiences to answer some of the questions posed by the teacher.

Research findings with regard to tests and teaching strategies, show that all three teachers look for better ways to teach science and that tests do not merely test facts (Table 8). Pupils are required to apply the facts learnt to new situations (Table 8). However, if science is treated as a collection of facts and these facts are conveyed by the teacher to pupils who unquestioningly accept these facts, then the purpose of testing is to appraise the extent to which this has occurred. Similar findings are reported by Stinner (1992). According to teacher A :

> ***"Pupils are to understand basic concepts taught in science and to use this knowledge to new or given situations. Science is not just memorising for an exam."***

The extent to which the application of science is used by teachers is not examined in this study.

Teachers A and B only used class tests to evaluate their pupils whilst teacher C used other forms of assessment such as peer assessment, group assessment, and other techniques. Teachers A and B focussed on individual assessment and emphasized competition between pupils. Teacher C, on the other hand, believes strongly in co-operative learning with pupils interacting and sharing with each other. She de - emphasized competition for marks between pupils and focussed on working together. The assessment strategies used by the different teachers clearly indicate their mindset and theoretical framework.

From the analysis in this chapter, it is clear that regardless of the nature of curricular materials being developed and 'used' in the teaching process, the teacher continues to play a key role in instruction in the class. The teacher's role in the class, together with implications and recommendations for this study, will be dealt with in chapter five (5).

CHAPTER 5

IMPLICATIONS, RECOMMENDATIONS AND CONCLUDING COMMENTS

5.1 DISCUSSION OF FINDINGS

Although it is not possible to generalise from this small sample of science teachers in the Richards Bay / Empangeni area, it is possible to draw some conclusions about the teachers' beliefs about the nature of science and how it influences their classroom practices. Findings from the research show that teachers' instructional strategies are consistent with their personal educational philosophies. A similar conclusion was reached by Brickhouse (1991). Teachers A and B in the study operated largely within the empirical scientific paradigm. This positivistic approach to science is entrenched by textbooks used by teachers and the present science curriculum. Research findings show that the teachers in the study do not create a critical environment for their pupils. This results in pupils accepting unquestioningly everything the teacher has to say. Pupils, therefore, ask very few questions (Table 8). The questions posed by the pupils generally seek clarity and are not questions relating to understanding or a challenge to the status quo. According to Lucas and Wagner (1977), pupils experience difficulties dealing with problems and 'seeing' the relationship between science and their daily lives since they have not been taught to think and evaluate information critically.

A major finding of this research is that the nature of science is largely ignored in textbooks and the curriculum. Also teachers neglect the nature of science in their teaching of science. The nature of science in the curriculum is restricted to performing 'guided' experiments and making observations to confirm and verify scientific laws and theories. Scientific knowledge is gained by testing hypotheses through the process of experimentation. Scientific processes taught to pupils involve manual skills such as handling apparatus, observing, analysing and interpreting results, inferring, and other similar skills. These processes provide a partial insight into the methods employed by scientists and, therefore, do not fully represent the nature of science.

The present science curriculum does not allow pupils to design and perform experiments of their own choice outside the curriculum. Analysis of teachers' classroom practice and interviews with teachers reveal that teachers A and B placed most emphasis on the body of knowledge of science which can be 'discovered' through experimentation. This inductive approach to experimentation results in a positivistic notion of science being propagated by teachers. Teacher C believed that it is important to teach pupils that :

> ***"Science is not just a body of facts and theories. Science is a dynamic subject and that information is changing all the time."***

Teacher C emphasized the processes of science in her teaching and allowed pupils to learn science through discovery and inquiry. She allowed her pupils freedom to pursue topics of their own interest and to have a voice in their own learning.

Only teacher C, in the study, reflected on what she was doing in the classroom on a continual basis. According to the teacher reflection is necessary to ensure that she :

> ***"find new ways to improve her teaching and examine her pupils' understanding of science"***

She felt a moral obligation and a personal responsibility for her pupils' learning. She believed that the process of reflection was important for her to keep in touch with what happening in her classroom. Also her constructivist beliefs were enhanced when she reflected on her classroom practices. She believed that constructivism was a common - sense way of thinking about student learning. Teachers A and B did not believe that reflection would improve their teaching. They believed that the state laid down guidelines for teachers and these must be adhered to. Also the objectives laid down by the state, in the curriculum, must be completed and tested in an examination.

Another important conclusion of this study is that teachers A and B believe that scientific laws are unchangeable and absolute truths (Table 6). These teachers strongly believe that the purpose of science is to help pupils understand the physical world they live in. They believe that the 'truths' discovered through experimentation will help pupils understand the world they live in. This absolutist view of truth and knowledge corresponds with the empirical - inductivist conception of science.

Another finding of the research is that teachers that hold the empirical - inductivist conception of science neglect the pupils own conceptions and personal experiences. Science has to have meaning for the teacher, to have meaning for the pupils. Hence, if the teacher neglects the personal experiences of the learners, he assumes that it is his / her job to provide pupils with all knowledge and that they bring nothing to the classroom. This results in pupils in these classes not actively participating in lessons and the lessons are teacher dominated. Gilbert and Pope (1983) found that teachers functioning in the scientific paradigm ignore the personal experiences of pupils. It is important for a teacher to know who he /she is teaching, that is, know the pupils' background. This enables a teacher to plan his / her lessons so that all pupils can get involved in the lessons.

Further this study has shown that the present curriculum is 'outmoded and too academic' and is irrelevant to the lives of pupils. Pupils are therefore forced to learn information not relevant to their daily lives. This inflexibility, that is, forcing pupils to learn irrelevant information, is characteristic of the analytical scientific paradigm. Clearly pupils were the end products of a school system that promoted science knowledge as isolated from their lives and alien from their ways of making sense.

A major finding of the research shows that curricular materials such as the syllabus and textbooks contribute to the under-emphasis and misrepresentation of the nature of science in the classroom practices of teachers. A similar finding is reported by Bentley and Garrison (1990). An evaluation of the textbooks used by teachers in the study shows that textbooks concentrate on presenting concepts and principles of science, with little emphasis on the nature of science, or how the knowledge of science is formulated or validated. Textbooks neglect the history and philosophy of science as they do not form an integral part of the curriculum. The present science curriculum does not show the pathway by which science has arrived at its present state, that is, the historical development and context of scientific knowledge are overlooked in textbooks.

Scientists are persons trained in some field of science who study phenomena through observation, experimentation and other rational and analytical activities. They are motivated by their philosophy of science. The data is collected, analysed, evaluated and interpreted. Scientists represent the data in different forms such as tables and graphs. These activities are called the processes of science. The discoveries and findings made by scientists become the products of science. The child must be exposed to both the products and processes of science.

The emphasis on the products of science and the neglect of the processes of science in the curriculum and textbooks has contributed to teachers A and B, in the study, ignoring the nature of science. Findings from the research show that teachers operating in a positivistic framework concentrate on the products of science, that is, the scientific laws, concepts, theories, and others in accordance with the curriculum. However, teachers operating in the hermeneutic or critical paradigms focus on the product and processes of science such as the way scientists work and think, their attitudes, the values underlying science, the relevance of scientific knowledge, and other similar aspects. The processes of science were neglected by teachers A and B who operated in the empirical - analytical paradigm. The developers of the present science curricula failed to 'see' that science is incomplete if it consists only of answers without understanding the nature of those answers and the processes by which these answers were arrived at.

Textbooks contribute to an inductivist perception of science by emphasizing the finished product of a 'scientific fact' as reported by Stinner (1992). Conclusions from this research reveal that science teaching is generally textbook centred (Table 4). Textbooks seldom deal with aspects such as : On what assumptions is a law based ?; What experiments did a scientist perform?; What kind of reasoning did he use in arriving at a law ?; and other historical questions. These questions examine all aspects of scientific knowledge. Teachers, themselves products of textbook teaching, bypass such questions. Textbooks portray science as a collection of facts to be transmitted by teachers and learnt by pupils. It is not surprising, therefore, that teachers A and B perceive science as an empirical - inductive enterprise as this is implicitly supported in textbooks. The same conclusion was reached by Stinner (1992); Bentley and Garrison (1990); Groves (1995) and Gallagher (1991).

A study of the findings of this research show that teachers A and B were not consciously influenced by any philosophies of science. However, teacher C was strongly influenced by the constructivist philosophy and this was evident in her teaching. Teacher C stressed the social construction of knowledge and the need for inclusion of history and philosophy of science in the curriculum. Findings by King (1991), show that an inclusion of history and philosophy in the curriculum would help pupils and teachers understand the processes and nature of science. Teacher C, in the study, calls for science to be 'humanised' and made more relevant to the lives of pupils by placing it in a wider historical, sociological and philosophical context. A similar call is made by Kelly (1983). A disturbing finding of this research is that teachers A and B ignore the cultural influences of the curriculum and neglect the personal experiences of pupils. Further teachers A and B adopted the transmission approach to science teaching. According to Gilbert and Pope (1983) this method of teaching neglects the personal experiences of students in their construction of knowledge.

5.2 RECOMMENDATIONS

Recommendations made by the researcher include the development of new curricula, textbooks, teaching techniques and approaches to science. These are examined below. The researcher is familiar with current curriculum trends, especially outcomes - based education. However, the teachers in the study, used the present interim core syllabus which has not changed in the last ten years. Hence, the recommendations made by the researcher are based on the old syllabus.

Firstly, science needs to be presented to pupils as a dynamic on - going enterprise rather than an accumulated body of knowledge. Previously, science teaching emphasized the knowledge discovered by scientists, now the emphasis should be directed towards how such discoveries are made. Science teaching should, therefore, attempt to produce more rounded personalities who will be able to cope with their environment. It is essential that pupils find science relevant and true to their daily experiences and lives. According to Hodson (1993: 685) any science curriculum should take into consideration the following aspects :

"- addressing 'real - life' situations;

- relate science to wider societal and technological issues;

- developing scientific literacy in the context of active and responsible citizenship;

- promoting science as a cultural phenomenon;

- ensuring that science is more person - oriented;

- start from and build on children's existing knowledge and experience;

- using problem - solving activities to develop creativity and promote decision - making and social skills;

- enhancing each student's self - image and self - worth."

It is heartening to note that these aspects have been taken into consideration in the development of the outcomes - based model for science education. Secondly, the role of the teacher changes when science is considered as a dynamic on - going enterprise. The teacher needs to act as a facilitator in the classroom rather than as an authoritarian as proposed by a teacher in the research by Fraser; Kahle and Tobin (1990). Teacher C acts as a facilitator in her science lessons. It is important that the methods of instruction correctly reflect the nature of science. Teachers need to operate within the critical paradigm, that is, act as transformative intellectuals.

As transformative intellectuals, teachers will have to question the scientific knowledge they teach, continually looking for new and better methods to teach; teach pupils to work independently and think critically; get pupils actively involved in lessons; encourage self - discovery by pupils and make science meaningful and relevant to pupils. Co - operative learning, class discussions, role playing are some teaching strategies that teachers need to use to create an environment where the nature of science cannot be taken for granted and students are active participants in the learning process. Also, science in the classroom must be taught through a process of deduction rather than induction.

Thirdly, in South Africa, it is essential to make science accessible to all pupils, irrespective of their social backgrounds. The curriculum must be made relevant to the daily lives and experiences of all pupils irrespective of their social or economic backgrounds. By ensuring equal access to science for all citizens, a scientifically literate society can be created. All sectors of the community must be consulted when developing a curriculum. The present outcomes - based model has had extensive consultation with all stakeholders. This ensures that the curriculum is truly representative of the inputs of all people and that a single ideology is not propagated.

An inclusion of history and philosophy of science in the curriculum is essential to reflect accurately the nature of science. The inclusion of history and philosophy of science in the curriculum can help pupils understand the nature of science and the role that it plays in society and civilization at large. A similar call is made by Gruender and Tobin (1991); Hodson (1988) and Hodson (1993). Philosophy of science will help pupils and teachers appraise the values of science as a human activity. It will help pupils and teachers 'see' behind specific research methods, laws and theories, the works of scientists, and other aspects of science. The history of science places scientific knowledge in a wider context, pointing out where the knowledge evolved from and how it developed. The relationship between history and philosophy of science to classroom practice is supported by Rutherford who is quoted in Bybee, et al (1991 : 148) :

> ***"Science teachers must come to understand just how inquiry is in fact conducted in the sciences. Until science teachers have acquired a rather thorough grounding in the history and philosophy of sciences they teach, this kind of understanding will elude them, in which event not much progress towards the teaching of science as inquiry can be expected."***

Fourthly, science textbooks in South Africa need to change. Aspects previously ignored by textbook writers should be included in the textbooks.

The historical development of science and questions that examine the processes of science should form an integral part of any new textbook. Textbooks, therefore, need to reflect the new contents; approaches and philosophies of the curriculum. Also, textbooks must provide an authentic representation of the nature of science.

Finally, the possibility of integrating science with other subjects offered at school, needs to be examined. An integrated approach to the curriculum, in South Africa, can help build bridges between pupils and the different forms of knowledge that they are exposed to. Integrated studies can involve taking a law or theory and examining its historical development, relevance to pupils lives, mathematical applications, the type of language used and why, and many other aspects. This will enable the pupil to develop a holistic picture of science and society.

5.3 IMPLICATIONS FOR FURTHER RESEARCH

Literature reviewed for this research reveal that the following aspects also influence the teacher's belief about the nature of science which in turn affects his / her classroom practice :

a) advanced science technology - especially computers.
b) gender discrimination in textbooks and by teachers.
c) teacher preparation, that is, tertiary education and the way teachers were taught at school.
d) the 'hidden' curriculum - things pupils learn which are implied in the curriculum.

The above factors are not examined in detail in this research study. However, findings from the research indicate that the nature of science is largely neglected in teacher training institutions. Research findings show that the lack of understanding of the nature of science by teachers negatively influences their classroom practices. Any future research on teachers' beliefs about the nature of science and its influence on their classroom practice must take into consideration the four (4) aspects mentioned above.

This research study was undertaken as a case study using only three teachers due to time and monetary constraints. Information obtained from all data sources, namely, questionnaire, interviews and classroom observations, were used to derive certain findings. It is the view of the researcher that an ethnographic study, using interviews and participant observation, will be a more effective method to determine the relationship between teachers' beliefs about the nature of science and their classroom practices.

5.4 CONCLUDING COMMENTS

All teachers teach science according to a belief system. If what the teacher teaches is in conflict with his / her belief system, then the teacher is disempowered in his / her classroom practices, that is, the teacher merely acts as a transmitter of knowledge. Traditional classroom techniques 'encourage' the teacher to accept the status quo and not to question the knowledge he / she is transmitting to his / her pupils.

For changes to occur in teachers' classroom practices, the teacher needs to examine his / her beliefs, judgements and thoughts about his / her classroom practices. The teacher needs to reflect on what he / she does and why he / she does it. This reflection by science teachers will enable them to critically evaluate their policies and practices and view science as an integrated process. As transformative intellectuals, teachers develop critical thinking strategies in their pupils. Teachers and pupils interacting in the critical plane never take the processes and nature of science for granted.

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APPENDIX 1

The purpose of this research is to ascertain the relationship between teachers' beliefs about the nature of science and their classroom practice.

All responses to the questionnaire are strictly confidential and are for research purposes only.

Your school will receive a full report of these research findings.

QUESTIONNAIRE

Should you experience any difficulties with the questionnaire, please contact Mr S.K.Singh at (0351) 972112. Thank You.

SECTION A : TEACHER BIOGRAPHY

1. NAME : ______________________

2. NAME OF SCHOOL : ______________________

3. SEX (male / female) : __________

Place an X in the appropriate box to the questions that follow.

4. WHAT SUBJECTS DO YOU TEACH AND FOR HOW LONG HAVE YOU TAUGHT THESE SUBJECTS ?

		subjects currently being taught	***teaching experience in years***
4.1	Biology		
4.2	Physical Science		
4.3	General Science		
4.4	Mathematics		
4.5	Other		

5. COMPLETE THE TABLE BELOW :

		YES	NO
5.1	*Do you have a qualification from a tertiary institution ?*		
5.2	*Did you study or take courses in the History and / or Philosophy of Science ?*		
5.3	*Do you belong to any professional organisation related to the subjects which you teach ? Eg. SAATPS; KASTE; regional / branch science committees ; SAARMSE ; AMESA*		

6. IF YOUR ANSWER TO ANY OF THE QUESTIONS ABOVE WAS YES, PLEASE ANSWER THE QUESTIONS BELOW :

6.1 WHAT ARE YOUR TEACHING QUALIFICATIONS ?

____

6.2 NAME THE PROFESSIONAL ORGANISATION/S TO WHICH YOU BELONG : ______________________

____

6.3 NAME SOME PHILOSOPHERS OR PHILOSOPHIES OF SCIENCE THAT YOU HAVE COME ACROSS IN YOUR STUDIES OR TEACHINGS.

____

____

____

6.4 IDENTIFY SOME IMPORTANT ISSUES DISCUSSED AT SCIENCE MEETINGS IN OR OUT OF SCHOOL.

____

____

____

____

____

____

____

SECTION B

The tables on pages 3; 4 and 5 concerns issues around the nature of science. Please indicate the degree to which you agree or disagree with each statement in the tables by placing an X in the appropriate box to the right of each statement.

The following key applies to the tables :

SA : STRONGLY AGREE
A : AGREE
UN : UNCERTAIN
D : DISAGREE
SD : STRONGLY DISAGREE

TABLE B.1

NO	STATEMENTS	SA	A	UN	D	SD
1.	*Science helps me understand the world around us.*					
2.	*Only science can help me to understand nature.*					
3.	*Scientific laws and facts are always produced through experimentation.*					
4.	*Laws and theories in science help clarify phenomena in nature / world*					
5.	*Science is objective and value free.*					
6.	*All scientific knowledge is true.*					
7.	*Scientific knowledge is socially constructed.*					
8.	*It is essential to make science relevant to my pupils.*					
9.	*Science is an accumulated, ever changing body of knowledge.*					
10.	*Science has a core body of knowledge that never changes.*					
11.	*All scientists follow a common routine when doing research.*					
12.	*Scientists are particularly objective people.*					
13.	*I adhere strictly to the syllabus when teaching science.*					
14.	*Scientific laws are unchangeable and absolute truths.*					
15.	*Socio-economic progress in society is dependent on society's acceptance and encouragement of the study of science.*					
16.	*Scientific experiments provide conclusive proof about phenomena in the world.*					

TABLE B.2

NO	STATEMENTS	SA	A	UN	D	SD
1.	*Science textbooks correctly represent the processes of science.*					
2.	*The textbook is an important resource guide when I teach.*					
3.	*Textbook drawings and pictorial illustrations are a true representation of science.*					
4.	*Textbook writers emphasize the finished product of a 'scientific fact'.*					
5.	*The present curriculum is irrelevant to pupils everyday experiences.*					
6.	*Teachers emphasize the finished product of science.*					
7.	*The curriculum should emphasize the processes of science.*					
8.	*I use references, other then the prescribed text, in my classroom practice.*					
9.	*The science syllabus and examinations dictate how I teach science.*					
10.	*The present science syllabus does not place science in a historical context.*					
11.	*The present science syllabus ignores the history and philosophy of science.*					
12.	*The present science syllabus has remained the same from 1985 to 1996.*					
13.	*The science syllabus has not kept up with advances in technology.*					
14.	*My teacher education training emphasized the content of the curriculum and not history or philosophy of science.*					
15.	*History and philosophy of science should be included in the science curriculum.*					
16.	*A study of the history and philosophy of science will enhance my understanding of science.*					

TABLE B.3

NO	STATEMENTS	SA	A	UN	D	SD
1.	*The main task of a teacher, when teaching science, is to disseminate scientific information.*					
2.	*I encourage my pupils to participate in classroom discussions.*					
3.	*Pupils do not ask sufficient questions during science lessons.*					
4.	*Pupil inquiry is restricted to classroom experiments from the syllabus.*					
5.	*Pupils learn the processes of science through induction, that is, doing an experiment by following a worksheet.*					
6.	*Large classes hamper my teaching of science.*					
7.	*The syllabus dictates what I teach.*					
8.	*The syllabus allows me freedom to do what I want.*					
9.	*Examinations determine what I teach.*					
10.	*I promote an interdisciplinary approach when I teach science, that is, science is integrated with other subjects.*					
11.	*The lack of facilities at school hinder the teaching of science.*					
12.	*I encourage my pupils to design their own experiments.*					
13.	*My pupils work independently and critically during science lessons.*					
14.	*I continually search for ways to improve my science teaching.*					
15.	*I always relate work done in class to pupils everyday experiences.*					
16.	*I encourage my pupils to become involved in investigating problems of their own selection.*					
17.	*Tests require pupils to apply knowledge gained during science lessons.*					
18.	*Tests encourage pupils to memorise laws and facts.*					
19.	*Science teachers are responsible for the way their pupils perform in tests and examinations.*					

SECTION C : OPEN ENDED QUESTIONS

ANSWER THE QUESTIONS BELOW.

1. *What is science ?*

2. *Is the nature of science similar or different to the nature of any other subject ? Identify some similarities and differences between the nature of science and the nature of other subjects ?*

3. *What are some ways in which scientific knowledge is produced ?*

4. *Why is an understanding of the nature of science important ?*

5. *What are your goals as a science teacher ?*

6. *What does doing science involve?*

7. *How should science be taught in schools?*

8. *Is there a difference between a law and a theory? Explain your answer.*

9. *What is it about science that is most important to teach to pupils?*

10. *Is it necessary for science to be made relevant to the lives of pupils? Explain your answer.*

THANK YOU FOR YOUR TIME AND INVALUABLE CONTRIBUTION TO THIS RESEARCH.

APPENDIX 2

TEACHER INTERVIEW SCHEDULE

CHAT : Thank you for agreeing to participate in this study. I would be audio taping this interview. May I do that ?

1. Very briefly tell me about of your school.

2. Identify some highlights and disappointments for you as a science teacher.

3. If there are vacancies at your school, would you encourage other science teachers to apply ? Why ?

4. Why did you decide to become a science teacher ?

5. I have notice from your questionnaire that you attended college / university. Briefly describe your teacher training programme. What was emphasized in your teacher training programme ... the content of science or methodology or both. ...... Did you receive training in analysing or evaluating a curriculum ? Were you exposed to issues surrounding the nature of science ?

6. You have studied science for many years. What, in your opinion, is science? ....Is science different from other academic disciplines ? ..... Do you believe that science has a nature unique to itself ? ..... Is there a scientific method? If yes, what is a scientific method ? .....What does doing science involve ?

7. Do scientists engage in a scientific method ? ..... Do scientists only produce scientific knowledge ? If no, in what other ways is scientific knowledge produced ?

8. What is the purpose of studying / learning science ? ... Why is it important to teach science to your pupils ? Do you believe that understanding the nature of science is important ? Why ? What can teachers do to enhance their understanding and their pupils understanding of the nature of science ?

9. What are your goals as a science teacher ? ..... How do you teach science to your pupils ? .... Do you believe that this is the best way ? If yes, why? ..... Have you used other ways to teach your pupils science ? If yes, identify them. .... How often do you examine / reflect what you teach your pupils ? Do you believe that regular reflection will enhance your teaching ? ...Identify some factors that hinder your teaching. .... Have you been able to overcome these factors. If yes, state how.

10. Why are experiments important in science ? ....How often do your pupils do experiments ? .... What is the purpose of the experiments that your pupils conduct ? ......Are these experiments in the syllabus ? Do you conduct experiments outside the syllabus ? What methods do you use to encourage pupil inquiry in your science classes ? Do you believe that the lack of facilities / equipment in school impacts negatively on pupil inquiry ? Explain.

11. How do you evaluate what you have taught your pupils ? ..... I notice that testing is one of your responses. ...What do you believe is the purpose of testing? ...... Why do you set class tests ? ....Do your pupils look forward to writing a science test ? How do you know ? What other assessment techniques do you use to assess your pupils ?

12. What resource materials do you use when you teach science ? .... I notice that you consider textbooks as a resource material. How important are textbooks in your lessons ? ..... What do you use textbooks for ? ..... Do you believe that science textbooks accurately represent the nature of science ? Explain.

13. A science textbook generally adheres to the science syllabus. In your opinion, do science textbooks adequately cover the science syllabus? Do you believe that the present science syllabus should change ? Why ? .... What should any science curriculum emphasize ? ...... Do you believe that the present science syllabus correctly represents the nature of science ? Should history and philosophy of science be included in the science curriculum ? Why ?

14. Finally in the curriculum we have facts, laws and theories. What do we mean by a fact in science? ..... Are scientific facts open to question ? Is a fact different from a law ? ..... How does a law differ from a theory?

Thank you for you invaluable contribution and time.

APPENDIX 3

CLASSROOM OBSERVATION SCHEDULE

TEACHER	A	B	C

A. GENERAL

1. DATE OF OBSERVATION	
2. GRADE / STANDARD OBSERVED	
3. SUBJECT	
4. TOPIC TAUGHT BY TEACHER	

B. TEACHING STRATEGIES

1. WHAT OVERALL TEACHING STRATEGIES DID THE TEACHER IMPLEMENT ?	
2. DID THE PUPILS WORK INDIVIDUALLY OR IN GROUPS ?	
3. WHAT ROLE DID THE TEACHER PLAY IN THE LESSON?	
4. WHAT DID THE PUPILS DO WHILE THE TEACHER TAUGHT THE LESSON ?	
5. WHAT ASPECTS DID THE TEACHER EMPHASIZE IN THE LESSON EG. LAWS, APPLICATION ?	

C. INTRODUCTION TO LESSON

1. HOW DID THE TEACHER INTRODUCE THE LESSON ?	
2. WHAT DID THE TEACHER DO TO GAIN THE INTEREST OF THE PUPILS ?	
3. WERE PUPILS ALLOWED TO USE THEIR PERSONAL EXPERIENCES TO EXPLAIN NEW SCIENCE CONCEPTS ?	

D. BRIEF DESCRIPTION OF THE LESSON

E. QUESTIONS

1. DID THE TEACHER POSE QUESTIONS TO THE PUPILS ? WHO ANSWERED THESE QUESTIONS ?	
2. DID THE QUESTIONS REQUIRE PUPILS TO HAVE AN UNDERSTANDING OF SCIENCE OR MERE RECITING OF LAWS AND DEFINITIONS ?	
3. DID THE PUPILS POSE QUESTIONS TO THE TEACHER ? WHAT KINDS OF QUESTIONS DID THE PUPILS ASK ?	
4. HOW DID THE TEACHER RESPOND TO THE QUESTIONS FROM THE PUPILS ?	

F. TEXTBOOKS

1. DID THE TEACHER USE A TEXTBOOK DURING THE LESSON ?	
2. FOR WHAT PURPOSE WAS THE TEXTBOOK USED ?	
3. HOW OFTEN DID THE TEACHER REFER TO THE TEXTBOOK ?	
4. DID THE TEACHER USE ANY OTHER REFERENCE WORKS IN THE LESSON ?	

G. SYLLABUS

1. WAS THE TOPIC TAUGHT FOUND THE SYLLABUS ?	
2. DID THE TEACHER USE EXAMPLES OUTSIDE THE SYLLABUS IN THE LESSON ?	
3. WERE EXPERIMENTS CONDUCTED IN CLASS FROM THE SYLLABUS ?	
4. WERE PUPILS GIVEN A WORKSHEET OR DID THEY USE THE TEXTBOOK WHEN PERFORMING EXPERIMENTS ?	
5. WAS PUPIL INQUIRY ENCOURAGED IN THE LESSON ? IF YES, STATE HOW.	

H. TESTS AND EXAMINATIONS

1. DOES THE TEACHER FOCUS ON EXAMINATION PREPARATION IN THE LESSON.	
2. DO CLASS TESTS FOCUS ON MEMORY RECALL OR APPLICATION ?	
3. DO PUPILS LOOK FORWARD TO WRITING A SCIENCE TEST ?	
4. ARE TESTS THE ONLY CRITERIA USED TO EVALUATE PUPILS WORK ? IF NO, NAME OTHER METHODS USED.	

I. OTHER OBSERVATIONS
