

CHAPTER 1

ORIENTATION

1.1 INTRODUCTION

The government of Botswana intends to provide all its learners with high-quality science education (Nganunu 1996:1; Okatch 1989:2). The Report of the National Commission of Botswana Education (1993:175) recognised the important role of science and technology in the country's economic, social and cultural growth potential.

According to the Report (1993:27), the goal of science education in Botswana is to make all learners scientifically literate and to develop scientifically skilled human resources. Scientific literacy will enable Botswana's learners to participate in rapidly changing scientific and technologically oriented societies, and is seen as the educational solution to the economic, social and environmental challenges of the 21st century (Moss, Elenaor & Judith 2001:771).

An adequate understanding of the nature of science and the scientific method is an important and essential component of scientific literacy. It is also important to note that an understanding of the nature of science and the scientific method is important, because both contribute to the advancement of scientific literacy.

An analysis of the Botswana science curriculum indicates that learners' understanding of the nature of science and the scientific method is a stated objective. The importance of developing an adequate understanding of the nature of science and scientific method is evident from the assertions made by researchers, who argue that scientific literacy constitutes a core

objective of science education throughout the world (Akersen, Abdl-El-Khalick & Lederman 2000:295; Abdl-El-Khalick, Bell & Lederman 1998: 417; Lederman 1999:916; 1992:331; Bently & Garrison 1991:67; Lederman & Zeidler 1987: 721; Ogunniyi 1982:25).

Science learners' understanding of the nature of science and the scientific method results from the interaction of formal curriculum experiences and informal learning experiences. Learners tend to be strongly influenced by curriculum experiences, and these are determined by the teachers' own views on science (Hodson 1993: 5).

Lederman (1992:335) claimed that many previous research studies indicated that science learners' understanding of the nature of science was seriously inadequate. In order to find a solution to this problem, researchers first need to analyse science learners' experiences of the science curriculum. Researchers also need to find out what teachers think about the nature of science and the scientific method, to find out if they (i.e. teachers) are exacerbating the problem.

Science teachers' own views about the nature of science and the scientific method will influence their instructional practice, their choice of methods, selection of learning experiences, and selection of evaluation procedures. Hassan (2001); Kumano (1998); Hammrich (1997); Ogunniyi, Ogawa, Yandila, Oladele (1995); Abell and Deborah (1994); Hodson (1993); Lederman (1992); Bently and Garrison (1991); Brickhouse (1990); Hodson (1988); and Lederman and Zeidler (1987) all indicate that teachers' views on the nature of science and the scientific method constitute a major factor in communicating implicit and explicit messages in the science curriculum. Teachers convey explicit messages about the nature of science and the scientific method by their particular emphasis on certain features of the scientific method during laboratory work, class discussions, and supportive

teaching materials. The implicit messages about the nature of science and the scientific method are conveyed through teacher's instructional language and the way teachers design certain features of learning experiences. Teachers, therefore, consciously or unconsciously, shape the nature of the information about the nature of science and the scientific method conveyed to learners. This, in turn, influences learners' understanding of the nature of science and the scientific method.

Science teachers are the key to the implementation of the science curriculum; it is teachers who determine the success of the curriculum. The Report of the National Commission on Education (1993: 335) recognised the important role played by the teacher in implementing the school curriculum.

Ogunniyi et al (1995); Lakin and Wellington (1994); and Hodson (1993), however, found that science teachers' conceptions about the nature of science and the scientific method are not consistent with currently accepted conceptions. This raises the question: do science teachers themselves acquire a proper understanding of the nature of science during their professional training? To answer this question, the researcher has focused on student teachers (pre-service teachers) in science education in Botswana, to determine whether student teachers, in fact, have an adequate understanding of the current interpretation of the nature of science and the scientific method.

The concept of the "nature of science" is, according to Hammarich (1997: 141); Bentley and Garrison (1991: 67), a foundational and important part of the knowledge base for teaching and learning science. Student teachers should develop a healthy respect for the achievements of science and for the scientific method; they should also develop a healthy scepticism of any claims to final truth (Burbules and Linn 1991: 228). An understanding of the nature of science, its presuppositions, values, aims and limitations,

should be a central goal of science teaching and learning. An understanding of the nature of science, its processes, concepts, principles, theories, laws, scientific models, processes for generation and validation of scientific knowledge and the nature of scientific endeavour are, therefore, important for student teachers.

Student teachers should gain an appreciation of how the achievements of science actually come about. They should develop a realistic picture of the different scientific methods used by science. An understanding of the scientific method helps student teachers to determine the purpose of scientific investigations, and also helps them to design, develop and organise scientific investigations.

McComas (1998:5) identified teachers' understanding of the nature of science as a fundamental factor in guiding science educators to accurately portray science-to-science learners. An adequate understanding of the nature of science and the scientific method will therefore contribute to successful teaching practices in future.

Consequently, teacher education needs to include the nature of science and the scientific method in its curriculum. The rationale of dealing with this issue in the curriculum for teacher education is (mainly) to foster the development of adequate conceptions of the nature of science and the scientific method.

Well-trained teachers with an understanding of the nature of science and scientific methods will, in the end, determine the success of science education. It is better to ensure that student teachers are adequately trained, from the beginning, in a proper understanding of the nature of science and scientific methods rather than trying to correct misconceptions at a later stage in their careers.

1.2 THE SIGNIFICANCE OF THE PRESENT STUDY

This study is aimed at finding out and exploring the views held by secondary science student teachers studying at Secondary Colleges of Education in Botswana. This study is based on the assumption that a personal understanding of the subject matter influences the effectiveness of instructional practice in the classroom (Hammrich 1997:141; Hassan 2001:236; Bently & Garrison 1991: 67). Student teachers' understanding of the nature of science and the scientific method will influence both effective classroom practice, and the achievement of course aims and objectives in the future. Student teachers views on the nature of science and the scientific method are obviously central to their own professional development during their teacher-training period and to their careers as science teachers.

Central to the problem of learning science appears to be what student teachers already know when they come to the science class. Each student teacher comes with his/ her knowledge about science from his/her secondary school and informal learning experiences (e.g. the media). Eugene, Thomas, and Collette (1998: 81) state that effective science teaching must take into account what the student knows already. Previously acquired concepts about the nature of science and the scientific method will influence what is learnt from new learning experiences and will also act as filters through which new learning takes place during their teacher training.

Teacher trainers should, therefore, have some insight into student teachers' preconceptions, insight that will enable them to facilitate student learning by providing their student teachers with suitable learning experiences (and thus facilitate conceptual change). In order to develop an

adequate understanding of the nature of science and the scientific method there is, therefore, a need to assess student teachers' perception of the nature of science and the scientific method.

Giving student teachers an adequate understanding of the nature of science and the scientific method is obviously a challenging job. Student teachers views are also relevant in the design of the curriculum for teacher trainees, and in providing the type of learning experiences that will support proper teacher development. The present study encourages science educators to do further research into the possibility of including historical, philosophical and sociological dimensions of natural science in the curriculum.

The present study also throws light on how student teachers' views are associated with gender and the years they have spent studying. The present study aims at finding out whether the type of educational institution has any influence on student teachers' views. This study concentrates on how these views are associated with student groups who are studying science as a major teaching subject and with those who are studying science as a minor teaching subject. This study therefore contributes to our understanding of how student teachers construct conceptions about the nature of science and the scientific method and which aspects of teacher educational programmes contribute to student teachers understanding of the nature of science and the scientific method.

The views held by student teachers in Botswana can inform the researcher and policy-makers about the possibilities of improving pre-service science training in the country. The researcher is therefore interested in finding out student teachers' views on the nature of science and the scientific method.

1.3 STATEMENT OF THE PROBLEM AND BACKGROUND INFORMATION

As discussed above, student teachers views on the nature of science and the scientific method act as a filter in their construction of new knowledge during their professional development. If student teachers have misconceptions about, and incoherent views on, the nature of science and the scientific method, subsequent knowledge and concepts built upon these ideas are likely to be both erroneous and fragmented (Hammarich 1997:141).

Student teachers' understanding of the nature of science and the scientific method is therefore most important. Student teachers cannot be expected to contribute to science learners' understanding of the nature of science and scientific method in future, if they themselves do not possess adequate understanding of what science is. Arguably, student teachers with an inadequate understanding of the nature of science and scientific method may hinder efforts to achieve science learners' understanding of the nature of science and scientific method. Worse still, student teachers may perpetuate misconceptions about science during their teaching careers if these student teachers have not themselves acquired acceptable/adequate understanding of the nature of science and scientific method.

In Botswana, Secondary School science teachers are trained at Secondary Colleges of Education and in the Departments of Mathematics and Science Education (DMSE) of the University of Botswana. The main aim of the science programme at the Secondary Colleges of Education is to produce competent science teachers with the knowledge, skills and attitudes required to teach science. In acquiring such knowledge, skills and attitudes it

is hoped that science teachers, in turn, will contribute to science learners' scientific literacy and scientific thinking in future.

In order, therefore, to function as competent science teachers in the future, science student teachers require an adequate understanding of how science operates. Knowledge of post-positivist / non-traditional views of the nature of science and the scientific method is necessary to properly understand current beliefs about the nature of science, both its scope and its limits. For the purposes of the present study, post-positivism is defined as a cumulative doctrine of different philosophical viewpoints held by a variety of philosophers such as Feyerabend, Lakatos, and Kuhn.

According to Karen and Renato (1999), non-traditionalists / post-positivists believe that scientific observations are both theory dependent and fallible. Non-traditionalists / post-positivists believe that scientific theories are human creations which have an interpretative and explanatory role in scientific research. Scientific theories grow and develop in order to accommodate scientific observation. In other words, non-traditionalists / post-positivists believe that scientific theories are not final truths. The validation and acceptance of scientific theory is a complex activity within a community of scientists. Scientific theory is validated in terms of theoretical arguments, experiments, and the personal opinions of the scientists. Scientists' work is affected by many factors, such as the personal knowledge of scientists, and social, cultural and political factors. The objectivity of a scientist's work is achieved through criticism/testing by other scientists within a community of scientists. Thus, objectivity in a scientist's work is not characteristic of an individual; it is inherently a social phenomenon.

Karen and Renato (1999) further posits that non-traditionalists / post-positivists believe that scientific progress is not only cumulative, but also evolutionary and revolutionary in nature. Scientific knowledge is subject to change, is subjective and is culturally embedded. Post-positivists believe that there is no single, universally accepted scientific method. Science has different methods; the nature of the scientific method depends upon particular circumstances.

An awareness of post-positivist views is very important for student science teachers because, while it creates a healthy respect for science achievements and the methods of science, it also encourages a healthy scepticism concerning the finality of scientific truth. Such an understanding will help student teachers in their own learning as science teachers, and will help to develop effective instructional science teaching in the future.

Empirical research conducted by Burbules and Linn (1991: 228) and Khan (1993: 12) shows that science teachers do not possess an adequate understanding of the nature of science and the scientific method. Teachers may simply not be aware of non-traditional / post-positivist views of science and there is therefore a chance of conveying misconceptions about what science is and what it is not through implicit and explicit messages.

These observations immediately raise the question of whether teacher-training courses help teachers to acquire an adequate understanding of science. The empirical research findings of Hassan (2001); Abdl- El-Khalick and Lederman (2000); Karen and Renato (1998); Kumano (1998); Nott and Wellington (1998); Mellado (1997); Gustafson and Rowell (1995); and Abell and Deborah (1994) show that pre-service teachers do not possess an adequate understanding of the nature of science and scientific method.

Most of the studies related to the nature of science and the scientific method have been done in different countries and in a variety of educational contexts. In general, there is insufficient literature about student teachers' understanding of the nature of science and scientific method in Botswana. As far as the researcher is aware, no studies have been conducted in Botswana's Secondary Colleges of Education to find out what student teachers think about science.

Since views held by student teachers about the nature of science and scientific method are important to their professional development and future teaching career, it is important therefore, to conduct research, which seeks to understand these views. In other words, the conceptions of the nature of science and scientific method possessed by the student teachers need to be scrutinised, as these are essential in an adequate teacher preparation programme for science teachers (Hassan 2001: 236).

Another important aspect of the study is to determine what the different factors are that contribute to student teachers' adequate understanding of the nature of science and scientific method. Adequate understanding of the nature of science might be affected by gender, type of educational institution where student teachers study, duration of study, and whether student teachers are studying science as major / minor teaching subject. The concern of the present study is to determine the association between the above-mentioned factors and an adequate understanding of the nature of science and scientific method. Gender specific roles of traditional societies may influence student teachers' views on what science actually involves. Also, of course, student teachers' views might change as they progress through their three years of study. It is very interesting to determine how the gradual evolution and development of an adequate understanding of the nature of science and the scientific method occurs. Student teachers studying in different institutions might form different

perceptions of science purely on the basis of institutionalised factors. Student teachers that chose science as the major teaching subject might have a better understanding of the nature of science and the scientific method than those who chose science as a minor teaching subject.

At present, there is insufficient literature dealing with the influence of the above factors on the formation of an adequate understanding of the nature of science and the scientific method.

In light of the above discussion, the present study attempts to answer the following research questions:

(a) Do student teachers' views reflect currently accepted views (non-traditional / post-positivist) of the nature of science and the scientific method?

(b) Is there any association between student teachers' scores on the nature of science, scientific method and variables such as gender, type of educational institute which student teachers attending, years spent studying, and whether student teachers are studying science as major/ minor teaching subject?

1.4 OBJECTIVES

The present study attempts to:

(a) determine student teachers' views on the nature of science and the scientific method.

(b) determine the association between student teachers scores on nature of science, scientific method and gender, type of educational institute, years spent studying, and student teachers science major/ minor teaching subject.

1.5 CLARIFICATION OF CONCEPTS USED IN THE RESEARCH PROJECT

1.5.1 The nature of science

In this study 'the nature of science' means the way in which science operates in terms of the following:

- nature of scientific observations
- status, role and validation of scientific theories
- status and role of scientific laws
- status of scientific models
- nature, generation, development and progress of scientific knowledge
- nature of scientists' work

1.5.2 The scientific method

The 'scientific method' in this study refers to all those methods used to obtain and verify scientific knowledge

1.5.3 Student teachers

In this study, 'student teachers' refer to science student teachers enrolled in the Diploma of Secondary Education at both Tonota College of Education and Molepolole College of Education (Secondary Colleges of Education) in Botswana.

1.6 THEORETICAL FRAMEWORK AND RESEARCH DESIGN OF PRESENT STUDY

1.6.1 Theoretical framework

The theoretical framework underpinning the present study is the non-traditional / post-positivist view of the nature of science and the scientific method. To reiterate: post-positivism is, in effect, a cumulative doctrine based on different philosophical viewpoints held by a variety of philosophers such as Feyerabend, Lakatos, and Kuhn. Karen and Renate (1999: 1125) claim that researchers such as Lederman (1992) and Ryan and Aikenhead (1992) are consistent with the views of post-positivism. References to non-traditional / post-positivism generally refers to currently accepted views on the nature of science and the scientific method.

Non-traditionalists / post-positivists argue that scientific observations and scientific processes are theory dependent (Karen & Renato 1999:1124). Post-positivists argue that scientific theories are not derived directly from scientific observations, but that their value to scientists instead lies in their ability to describe, explain and predict scientific observations. Scientific theories therefore have an interpretative and explanatory role in research. Scientific theories grow and develop in order to accommodate observational evidence. Scientists create scientific theories to serve as tools for organising and interpreting their knowledge, to solve problems, and to help them see new possibilities in research. In short, scientific theories are human creations used as a device to understand the world.

According to post-positivists (e.g., Bentley & Garrison (1991)), scientific laws are simply scientists' best efforts to explain nature. Scientific laws state, identify or describe relationships among observable phenomena. Scientific models are socially constructed devices, ideas, or structures designed to understand scientific phenomena. Scientific models are not, in other words, copies of scientific reality.

According to Bentley and Garrison (1991:68), post-positivists reject the hierarchical relationship between theory and laws, in which theories become scientific laws depending on the availability of supporting evidence. According to post-positivists, scientific laws may not be induced with certainty from any empirical / experimental evidence.

An awareness of non-traditional / post-positivist views improves student teachers' understanding of the complex relationship between scientific observations, experiment and scientific theory. Student teachers need to realise that some theories originate from pre-theoretical experimentation, some have no experimental support and some are based on a mixture of theory and experimental work.

According to non-traditionalists / post-positivists (e.g., Bentley & Garrison (1991)), the acceptance of a scientific theory is a complex activity within any community of scientists. It is an interaction between theoretical arguments, experiments and the personal opinions of scientists themselves. Other factors, such as social, economic, political, religious, moral, and ethical considerations, may influence the criteria according to which a scientific theory is selected. Post-positivists believe that scientists study a world of which they are a part and, as such, their work is neither objective nor value free. Scientists are influenced by prior knowledge, theories, social

factors and other issues. An individual scientist's confidence in new experimental results or a new theoretical system is insufficient to establish that theoretic system as a part of scientific knowledge; it must stand up to criticism or testing by other practitioners. The community of scientists determines the criteria of truth and acceptability. An exposure to and understanding of post-positivists' views help student teachers to understand that there are clear distinctions between hypothesis generation, hypothesis testing and the social process of accepting and recording scientific knowledge (Hodson 1993:11).

According to post-positivists (Kourany 1998: 259), science progress is not only cumulative as the number of observations increases, but also has an evolutionary and revolutionary character. Science progress is viewed as evolutionary when it replaces current theories with more successful theories. Science also progresses when it replaces current theories, associated facts, methods and goals with new theories, associated facts, methods and goals. This is why scientific progress is viewed as revolutionary (Rosenberg 2000:147). In fact, scientific progress can be best described as a revisionary process rather than merely a cumulative process. In this revisionary process, scientific theories are either revised or replaced.

Post-positivists consider science as an attempt to explain natural phenomena, not as something that provides us with complete answers to all questions. Science is seeking approximate answers to questions about nature. The interpretations of nature constantly change with new experiences, and with new conceptions of the universe.

According to post-positivists, science has many methods, but the precise nature of the method depends on particular circumstances. Hodson (1998:28) states that the "scientific method", like the knowledge it produces, changes and develops in response to the context of inquiry." In other words, there is no one method of science applicable at all times. The current scientific method suits the current situation, the problems, the stock of theoretical knowledge, the investigation techniques and the instruments available to us. When the situation changes, the method changes (Hodson 1986:219; 1985: 34; 1982: 112). Such an understanding helps to encourage student teachers to rely on many avenues and methods of investigation; to understand that questions or problems can be tackled in multiple ways, given different purposes. Post-positivists not only recognise, but also celebrate the richness and variety of experiences that constitute valid scientific discovery (Pomery1993: 263). Such awareness helps student teachers to encourage activities that foster analysis and an evaluation of multiple-data sources. New scientific knowledge is produced as a result of creativity and imagination coupled with a certain scientific method. An understanding of scientific practices requires creativity and encourages student teachers to provide learners with opportunities to think creatively. In short, knowledge of non- traditional/post-positivism philosophy improves student teachers' understanding of the nature of science and scientific methods.

The research findings of Gallagher (1991:121-133); Abell and Deborah (1994:475-487); Mellado (1997: 331-354) and Karen and Renato (1999:110-120) indicate that pre-service teachers do not have an adequate understanding on the nature of science and scientific method and that their views do not reflect the current understanding of the nature of science. This lack of knowledge has far-reaching consequences. Consequently, an awareness of post- positivist views is instrumental in developing an adequate understanding of the nature of science and scientific method in student teachers.

1.6.2 Research design

The researcher decided to conduct a survey and collect data by means of a questionnaire. The questionnaire statements were compiled mainly from questionnaires developed by Deborah Pomery (1993: 273-277), Jandhayala (1996) and Haidar (1999).

The questionnaire used in this study consists of 21 statements. Statements 1 to 5 deal with scientific knowledge. The scientific assumptions guiding these questions are: the nature of scientific knowledge is tentative, subjective, does not correspond directly to reality, and is a revisionary rather than a cumulative process.

Statements 6 to 9 deal with scientific methods. The assumptions guiding these questions are that scientists use a variety of methods, depending on the circumstances; scientists do not necessarily follow a scientific method on a step-by-step basis and progress in science depends on the use of a number of different scientific methods.

Statement 10 deals with scientific observations themselves. The assumption guiding this statement is based on the claims that these observations are theory laden.

Statements 11 to 14 and 21 deal with the nature of scientists' work. The assumption guiding these statements is that scientists use several methods in their investigations, and that scientists' work is influenced by a number of factors such as theoretical, social, cultural and political considerations.

Statements 15 to 18 focus on scientific theories. The assumptions guiding these statements are based on the belief that theory generation occurs within a certain paradigm, that certain criteria guide theory selection, that any theory is validated by a scientific community, and that scientific progress depends on the existence of incompatible theories.

Statement 19 deals with the status of scientific models. The assumptions guiding statement 19 are that scientific models are not copies of reality and that scientific models do not describe reality as it is. Statement 20 deals with the status of scientific laws. The assumptions guiding statement 20 are that scientific laws are only scientists' best efforts to explain nature and are neither absolute nor certain.

Student teachers were asked to choose one of five alternatives on a continuum for each statement that best fit their views on the nature of science and scientific methods. The continuum extends from strongly agree, agree, undecided or neutral, disagree and strongly disagree.

The study was conducted with science student teachers at both Tonota College of Education and Molepolele College of Education in Botswana. The sample includes all student science teachers at both Secondary Colleges of Education in Botswana. The sample size was about 274. The data was analysed using descriptive analysis techniques such as frequencies and percentages. Inferential statistical techniques such as the chi-square test were used to test the hypotheses of this study.

1.7 PROGRAMME OF STUDY

In chapter one, I discussed the following: the background of the present study, the rationale for studying student teachers' views, formulation of the research problem, significance of the present study, aims and objectives of the present study, clarification of concepts used in the project, theoretical framework and research design.

1.7.1 Further programme of research

In chapter 2, I will attempt to present previous research studies on pre-service teachers' conception of the nature of science and the scientific method.

Chapter 3 includes the implementation of the research design and analysis, discussion of results for this study. This, in turn, includes the method, description of subjects, sample size, sampling methods, instruments, data-collection procedures, and data-analysis procedures. It also includes the data analysis and interpretation of collected data.

Chapter 4 contains the conclusions, implications, suggestions, and recommendations.

CHAPTER 2

VIEWS ON THE NATURE OF SCIENCE AND THE SCIENTIFIC METHOD: AN INTERNATIONAL PERSPECTIVE

2.1 INTRODUCTION

The main aim of this study is to determine student teachers' views on the nature of science and the scientific method. In the first chapter, I attempted to build up a conceptual framework of the study by examining the background of the present study, the rationale for studying student teachers' views and the significance of the present study. Chapter 1 also stated and provided information of the problem the study attempts to address. Furthermore, the concepts used in the project, and its aims and objectives, were clarified. This was followed by discussions on the theoretical framework, the research design, and the research programme.

In chapter 2, I review the literature that has been generated on pre-service teachers' views and conclude by discussing those factors that enhance the understanding of the nature of science and the scientific method. At the outset, I should say that, in Botswana, there is a definite paucity of literature on student teachers' (pre-service teachers') views concerning the nature of science and the scientific method. This meant that I had to depend heavily on foreign studies. Some of these studies attempt to look into various aspects of the nature of science; that is, the nature of scientific knowledge, scientific theories, scientific laws, scientific models and the nature of scientists' work, in a comprehensive manner. Some studies, however, focus on only one or two aspects of the nature of science.

These studies have helped me to get some insight into the concept of the nature of science and the scientific method and to clarify the concept presented in chapter 1. These studies have also helped me to design the tools used for my own study.

Akersen, Abd-El –Khalick and Lederman (2000:295); Abd-El –Khalick, Bell and Lederman (1998: 417); Lederman (1999:916; 1992:331); Bently and Garrison (1991:67); Lederman and Zeidler (1987: 721) and Ogunniyi (1982:25) argue that the development of an adequate understanding of the nature of science and the scientific method is important and, indeed, is a primary objective of science education. According to Lederman (1992: 335), the majority of previous research findings on science learners' understanding concerning the nature of science and the scientific method reported that, generally, science learners do not have an adequate understanding of the nature of science and the scientific method.

The above research conclusions, as Lederman (1992: 335) pointed out, led researchers to concentrate on teachers' understanding of the nature of science and the scientific method in order to improve their learners' understanding of what is meant by the term " nature of science". This is based on the assumption that teachers' understanding of the nature of science is related to their learners' understanding of the nature of science and that teachers' instructional behaviour is directly influenced by teachers' conceptions of the nature of science (Hamrich 1997: 143; Lederman 1992:350). The research findings of Gallagher (1991:133) and Brickhouse (1990: 53) support the above assumption and indicated that teachers' conceptions of the nature of science influenced their instructional behaviour. This study further revealed that teachers' beliefs influenced, not only lessons explicitly to teaching the nature of science, but also implicit curricular messages dealing with the nature of science.

Ogunniyi et al (1995); Lakin and Wellington (1994) and Hodson (1993) reported that teachers themselves lack an adequate understanding of the nature of science and the scientific method. This immediately raises the question of whether teachers are taught currently accepted conceptions of the nature of science and the scientific method during pre-service training.

The following sections of chapter 2 discuss pre-service teachers' views concerning the nature of science and the scientific method as reported in the literature.

2.2 PRE-SERVICE TEACHERS' VIEWS ON THE NATURE OF SCIENCE AND THE SCIENTIFIC METHOD

Exploring pre-service teachers' (student teachers') views on the nature of science and the scientific method helps teachers to find out if there is any need to improve their training and thus to enhance their understanding of the nature of science and the scientific method. Numerous research studies on pre-service teachers' views on the nature of science and the scientific method have therefore been undertaken (in different countries). The aim of these studies was to systematically investigate pre-service teachers' understanding of the nature of science and the scientific method.

As discussed in chapter 1, student teachers' (pre-service) understanding of the nature of science and the scientific method is important and enhances learners' understanding of science. Such an understanding contributes to successful learning in teacher-training programmes and to future science teaching practices. The non –traditional / post-positivist stance presents a valid view of the nature of science and the scientific method (Karen & Renato1999: 1125). Non - traditional / post-positivist views of the nature of science and scientific method are needed to properly understand current beliefs regarding the nature of science, and to have a better understanding of both the scope and limits of science.

The following section presents previous research findings of pre-service teachers' views concerning the nature of science.

2.2.1 Pre-service teachers' views on the nature of science

For the purposes of the present study, the phrase "the nature of science" is taken to consist of the nature of scientific observations, scientific theories, scientific laws, scientific models, the development and progress of scientific knowledge and, finally, the nature of scientists' work. A literature review of pre-service teachers' views concerning the nature of science reveals that their views differ.

2.2.1.1 Pre-service teachers' views and scientific observations

Non - traditionalists / post positivists argue that scientific observations and scientific processes used by scientists depend upon theories, prior knowledge, beliefs and expectations (Karen & Renton 1999:1124). It is important that student teachers are aware of post - positivists' views so that they can communicate this idea in their teaching. An adequate understanding of scientific observation as described above has been identified by researchers as important and has therefore been the subject of numerous studies.

The literature consulted gives mixed results when it comes to pre-service teachers' understanding of the nature of scientific observations. Some studies indicate that pre-service teachers have an adequate understanding of the nature of scientific observation. For example, Hassan (2001: 235-250) found that most pre-service and in-service teachers believed scientific observation and process-oriented investigative activities are largely driven by theories and the conceptions of scientists themselves. Similarly, Brickhouse (1990: 53-62) reported that some pre- service teachers are of the opinion that scientific observations and experimentation are theory-driven processes. In addition, Abd- El- Khalick, Bell and Lederman (1998:417-436) reported that most of pre-service teachers demonstrated a clear understanding of the difference between observation and inference.

In contrast, the research findings of Abd- El- Kahlick and Lederman (2000:1057-1097) pointed out that the majority of pre-service teachers lack any real understanding of the theory-laden nature of scientific knowledge. Most of the pre-service teachers in these studies believed that scientific observations and scientific processes are theory independent. Abell and Deborah (1994:475-487) reported that pre-service teachers had an inadequate understanding of the nature of scientific observations.

Pre-service teachers with an inadequate understanding of the process of science might think scientific observations are discrete, theory independent and provide a secure base for scientific knowledge. Such an image of science is misleading when it comes to understanding the influence of social and other factors on the generation and validation of scientific knowledge.

The analysis of these mixed results indicate that some pre-service teachers definitely have an inadequate understanding of the nature of science. Some researchers, however, reported that the subjects do have an adequate understanding of what is meant by "scientific observations". The above research studies which concentrated on secondary pre-service teachers reported that subjects do have an adequate understanding of scientific observations. On the other hand, some studies which concentrated on secondary and elementary pre-service teachers reported that these teachers had an inadequate understanding of scientific observations. In short, there is no obvious pattern emerging as far as pre-service teachers with a higher educational background are concerned. For example, pre-service teachers with higher educational background who participated in Abd- El- Kahlick and Lederman's (2000:1057-1097) research displayed an inadequate understanding; at the same time, some pre-service teachers in Abd- El- Khalick, Bell and Lederman's work (1998:417-436) displayed an adequate understanding of scientific observations.

Some of the above research studies assessed pre-service teachers views at different times; immediately on joining the course, during the course or on completion of the course. An inspection of the above studies indicated that there is no distinct pattern evident from assessment of pre-service teachers views at different stages of their training. Some research studies, irrespective of the stage at which the assessment was conducted,

reported that pre-service teachers' had an inadequate understanding and some reported that they had an adequate understanding of scientific observations. It is important to note that the above research studies used different instruments or a different combination of a variety of instruments, ranging from questionnaire, interviews, and observations and teaching records. Given that there was no particular pattern emerging when it came to pre-service teachers' understanding of the nature of scientific observations, a further assessment of the situation was imperative.

2.2.1.2 Pre-service teachers' views on the status, role and validation of scientific theories

As discussed in chapter 1, student teachers have an adequate understanding of scientific theories. Scientific theories are created by scientists and used as devices to understand the world. In other words, scientific theories are human constructions intended to describe and / or explain scientific phenomena; scientific theories have an interpretative role, as well as an explanatory role in research. The generation, validation and acceptance of scientific theory is a complex process. A new theory is generated from an old theory or paradigm that is based on a set of assumptions that has worked for science over a certain period of time (Thompson 2001: 102). Scientific theories grow, develop, and are revised and replaced in order to accommodate observational evidence (Losee 2001:203). Empirical factors, conceptual / theoretical factors such as logical structures, accuracy, consistency, scope, simplicity and fruitfulness play an important role in the evaluation of scientific theory (Thompson 2001: 77). In addition, other factors such as experiments, scientists' prior knowledge and personal opinions, social, cultural, moral and political factors, play an important role in the validation of scientific theory. Scientific theories are judged in relation to supplementary theories and in relation to alternative

theories. Once the scientific community accepts a theory, there is no guarantee that it is absolute. It is not possible to prove whether the theory is true or false, but it might be true (Thompson 2001: 76). The status of the theory is based on whether the theory is likely to be true and whether it is useful to the scientific community. Based on its evaluation of the theory, the scientific community will decide whether to retain, modify, revise or reject the theory. If theory is rejected or decision is delayed on status of theory, such theories might be helpful to the scientists in future.

Given this conceptualisation of the status of theory in a post-positivist dispensation, researchers investigated pre-service teachers' understanding of scientific theory. The research findings of Abd- El- Kahlick and Lederman (2000:1057-1097) showed that the majority of pre- service teachers displayed an adequate understanding of the changing nature of scientific theories. Similar findings are reported by Abd- El-Kahlick, Bell and Lederman (1998: 417-436) who indicated that many pre-service teachers believed that theories would grow, develop, and be refined and changed as a result of new empirical observations and experiments. The researcher further pointed out that most of the pre-service teachers realised that individual beliefs would play a major role in the validation of scientific theory. In addition, Haidar (1999:807-822) reported that the majority of pre-service teachers (77%) agreed that the scientific theories lie within the scientific paradigm, which is a basic set of assumptions that work for science over a particular period of time. As far as the role of scientific theories is concerned, the research findings of Brickhouse (1990: 53-62) revealed that some pre-service teachers believed that theories serve as tools that can solve problems.

In contrast, the research findings of Hassan (2001: 235-250) indicated that some pre-service teachers confused scientific theory with scientific fact. The research findings of Abd- El- Kahlick and Lederman (2000:1057-1097) indicated that most pre-service teachers failed to recognise factors (other than data) that might play a role in generating and supporting scientific claims. In other words, pre- service teachers showed a lack of understanding as far as the nature of theory testing is concerned. Moreover, Haidar (1999:807-822) found that pre-service teachers incorrectly stated that a hypothesis, when tested empirically, becomes a theory. The above findings are reinforced by the findings of Abell and Deborah (1994:475-487), who reported that most of these pre- service teachers also viewed scientific knowledge as having originated directly from observations and that scientific knowledge increased as observations increased (i.e. cumulatively). These observations, in turn, directly prove scientific knowledge claims. In addition, he argued that the formal science education of prospective and practising teachers focuses on the body of knowledge of science and puts very little emphasis on the process whereby scientific knowledge is developed and validated. The empirical research findings of Gallagher (1991:121-133) and Brickhouse (1990: 53-62) indicated that most pre- service teachers failed to explain the role of social and cultural factors in the construction of scientific knowledge. They were also unable to explain the role played by the scientific community in the debating of, and acceptance of, competing theories. Pre-service teachers therefore demonstrated an inadequate understanding of how theories are generated, developed and accepted; they also failed to show that they understood the guiding role played by theories in scientific investigations.

As we mentioned above, pre-service teachers do not really understand that the generation of scientific theory and think theory generation is no more than a process of looking for regularity in nature and theory testing is regarded as simple confirmation or refutation based on sufficient evidence, either through observation or critical experiments. The above conception would have serious implications on science learning and would lead to the belief that the experiments conducted in the classroom are directly related to the acceptance or rejection of a theory. As a result, student teachers get an inflated sense of the importance of their experimental results and come to possess misleading views concerning the relationships between observation, experiments and theory.

The above research studies regarding pre-service teachers understanding of scientific theories indicated that pre-service teachers do not have an adequate understanding of such theories, while some studies reported that pre-service teachers do have an adequate understanding of such theories. The above research studies concentrated on the secondary and elementary pre-service teachers. The research study concentrated on primary pre-service teachers reported that primary pre-service teachers had an adequate understanding of scientific theories. As far as pre-service teachers with higher educational backgrounds are concerned, no obvious pattern emerges. For example, pre-service teachers with higher educational backgrounds who participated in Gallagher's (1991:121-133) research displayed an inadequate understanding. However, pre-service teachers who participated in the research of Abd- El- Kahlick and Lederman (2000:1057-1097) and Abd- El-Kahlick, Bell and Lederman (1998: 417-436) displayed an adequate understanding of scientific theories. The above research studies assessed pre-service teachers views at different times (i.e. after they joined the course, some immediately entering and some after they had completed the course).

An analysis of research studies indicated that no obvious pattern is evident as far as the stage at which the assessment was conducted. Some research studies, irrespective of the stage at which the assessment was conducted, reported that pre-service teachers had an inadequate understanding of scientific theories, while some reported that they had an adequate understanding of scientific theories. It is important to note that the above research studies used different instruments or combinations of various instruments ranging from questionnaire, interviews, observations and teaching records in order to assess pre-service teachers understanding of the scientific theories. Given that there is no particular pattern in how pre-service teachers understand scientific theories, there is a definite need to further assess pre-service teachers' views of scientific theories.

2.2.1.3 Pre-service teachers' views on the status and role of scientific laws

According to post – positivism, scientific laws are only scientists' best efforts to explain nature. Scientific law states, identifies or describes relationships between observable phenomena. According to post - positivists, scientific laws are neither absolute nor certain and may not be deduced with certainty from empirical / experimental evidence.

An adequate understanding of scientific law as described by post - positivist is important for pre-service teachers and has been the subject of a number of studies. Again, the literature consulted provides mixed results. Some of the research studies reported that pre-service teachers had an adequate understanding of scientific laws. For example, the research findings of Abd- El- Kahlick and Lederman (2000:1057-1097) disclosed that pre-service teachers have an adequate understanding of scientific laws and the relationship between laws and theories, that scientific laws state, identify or

describe relationships between observable phenomena and that scientific theories are inferred explanations for observable phenomena. Haidar (1999:807-822) reported that 61% of pre-service teachers said that scientific laws are only scientists' best efforts to explain nature; the remaining 29% of pre-service teachers do not have an adequate understanding on the scientific laws.

In contrast, Abd- El- Khalick, Bell and Lederman (1998:417-436) state that pre-service teachers are not well informed about the relationship between theories and laws. They see the relationship between scientific theories and laws as being hierarchical; theories become laws, depending on the availability of supporting evidence. Most pre-service teachers believe that scientific law is a theory that has been accepted by all scientists and that this law has been proven over time to be true. The research findings of Abell and Deborah (1994:475-487) indicate that most pre-service teachers do not have an adequate understanding of the nature of scientific laws. Most pre – service teachers believe that scientific laws are absolute or certain; they also believe that scientific laws are induced with certainty from empirical / experimental foundations.

An analysis of the above research findings with regard to pre-service teachers' understanding of scientific laws indicates that past research studies such as those undertaken by Abd- El- Khalick, Bell and Lederman (1998:417-436) and Abell and Deborah (1994:475-487) clearly indicate that pre-service teachers do not have an adequate understanding of scientific laws. Recent studies, such as those of Abd- El- Kahlick and Lederman (2000:1057-1097) and Haidar (1999:807-822) reported that most pre-service teachers do have an adequate understanding of the scientific laws. Some of the above research studies concentrated on the secondary and elementary pre-service teachers. Some of the previous studies reported that they had inadequate understanding and some reported that they had adequate

understanding on the scientific laws. For example, Abd- El- Khalick, Bell, and Lederman (1998:417-436) concentrated on the secondary and Abell and Deborah (1994:475-487) research concentrated on elementary pre-service teachers and reported that pre-service teachers had inadequate understanding on the scientific laws.

The research studies of Abd- El- Kahlick and Lederman (2000:1057-1097) concentrated on secondary pre-service teachers and reported that they do have an adequate understanding of scientific laws. There is no pattern that emerged to indicate that, before entering teacher training courses, pre-service teachers with a higher educational background possess an adequate understanding of scientific laws. For example, pre-service teachers with higher educational backgrounds before entering teacher training participated in Abd- El- Khalick, Bell and Lederman's (1998:417-436) research. This research reported that these people had an adequate understanding of scientific laws, whereas, in the research of Abd- El- Kahlick and Lederman (2000:1057-1097), participants displayed an inadequate understanding of scientific laws. An analysis of the research studies indicated that there is no obvious pattern evident as far as stage of training period at which assessment was conducted. Some research studies, irrespective of the stage at which the assessment was conducted, reported that pre-service teachers had an inadequate understanding of scientific laws, while some reported that they had an adequate understanding of scientific laws. It is important to note that the above research studies used different instruments or a combination of different instruments, ranging from questionnaires, interviews, observations and teaching records in order to assess pre-service teachers understanding of scientific laws. An analysis of above studies indicates a dearth of a particular pattern in pre-service teachers' understanding of scientific laws. It is therefore necessary to assess pre-service teacher's views of scientific laws.

2.2.1.4 Previous studies related to pre-service teachers views' on the status of scientific models

Student teachers should be aware that scientific models are socially constructed devices, ideas or structures designed to help understand, describe and predict scientific phenomena. In other words, scientific models are not copies of reality about science.

The outcome of investigations by Haidar (1999:807-822) and Abd-El-Khalick, Bell and Lederman (1998:425) indicated that pre – service teachers have adequate understanding of scientific models. Abd-El-Khalick, Bell and Lederman (1998:425) described pre- service teachers as having articulated the role of models as representations, rather than as exact replicas of empirical phenomena. These findings are reinforced by findings of another empirical investigation carried out by Haidar (1999:807-822), which reported that most pre-service teachers said that scientific models are not copies of reality, but scientists' representations of reality.

Even though the above research studies indicated that pre-service teachers have an adequate understanding of scientific models, the pre-service teachers who will participate in the present study may have alternative views. It is therefore important to assess student teachers views of scientific models.

2.2.1.5 Pre-service teachers' views on the nature, generation, development and progression of scientific knowledge

Student teachers should develop an adequate understanding that science is seeking approximate answers to questions about nature. The interpretations of nature constantly change with new experiences and new conceptions of the universe. Scientific knowledge is tentative, developmental and subjective and demands evidence. Scientific progress is evolutionary (current theories are replaced with more successful theories) and revolutionary (current theories, methods and goals are replaced with new ones) rather than cumulative.

The literature reviewed provided mixed results regarding pre-service teachers understanding of scientific knowledge. Some research studies reported that pre-service teachers had adequate understanding of scientific knowledge. For example, the research findings of Hassan (2001:235-250) and Haidar (1999:807-822) stated that the pre-service teachers had an adequate understanding of the empirical and tentative nature of science; they also recognised that subjectivity and creativity contribute to the tentative nature of science. These findings, validated by the research findings of Abd-El-Khalick, Bell and Lederman (1998:423), indicated that all the pre-service teachers' expressed the view that scientific knowledge is subject to change.

Karen and Renato's findings (1999:110-120) indicated that pre-service teachers believed that science is a process of discovery; according to these pre-service teachers, science uncovers the truth about the world. Similarly, the findings of Gustafson and Rowell (1995: 589-605) indicated that the majority of pre-service teachers viewed science as a body of knowledge waiting to be discovered; science, therefore, was totally separate from human beings. The research findings of Haidar (1999:807-822);

Mellado (1997: 331-354) and Gallagher (1991:121-133) reported that many pre - service teachers believed that scientific knowledge directly corresponds to reality, and fails to recognise that scientific knowledge is subject to change. The above research findings therefore reported that most pre-service teachers do not have an adequate understanding of scientific knowledge. The research findings of Abell and Deborah (1994:475-487) indicated that most pre- service teachers had an inadequate understanding of scientific knowledge; research participants believed that scientific knowledge originated directly from observation and was cumulative.

If pre-service teachers think that scientific knowledge is final, absolute and increases cumulatively as observations increase, then this carries the implicit message that the role of student teachers is to point out the facts of nature and then organise these facts (Haider 1999:808). Pre-service teachers' consideration of science is devoid of creativity and intolerant of individual views; such views certainly discourage speculative thought.

An examination of the above literature findings indicated that some past and present studies reported that pre-service teachers do not have an adequate understanding of scientific knowledge, while some reported that they do have an adequate understanding of scientific knowledge. Some of the above research studies concentrated on the secondary pre-service teachers and their reports were contradicting with each other. The research studies concentrated on the elementary and primary pre-service teachers displayed inadequate understanding on the scientific knowledge. There is no specific pattern become manifested from pre-service teachers with higher educational background before entering into teacher-training courses possessed the adequate understanding. For example, before entering teacher training, pre-service teachers with higher educational backgrounds who

participated in Abd- El- Khalick, Bell and Lederman's research (1998:417-436) displayed an adequate understanding of scientific knowledge, whereas those who participated in Gallagher's research (1991:121-133) displayed an inadequate understanding of scientific knowledge.

An analysis of the above research studies indicated that no obvious pattern is evident when it comes to the stage at which assessment was conducted. Irrespective of the stage at which the assessment was conducted, some research studies reported that pre-service teachers had an inadequate understanding of scientific knowledge and some reported that they had an adequate understanding of scientific knowledge. For example, after being trained in aspects of the nature of science, the pre-service teachers in Mellado (1997: 331-354) and Gustafson and Rowell's (1995: 589-605) research showed an inadequate understanding of scientific knowledge, whereas those who participated in Hassan (2001:235-250) and Haidar's (1999:807-822) research showed that they had an adequate understanding of scientific knowledge. Note that the above research studies used different instruments or a combination of different instruments, ranging from questionnaires, interviews, and observations and teaching records. An examination of the above studies indicates that there is no particular pattern in pre-service teachers' understanding of scientific knowledge. It is therefore necessary to assess pre-service teacher's views of scientific knowledge.

2.2.1.6 Previous studies related to pre-service teachers' views on the nature of scientists' work

Student teachers should recognise that science is a social activity that both influences and responds to social needs. They should realise that scientists' work is influenced by many factors, including existing theories, scientists' prior knowledge, experiences, ideological principles, metaphysical worldviews, social factors, cultural norms, and moral and political factors. The objectivity of a scientist's work is achieved through criticism/ testing by other scientists working within the community of scientists.

The various research studies focused on pre-service teacher's views concerning the nature of scientists' work. The literature reviewed indicated that pre-service teachers held various views concerning the nature of scientists' work. For example, the research findings of Haidar (1999:807-822) revealed that nearly half of the pre-service teachers (42%) believed that a scientist is influenced by many factors, including previous knowledge, logic and social factors. These findings are further supported by the work of Abd-El-Khalick, Bell and Lederman (1998:424), namely, that many pre-service teachers believed that theoretical backgrounds, the individual opinions of scientists; and their beliefs also played a major role in the development of scientific ideas. These findings are strongly supported by the research findings of King (1991: 135-141), who claimed that pre-service teachers recognised that scientific knowledge is a social construction and that the nature of scientific work is neither neutral nor objective.

In contrast, the investigation results of Hassan (2001: 235-250); Haidar (1999:807-822); Abell and Deborah (1994:475-487) and Gallagher (1991:121-133) showed that pre-service teachers do not have an adequate understanding of the nature of scientists' work. The research work of Hassan (2001: 235-250) and Gallagher (1991:121-133) point out that pre-service teachers failed to recognise that scientists' work is influenced by a number of different factors (e.g. social, political factors etc). In addition, Haidar's research results (1999:807-822) indicated that pre service teachers believe that scientists record "sense-data". These findings are supported by the research work of Abell and Deborah (1994:475-487); these authors claim that pre-service teachers fail to recognise the role of the scientific community and its role in communicating findings or debating the validity of new knowledge claims.

If pre-service teachers hold a distorted image of scientists as being objective, open-minded, unbiased, and as possessing a critical and infallible methodology, then this means that they will seriously underestimate the complex relationship between observation and theory. This viewpoint also ignores the way in which the scientific community validates and disseminates scientific knowledge (Haidar 1999: 808;Throwbridge 1986:43). It is therefore essential to investigate student teachers' views on this aspect of the topic under discussion.

An analysis of the above research studies regarding pre-service teachers understanding of the nature of scientists' work indicates that the findings of these reports differed: some claim that pre-service teachers do not have an adequate understanding of scientists' work, while others claim that pre-service teachers do have an adequate understanding of scientific work. Some of the above research studies concentrated on secondary pre-service teachers, and others concentrated on elementary pre-service teachers.

No clear pattern emerged to show that pre-service teachers' academic backgrounds had any significant bearing on their understanding of the nature of science. For example, pre-service teachers who had higher educational backgrounds before entering into teacher training and who participated in Abd- El- Khalick, Bell, and Lederman's studies (1998:417-436) displayed an adequate understanding of science, but those who participated in Gallagher's research (1991:121-133) definitely displayed an inadequate understanding of the nature of scientists work.

In short, an analysis of the above research studies indicates that assessment of pre-service teachers were done at different stages but there is no obvious pattern that emerged. Some research studies, irrespective of the stage at which the assessment was conducted, reported that pre-service teachers had an inadequate understanding of the nature of scientists' work and some reported that they had an adequate understanding of the nature of scientists' work. It is important to note that the various research studies used different types of instruments in their research. The above discussion indicates that pre-service teachers' views on the nature of scientists' work requires more systematic research

2.2.2 Pre-service teachers' views on the scientific method

Pre-service teachers obviously need to have an adequate understanding of the scientific method. They should understand that scientific investigation uses a range of methods (*The Encyclopaedia of Philosophy*: 1996). The nature of the method used depends on the context. In other words, there is no single universal scientific method and nor are there step-by-step procedures that should be followed in some sort of rigid order. Creativity, logic, imagination and curiosity all contribute to scientific exploration. An adequate understanding of the scientific method, as described above, has been identified by researchers as important and has therefore been the subject of numerous studies.

The literature reviewed indicates conflicting findings as far as pre-service teachers' understanding of the scientific method is concerned. Some research studies reported that pre-service teachers had an adequate understanding of the scientific method. For example, Haidar's research findings (1999:807-822) indicated that 42% of pre-service teachers believed that scientists use several methods to obtain scientific knowledge. The research study undertaken by Abd- El- Khalick, Bell and Lederman (1998:417-436) reported that most of the pre-service teachers acknowledged the role of creativity in the construction of scientific ideas, and that they dismissed the view that science was a completely objective and rational activity.

On the other hand, Abd- El- Kahlick and Lederman's research study (2000:1057-1097) indicates that a majority of pre-service teachers believed that scientists follow some sort of established, orderly procedure that constituted the scientific method. Karen and Renato (1999:110-120); Haidar (1999:807-822); Mellado (1997: 331-354) and Brickhouse (1990: 53-62)

reported that pre-service science teachers possessed an inadequate understanding of the scientific method. Haidar's research study (1999:807-822) indicated that half of the pre – service teachers who participated in the empirical study believed that scientists do not use several methods to acquire scientific knowledge; instead, these pre-service teachers viewed the scientific method as a step-by-step process; this sequence of steps has to be followed exactly in order to obtain scientific results. Mellado (1997: 331-354) states that many pre-service teachers believe science starts with observation, is followed by the formulation of a hypothesis and, finally, "ends" with an experiment that tests this hypothesis. The research work undertaken by Brickhouse (1990: 53-62) indicates that pre-service teachers regard the scientific method as a linear, rational process that leads the scientist to unambiguous, scientific truth. The researcher argues that such an understanding carries with it the message that scientific procedures are predetermined. In other words, these pre- service teachers do not understand that science possesses several methods of enquiry and that the use of these methods depends on the context of enquiry.

If pre-service teachers believe that scientists possess an objective, open-minded, unbiased, and infallible method, then they will seriously underestimate the complex relationship between observation and theory. They will also neglect the activities of the scientific community in validating and disseminating scientific knowledge (Haidar 1999: 808;Throwbridge 1986:43).

An analysis of above research studies indicates that there is urgent need to assess pre-service teachers' views on what constitutes the scientific method. Past research studies such as that of Brickhouse (1990: 53-62) and Abd- El- Kahlick and Lederman (2000:1057-1097) report that pre-service teachers do not have an adequate understanding of the scientific method. Some of the research studies such as Abd- El- Khalick, Bell, and Lederman

(1998:417-436) reported that pre-service teachers had adequate understanding of scientific method. Some of the research studies concentrated on secondary pre-service teachers, and some on primary and elementary pre-service teachers. Some of these teachers showed that they definitely had an inadequate understanding of the scientific method. Some of the research studies that concentrated on secondary pre-service teachers reported that this group of teachers had an adequate understanding of the scientific method. Again, this understanding or lack of understanding is not related to pre-service teachers' academic background. Note, also, that the above research studies used different instruments or combinations of different instruments. An examination of the above research studies indicated that there is no obvious pattern that emerged as far as training period at which assessment was conducted. Some research studies, irrespective of the period at which the assessment was conducted, reported that pre-service teachers had an inadequate understanding of the scientific method, whereas others reported that pre-service teachers inadequate understanding of what constitutes the scientific method.

2.2.3 Summary of pre-service teachers' views on the nature of science and the scientific method

An understanding of post-positivism is needed to develop pre-service teachers' understanding of the nature of science and the scientific method. The literature gives conflicting views on the extent to which pre-service teachers understand the nature of science and the scientific method. As I have said already, some of the previous research studies indicated that pre-service teachers had an adequate understanding of what constituted science and the scientific method, whereas others claimed the contrary. Some research studies indicated that pre-service teachers possessed an adequate understanding of only some aspects of the nature of science and the scientific

method. The literature reviewed on the nature of science and scientific method indicates that there is no clear pattern emerging as far as they're being an improvement on the situation that obtained in the past is concerned. Some past research studies and some current research also indicate that there do exist pre-service teachers who do have adequate understanding of what science is all about.

There is no obvious indication that pre-service teachers' views are related to their academic backgrounds. Some research studies showed that pre-service teachers with higher educational backgrounds showed an adequate understanding of some aspects of the nature of science and the scientific method and some research studies showed the opposite. The research studies reviewed above used different types of instruments - either alone or combined. The research studies were conducted at various stages of teacher training; some immediately after entering training colleges, some after completion, and some on completion of the training period.

Some research studies concentrated on secondary pre-service teachers and some on elementary pre-service teachers. While others studies concentrated on secondary and elementary pre-service teachers reported that they possessed adequate understanding and some reported they had inadequate understanding on the nature of science and scientific method. The reasons for the divergency between these various research findings will be discussed in 2.2.4.

2.2.4 Possible reasons for discrepancies in previous research findings

An analysis of the foregoing remarks leads one to the following conclusions: the various research studies referred to above were all carried out in different countries. In addition to this, the researchers used different methodologies and different instruments for assessing pre-service teachers' understanding of the nature of science and the scientific method.

The discrepancies of the above investigation results mentioned in 2.2.1 and 2.2.2 might be due to the fact that previous studies concentrated on pre-service teachers who were enrolled in different types of teacher-training courses. Some of the research studies were conducted on elementary pre-service teachers, others on primary pre-service teachers and some on secondary pre-service teachers. Research studies which concentrated on elementary pre-service teachers, such as Mellado's (1997: 331-354), Gustafson and Rowell's (1995:589-605) and Abell and Deborah's (1994:475-487) reported that pre-service teachers seriously lack an adequate understanding of the nature of science and the scientific method. On the other hand, the research findings of King (1991: 135-141) reported that pre-service teachers do, in fact, have an adequate understanding of the nature of science and the scientific method.

The research study of Karen and Renato (1999:110-120) concentrated on primary pre-service teachers and reported that this group of pre-service teachers does not have an adequate understanding of what constitutes science.

Some research studies, such as Abd- El- Khalick, Bell and Lederman's (1998:417-436), concentrated on secondary pre-service teachers; according to these authors, pre-service teachers do have an adequate understanding of the nature of science and the scientific method. Gallagher (1991:121-133), however, came to the opposite conclusion. Other research studies, such as Hassan's (2001: 235-250); Haider's (1999: 807-822) and Brickhouse's (1990: 53-62) reported that pre-service teachers vary in how they understand nature of science: some report that they do have an adequate understanding and some that they do not have adequate understanding of some aspects of what constitutes nature of science and the scientific method. It is important to note that the entry requirements of pre-service teachers into the teacher training courses differ for elementary, primary and secondary pre-service training.

The analysis of the above might be an indication that pre-service teachers' entering into different types of teachers training courses have different academic backgrounds. The inconsistency of the results of the previous researches might, therefore, be due to the different academic backgrounds of pre-service teachers entering teacher-training courses. For example, the pre- service teachers who participated in Abd- El- Kahlick and Lederman's (2000:1057-1097) investigation had already earned Bachelor of Science degrees before entering teacher-training courses. The pre- service teachers who participated in Karen and Renato's (1999:110-120) research had 11-12 years of science education. Pre-service teachers who participated in another study of Abd-El-Khalick, Bell and Lederman's (1998:417-436) had earned Bachelor of Science degrees and, out of 14, seven pre-service teachers had Master of Science degrees. The participants in Mellado's (1997: 331-354) investigation had completed 6-12 years' primary education and three years' secondary education before enrolling on a three years' elementary science teacher-training course. All pre-service teachers in Gustafson and Rowell's study (1995:589-605) had done a compulsory junior-

level elementary science education course and had completed practical components of the undergraduate programme before entering the teacher-training course. Pre-service teachers in Abell and Deborah's study (1994:475-487) had completed three or five required science content courses before enrolling in the Elementary Science method course, whereas pre-service teachers in King's research study (1991: 135-141) had undergraduate degrees, and some pre-service teachers had studied the history and philosophy of science in their undergraduate courses. Pre-service teachers who participated in Gallagher's investigation (1991:121-133) had completed tertiary-level science study before enrolling in a science methods course. The pre-service teachers with different academic backgrounds might differ in their previous relevant knowledge about the nature of science and scientific method due to different learning experiences.

One might assume that pre-service teachers who had higher education backgrounds might have formed an adequate understanding of the nature of science and the scientific method. The above assumption is supported by the research findings of the Abd- El- Khalick, Bell and Lederman (1998:417-436). All the pre-service teachers who participated in his study had earned a Bachelor of Science degree, and some pre-service teachers had Master of Science degrees. As might be expected, the research findings indicated that these pre-service teachers did have an adequate understanding of the nature of science and the scientific method.

However, pre-service teachers who participated in Abd- El- Kahlick and Lederman's (2000:1057-1097); Gustafson and Rowell's (1995:589-605) and Gallagher's (1991:121-133) studies and who had completed higher educational studies before entering teacher training courses appeared not to have an adequate understanding of the nature of science and the scientific method.

In contrast, pre-service teachers who participated in King's research (1991: 135-141) and who had undergraduate degrees and the few pre-service teachers who had studied the history and philosophy of science as part of their undergraduate degrees, did appear to have an adequate understanding of science and the scientific method.

Although pre-service teachers have different educational backgrounds on entering teacher-training courses, there is no guarantee that those who have higher educational qualifications will possess an adequate understanding of what constitutes the nature of science. Understanding what the nature of science is, may, therefore, depend on the emphasis and design of the curricula followed.

As I have said already, most of the studies referred to above were carried out in different countries, and in different educational contexts. The variation in the findings may be due to the divergent curricula followed by pre-service teachers before entering teacher-training courses. The science curriculum varies widely between different countries, states, districts and schools (Lederman 1992:331). Specific content to be included in science courses, instructional methods/strategies and the learning experiences provided differ from country to country and, indeed, from school to school. It seems at present that there is no common agreement between science educators on what should be included in the curriculum of pre-service teachers if teachers are to have an adequate understanding of the nature of science and scientific methods. It is important to realise that, even within the teacher-training courses themselves, the emphasis in the curriculum varies from one country to another. So, obviously, there will be differences in pre-service teachers' understanding of what constitutes the nature of science and the scientific method.

The divergence in the findings of the research studies referred to above may be due to the fact that previous research studies were carried out during different stages of teacher-training courses. For example, Karen and Renato's research study (1999:110-120) and Abell and Deborah's research work (1994:475-487) assessed pre-service teachers views immediately after these people entered teacher-training courses. All these authors reported that pre-service teachers do not have an adequate understanding of the nature of science and the scientific method. In general, if assessment of pre-service teachers views conducted immediately after entering into teacher-training courses will disclose their prior conceptions about the nature of science and the scientific method.

The prior conceptions are formed as a result of their previous education and informal learning experiences. Ultimately, the findings of above research studies might lead to the assumption that pre-service teachers have not acquired adequate understanding before entering teacher-training courses. On the other hand, the investigations of Hassan (2001:235-250); Haidar (1999:807-822) and Abd-El-Khalick, Bell and Lederman (1998: 417-436) assessed pre-service teachers' views after they had received some training on the nature of science. Abd-El-Khalick, Bell, and Lederman (1998: 417-436) claimed that pre-service teachers do not have an adequate understanding of the nature of science, whereas Hassan (2001:235-250) and Haidar (1999:807-822) claimed that at least some pre-service teachers did have an adequate understanding of the nature of science (although some did not). The assessment of pre-service teachers that took place at the end of the teachers' training period may not give a clear idea of whether pre-service teachers developed an adequate understanding as a result of teacher-training courses or already they possessed an adequate understanding of science before teacher training.

The investigations of Abd- El- Kahlick and Lederman (2000:1057-1097); Gustafson and Rowell (1995:585-605) and King (1991:135-141) all involved collecting data at the beginning and end of the various teacher-training courses. The research findings of Abd- El- Kahlick and Lederman (2000:1057-1097) and Gustafson and Rowell (1995:585-605) revealed that pre-service teachers do not have an adequate understanding of the nature of science and the scientific method, whereas King (1991:135-141) reported the opposite. In addition, Mellado (1997:334) felt that “one of the causes of the discrepancy in results may lie in the disparity of methodologies and in the different philosophical assessment the investigators make of methodological instruments employed”.

The previous researchers used different types of instruments in order to obtain information from pre-service teachers about the nature of science and the scientific method. At this juncture it is also important to note, irrespective of the various assessments instruments used by different researchers, that Karen and Renato (1999:110-120), Mellado (1997: 331-354), Abell and Deborah (1994:475-487) and Gallagher (1991:121-133) all conclude that pre-service teachers do not have an adequate understanding of the nature of science and the scientific method.

The divergence of pre-service teachers' views may depend on the duration of the teacher-training period. It is important to note that the duration of teacher training courses is different in different countries. For example, the pre-service teachers who participated in Mellado's (1997: 331-354) investigation were enrolled for a three years' elementary science teacher-training course, whereas the pre-service teachers who participated in Gustafson and Rowell's study (1995:589-605) were enrolled for a four-year Bachelor of Elementary Science Education. Longer teacher-training courses obviously give pre-service teachers a better exposure to science and thus

mean they have a better chance to gain an adequate understanding of the nature of science and the scientific method.

The discrepancies in the results referred to above lead to a more complex situation. It is important to note that different factors interact with each other and play a role in pre-service teachers' understanding of science. Given the complexity of the situation, it is essential to recognise some of the possible factors that might contribute to pre-service teachers' ability to understand what science really is. The factors that influence this will be discussed in section 2.2.5.

The following section presents the literature review related to some of the factors that influence pre-service teachers' understanding of the nature of science and the scientific method.

2.2.5 Factors that influence pre-service teachers' understanding of the nature of science and the scientific method

It was evident that there is general appeal from the different investigations to include the history, philosophy and sociology of science in pre-service teachers' training courses.

The researchers Gallagher (1991:121-133) and Brickhouse (1990: 53-62) concluded that the major contributing factor in pre-service teachers having an inadequate understanding of what constitutes science is the lack of curricular emphasis on the nature of science. A similar view has been expressed by Mellado (1997: 331-354), who did an empirical study of the subject and who recommended the inclusion of the history, sociology and philosophy of science in teacher-training programmes and workshops.

Along the lines denoted above, Abd- El- Khalick, Bell and Lederman (1998:417-436) conducted a research on 14 pre-service teachers' understanding of science. All these pre-service teachers were trained extensively on certain aspects of the nature of science and the scientific method. Using an open-ended questionnaire, these researchers assessed these pre-service teachers' views. The results indicated that all these pre-service teachers did, in fact, have an adequate understanding of most aspects of science. Abd- El- Khalick, Bell and Lederman (1998:417-436) strongly believed that these pre-service teachers developed an adequate understanding of science as a result of direct instruction in science during their period of teacher training. At this juncture it is important to note that, in this study, there is no data available on these pre-service teachers' prior conception of science. It is, therefore, possible, that some of these pre-service teachers had an adequate understanding of science before they entered their teacher-training courses.

In contrast, another study conducted by Abd- El- Kahlick and Lederman (2000:1057-1097) examined undergraduate, graduate students and pre-service science teachers about the influence of history of science courses and conceptions of the nature of science. Pre-service teachers' contemporary conception of the nature of science and the scientific method were analysed before and after training in the history of science courses with the help of an open-ended questionnaire. The above researchers reported that almost all these pre-service teachers had an inadequate understanding of science before receiving this training in the history of science. The majority of pre-service teachers also had inadequate understanding of what constituted the scientific method. Abd- El- Kahlick and Lederman (2000:1057-1097) reported that few changes are evident in these pre-service teachers' views after they completed the history of science courses. The researcher concluded, therefore, that the results of the above study do not support the assumption that the history of science courses improves pre-

service teachers' understanding of science. In short, an education in the history of science does not guarantee that pre-service teachers' will understand what science is and what it is not. Furthermore, the researcher felt that pre-service teachers had misconceptions about the nature of science as a result of their previous learning experiences from previous education and that these views persisted even after explicit teaching on the nature of science.

Similar views are expressed by Abell and Deborah (1994:475-487); Gustafson and Rowell (1995:589-605) and Mellado (1997: 331-354) that is, that pre-service teachers bring ideas about the nature of science from their previous learning experiences, and that these influence their understanding of science. These researchers also indicated that pre-service teacher's ideas remain uninfluenced by classroom science teaching.

In short, Abd-El-Kahlick and Lederman (2000:1057-1097); Gustafson and Rowell (1995:589-605) and Abell and Deborah (1994:475-487) all emphasised the fact that pre-service teachers' prior concepts, ideas and views/beliefs can definitely influence their ability to learn about science. Given this, these researchers recommended that a conceptual change approach might be more effective as a means of altering pre-service teachers' prior ideas. In this approach, pre-service teachers' views on the nature of science are elicited through discussion, providing the respondents with opportunities to reflect on their conceptions and, importantly, providing them with alternatives that challenge these conceptions.

Along the lines specified by Gustafson and Rowell (1995:589-605), the focus was on altering pre-service teachers' prior views through a conceptual change approach. They observed modest changes in pre-service teachers' views about the nature of science as a result of conceptual change approach. The researcher felt that pre-service teachers' prior ideas seemed to

have been rooted in past life experiences, such as previous practical experiences, undergraduate courses, and a variety of personal experiences. Prior ideas were predominantly influenced by participants' own learning preferences, which had the power to outweigh course ideas. The researcher also indicated that pre-service teachers selected the elements from the teacher-training course that reinforced their pre-existing ideas. The researcher recommended a focus on two specific areas of research. The first one is pre-service teachers' prior ideas about the nature of science. The second area is on those aspects of teacher education programmes, which either constrain or encourage intellectual change.

Gustafson and Rowell (1995:589-605) felt that a conceptual approach seems to increase awareness and encourage people to reflect on their existing ideas (rather than abandoning existing ideas). In order to reconstruct their ideas, pre-service teachers require much more time to integrate new ideas into their conceptual framework. The researcher suggested that pre-service teachers' ideas change considerably as a result of long times spent in classrooms.

The above findings lead one to ask the following questions:

- a)** How do the Botswana student teachers view the nature of science and the scientific method? What type of prior concepts concerning the nature of science and the scientific method do student teachers (pre-service teachers) have before they enter teacher-training courses?

- b)** Does the length of exposure to classroom activities (duration of the study) have any influence on the extent to which student teachers do/do not understand what constitutes science?

In Botswana, secondary school teachers are trained at the Tonota and Molepolole Colleges of Education and the University of Botswana. The student teachers from the Tonota and Molepolele Colleges of Education were considered for the present study. These student teachers are enrolled for a three-year diploma programme in Secondary Education. Student teachers enter into the Diploma in Secondary Education after completion of seven years' primary education, three years' junior secondary education and two years' senior secondary education. The rationale behind the present study's selection of pre-service teachers from Secondary Colleges of Education is that the entry requirements of both Secondary Colleges of education are almost similar. Also, they are exposed to the same curriculum. The nature of science and the scientific method is explicitly and implicitly emphasised in the science curriculum. It is, therefore, important to study student teachers' views of science in the Botswana educational context, as portrayed by Tonota and Molepolele Colleges of education.

The research findings of Gustafson and Rowell (1995:589-605) indicated that pre-service teachers' prior ideas about the nature of science play an important role in determining whether pre-service teachers acquire a proper understanding of science from their teacher-training courses. The views held by student teachers are important in terms of what they manage to learn during their professional training; these views also influence their (future) teaching practices. It is therefore necessary to investigate first-year, second-year and third-year student teachers' views on the nature of science, taking all factors into account. (That is, the nature of scientific knowledge, scientific observations, scientific theories, scientific laws, scientific models and the nature of scientists' work). It is also important to study student teachers' views on what constitutes the scientific method. Studying first-year student teachers' views on the nature of science and the scientific method as soon as they enter their teacher-training course will reveal the prior conceptions held by pre-service teachers.

The second part of Gustafson and Rowell's (1995:589-605) recommendation is that the length of exposure to classroom activities may contribute to pre-service teachers' understanding of science. What type of concepts about the nature of science and scientific methods do student teachers construct as a result of lengthy exposure to classroom activities? The present study is also interested, therefore, in finding out how this length of exposure contributes to pre-service teachers' understanding of science; a study is made of first-year, second-year and third-year pre-service teachers. This type of study could, potentially, yield information on how their conceptions develop as a result of their first-year, second-year and third-year teaching and learning experiences. The present study will also concentrate on the extent to which the length of exposure is a contributory factor in other ways: a study is made of the views of those pre-service teachers who choose science as a major teaching subject or a minor teaching subject. Those student teachers who choose science as a major teaching subject are more exposed to both the content of science and classroom activities involving science than those student teachers who select science as minor subject. There is insufficient literature, in Botswana, on the extent to which the length of exposure to classroom activities contributes to an adequate understanding of the nature of science and the scientific method.

King's research findings (1991:135-141) indicated that the learning environment might contribute to student teachers developing an adequate understanding of science. The learning environment is an aggregate condition; in other words, it provides circumstances that facilitate learning. The learning environment is therefore an important factor since it influences the student teachers' understanding of the nature of science and the scientific method. The learning environment in formal education is influenced by many factors, ranging from student teachers' personal knowledge, physical factors in the classroom, opportunity to participate in classroom activities,

etc. The factors that particularly influence classroom learning include: the curriculum, teaching methods, assessment methods, designing and conducting learning experiences, level of difficulty of assignments, provision of direction on crucial aspects of science, feedback, teachers' teaching styles, clarity of instruction, and connection of materials in the course. Some of these factors are influenced by teachers' own perceptions of the nature of science and the scientific method.

The present study assumes that the learning environments of the Tonota College of Education and the Molepolele College of Education may well be very different, even though both colleges are following the same curriculum. The present study will therefore attempt to determine the association between student teachers views and type of educational institution. To date, in Botswana, there is virtually no literature on this aspect of the problem.

Another important factor might be how gender influences the extent to which pre-service teachers obtain an adequate understanding of science. Socio-cultural pressures, parents' attitudes, early socialisation, childhood experience, teachers' attitudes, a masculine "image" of the science curriculum all work to provide different learning experiences for male and female student teachers. These experiences, in turn, influence the attitudes and interests of student teachers and, ultimately, influence their views on the nature of science and the scientific method. At present, there is insufficient research on the influence of gender on people's ability to understand what constitutes the nature of science.

There is, therefore, a pressing need to determine the factors that are associated with any increase in student teachers' (pre-service teachers) understanding of the nature of science and the scientific method in Botswana. Student teachers' (pre-service) understanding of the nature of

science and the scientific method may well depend on numerous factors. The present investigation is an attempt to pinpoint some of the relevant factors that might influence the development of pre-service teachers' understanding of science. In Botswana, there is insufficient literature on how the different factors (e.g. years of study, whether science is a major/ minor subject, gender, and type of training institution) contribute to pre-service teachers' development of an adequate understanding of the nature of science. The present research study, therefore, attempts to study the association of these factors with pre-service teachers' understanding of science (i.e. in Botswana). A knowledge of the influence of the above factors on pre-service teachers' understanding of the nature of science and the scientific method will, hopefully, help to improve pre-service science teacher training programmes. In addition, pre-service teachers' views on the nature of science and the scientific method influences instructional practices. By this I mean the choice of teaching methods, selection and presentation of learning experiences, evaluation and, finally, the development, implementation and evaluation of the science curriculum. Understanding how science operates is imperative in evaluating the strengths and limitations of science and might also help teachers in guiding classroom instruction in the future.

What is needed, therefore, is an in-depth study on pre-service teachers views of the nature of science and the scientific method in the Botswana educational context in terms of different variables such as gender, year of study (duration), type of institution and science as a major/ minor teaching subject.

The following section describes the different instruments used in previous research studies.

2.2.6 Data-collection instruments in previous research studies

In order to obtain information about pre-service teachers' understanding of the nature of science and the scientific method, different researchers used different measuring instruments such as questionnaires, interviews, classroom observations, and teaching plans.

2.2.6.1 Questionnaires

Questionnaires are valuable data-collection instruments. Questionnaires enable researchers to obtain information from geographically widespread groups of people and make it possible to use a large sample base (Best & Khan 1996:229; Gay 1987:195). This means that the results will be more reliable.

The following two types of questionnaires are generally used to assess pre-service teachers' views on the nature of science and the scientific method.

- (a) Closed or structured questionnaire
- (b) Open - ended or unstructured questionnaire

(a) Closed or structured questionnaire

Hassan (2001: 235-250) carried out an investigation on 41 Brunei pre-service and 54 in-service science teachers' views on the nature of science and technology with the help of a structured questionnaire called the Nature of Science and Technology Questionnaire (NSTQ). A structured questionnaire was also used by Haidar (1999:807-822) to investigate 224

pre-service and 31 in-service teacher's views on the nature of science and the scientific method. Closed or structured questionnaires contain structured or closed questions or statements requiring short, concise answers; for each question, the respondent chooses his or her answer from a number of alternatives (Cohen et al 2000:255). In other words, in closed questionnaires the responses are limited to a few alternatives. The main advantages of structured questions are that they are easy to respond to, take little time to answer, keep the respondent on the subject, are relatively objective, easy to tabulate, easy to analyse and less open to misinterpretations (McMillan & Schumacher 1993: 238; Gay 1987:195). The drawbacks of closed questionnaires are that they do not provide any opportunity to the respondents to further explain their answers; apart from this, they limit responses to the alternatives stated; the researcher may not provide all the alternatives and may force statements of opinion on an issue about which the respondents may not, in fact, have any opinion (Kothari 2001:125). Another disadvantage is that respondents might guess the answers. Whatever their advantages and disadvantages, structured questionnaires have been used to assess pre-service teachers' understanding of science.

(b) Open- ended or unstructured questionnaires

Karen and Renato (1999:110-120) carried out a survey of 73 volunteer pre-service teachers' views with the help of an open-ended questionnaire. In another study, Abd- El- Khalick, Bell and Lederman (1998:417-436) investigated 14 pre-service science teachers' views on science with the help of the same type of questionnaire. Abell and Deborah (1994:475-487) attempted to study 140 pre-service elementary science teachers' views of science, also using an open-ended questionnaire.

Open-ended or unstructured questionnaires allow respondents to express their responses in their own words. This means that open-ended questions have a wide range of correct answers. However, the respondents need to be able to express themselves in writing. Apart from this drawback, it is difficult to tabulate, interpret and summarise responses (Kothari 2001:126). Open-ended questionnaires have also been used to study pre-service teachers' understanding of what constitutes science.

The research studies referred to above have also used other data-collection instruments, such as observation and interviews. Some of the researchers used more than one type of instrument to collect data. For example, Abd- El- Kahlick and Lederman (2000:1057-1097) examined undergraduates, graduate students and pre-service science teachers about the influence of history of science courses on their understanding of science by using both open-ended questionnaires and interviews. Mellado (1997: 331-354) attempted to investigate pre-service teachers' conceptions about the nature of science by using a questionnaire, personal documents and classroom observations. Gustafson and Rowell (1995:589-605) attempted to study 27 elementary science pre-service teachers using both an open-ended questionnaire and interviews. Gallagher used classroom observations, teaching plans and interviews (1991:121-133) to study the views of prospective and practicing secondary science teachers on certain aspects of science and how these beliefs and knowledge influence classroom behaviour. King (1991: 135-141) investigated 13 pre-service teachers views by using questionnaires handed out at the beginning of their introductory courses in the science curriculum and instruction, and he interviewed 11 out of 13 pre-service teachers after participation in the course. Brickhouse (1990: 53-62) attempted to study seven pre-service science teachers' beliefs about the

nature of science and its relationship to classroom practice with the help of both interviews and classroom observations.

In short, previous researchers used different instruments to assess pre-service teachers' understanding of science. The different types of instruments are necessary to support the research on the nature of science and scientific method (Lederman 1992: 333). At this juncture it is also important to note, irrespective of the various assessment instruments used, pre-service teachers' understanding of the nature of science and scientific method as seen by different research studies. Some reported that pre-service teachers had an adequate understanding of the nature of science and some reported that they do not have an adequate understanding of the nature of science.

The selection of the data-collection instrument depends on the nature of the particular problem, and the availability of time and resources; a careful examination of different data-collection instruments (each instrument has its own advantages, disadvantages and limitations) shows that no instrument is superior to another. The present study explores student teachers' views on the nature of science and the scientific method and the researcher decided to obtain information from student teachers (secondary). As I have already said, questionnaires allow the researcher to obtain information from a large, and geographically widespread, sample. In view of the specific advantages offered by structured questionnaires, the researcher decided to use this type of questionnaire for the present study.

2.3 SUMMARY OF CHAPTER 2

In this chapter, an attempt was made to present and discuss previous literature related to pre-service teachers' views of what constitutes the nature of science and the scientific method. An understanding of post positivist / non-traditional views on the nature of science and the scientific method plays a vital role in developing an adequate understanding of the nature of science and the scientific method. Such an adequate understanding is essential if student teachers are to develop a better understanding of science as a subject, and communicate this better understanding to their science learners. A number of studies have concentrated on pre-service teachers' views on what constitutes science and the scientific method.

In Botswana, however, there is a scarcity of studies on pre-service teachers' views of science. For the purposes of this research, the researcher therefore considered general research studies on pre-service teachers' views on science. Some of the research findings showed that pre-service teachers have an adequate understanding of science, while others showed the opposite. Some of the research studies showed mixed results. Most of these studies have been conducted in a number of very different countries. There are many factors that might cause the divergence in previous research findings. The discrepancy in the previous research results might be due to the fact that previous research was conducted on elementary, primary and secondary pre-service teachers who had different educational backgrounds. Also, different countries follow different curricula. Then there is the fact that the research undertaken has been conducted during different stages of pre-service teachers' training. In addition, the duration of teacher-training courses differs. Many of the previous research studies recommend the inclusion of history, philosophy and sociology of science in the teacher-training curriculum. Previous research concentrated on training pre-service science teachers in the history of science. Some of these studies indicated

that courses in the history of science would help pre-service teachers to develop a better understanding of the nature of science and the scientific method. Some research studies, on the other hand, indicated that there is little or no significant change in pre-service teachers' views after completing history of science courses. The authors of these studies felt that pre-service teachers' prior conceptions might play a role in selecting learning experiences that reinforce the concepts of science that they have already. The research studies recommended the assessment of pre-service teachers' prior conception and changing pre-service teachers' views by adopting a conceptual approach. Research conducted on these lines indicated that pre-service teachers modify their understanding of science as a result of being exposed to a conceptual change approach, but require the more time to reflect on their conceptions so as to change their views. Another investigation recommended research on the influence of the learning environment on pre-service teachers' understanding of the nature of science and the scientific method.

Given this complex situation, the development of student teachers' (pre-service teachers) understanding of science and the scientific method is supposed to receive adequate investigation. It is recognised that exploring the views held by student teachers (pre-service teachers) is essential if teacher-training courses are to be improved. Since, in Botswana, there is a definite scarcity of studies on pre-service teachers' views on what constitutes science and the scientific method, there is need to explore the views held by student teachers as a first step towards documenting these views and beliefs. The aim of the present study, therefore, is to explore student teachers' understanding of science and how these student teachers' views are associated with gender, type of institute (learning environment), years of study and whether science was taken as major / minor teaching subject (length of exposure). In chapter three, the research methodology will be outlined.

CHAPTER 3

RESEARCH METHODOLOGY AND PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

3.1 INTRODUCTION

The purpose of this study is to explore the Tonota and Molepolele student teachers' views about the nature of science and the scientific method. The review of the literature regarding pre-service teachers' views on the nature of science and scientific method was presented in chapter two.

Sections 3.2 of this chapter mainly concentrate on possible methods to determine student teachers' views on the nature of science and the scientific method. In this section, implementation of the research design for the present study with procedural details will be outlined. The above section also includes the description variables, research problems, research questions, and specific problem statements. An attempt is made to focus attention on the formulation of the hypotheses to realise the objectives mentioned in chapter 1, paragraph 1.4. The above section also describes the population and sample used for the present study and development, and the description and administration of the instrument. In addition, the above section also describes the procedure for analysing the data obtained from the instrument.

In section 3.3, the results of the empirical investigation are presented, analysed and discussed. The analysis of the data, and the interpretation of data, provides an indication of student teachers' understanding of the nature of science and the scientific method.

3.2 RESEARCH METHODOLOGY

3.2.1 The main research questions

The main research questions are stated in chapter 1, paragraph 1.3. In this section, the questions are restated and further broken down into specific research questions for ease of implementation.

Thus, the main research questions are:

- (a)** Do student teachers' views reflect currently accepted views of the nature science and the scientific method?
- (b)** Is there any association between student teachers scores on the nature of science, the scientific method and variables such as gender, type of educational institution which student teachers attend, years spent in studying, and whether student teachers are studying science as a major or minor teaching subject?

3.2.1.1 The main research questions reformulated into specific questions

Consequently, in order to investigate the problems of this study in a logical way, the research problem 3.2.1 (b) was further broken down into specific research questions.

- (i)** Is there any evidence of an association between student teachers' scores on the nature of science, the scientific method and gender?
- (ii)** Is there any evidence of an association between student teachers' scores on the nature of science, the scientific method and type of educational institution which student teachers attend?
- (iii)** Is there any evidence of an association between student teachers' scores on the nature of science, the scientific method and years spent in studying science?
- (iv)** Is there any evidence of an association between student teachers' scores on the nature of science, the scientific method and whether student teachers are studying science as a major or minor teaching subject?

3.2.2 The methods of study

In order to study student teachers' views systematically, it is essential to choose an appropriate research method. The rationale for choosing one method over another is connected with the nature of the subjects studied and the underlying goals of the research. The researcher followed the quantitative paradigm of research and used a survey method.

Gay (1987: 191) defined survey as “ an attempt to collect data from members of a population in order to determine the current status of that population with respect to one or more variables”. A survey involves the frequency of demographic characteristics or traits held, explores relationships between different factors, or describes the reasons for a particular practice (McMillan & Schumacher 1993: 36). A survey therefore describes, records, analyses, and interprets conditions that either exists or existed.

The research method used was an explanatory survey that attempted to study student teachers' views on the nature of science and the scientific method. The rationale behind the selection of this cross-sectional survey is an attempt to collect data from members of a population at a certain point of time in order to determine the current understanding of the nature of science and the scientific method. It also attempts to study the relationship that exists between specific variables and the scores on the nature of science and the scientific method. The following section describes the variables included in the present study.

3.2.2.1 Variables used in the study

According to McMillan and Schumacher (1993:81) a variable is an event, category, behaviour or attribute that expresses a construct and that has different values, depending on how it is used in a particular study. As indicated earlier, in chapter 2, paragraph 2.2.1, “the concept nature of science” consists of scientific observations, scientific theories, scientific laws, scientific models, scientific knowledge and the nature of scientists' work. In the present study, therefore, observed variables such as scientific observations, scientific theories, scientific laws, scientific models, scientific knowledge and the nature of scientists' work contribute towards a latent factor - in this case, the nature of science. The table below presents the observed variables and the factor.

Table 1:Description of latent factor and observed variables

Factor	Observed variables
Nature of science	Scientific knowledge
	Scientific observations
	Nature of scientists' work
	Scientific theories
	Scientific models
	Scientific laws
	Scientific method

The statements were compiled mainly based on the above-observed variables, such as scientific knowledge, scientific observations, scientific theories, scientific models, scientific laws, scientists' work and scientific method.

3.2.3 Research design

According to McMillan and Schumacher (1996:31), research design refers to the plan and structure of the investigation used to obtain evidence to answer research questions. The research design is the procedure for conducting study. In order to collect data, it is essential to choose a suitable instrument. The following section describes the instrument used for the present study.

3.2.3.1 Description of instrument: Questionnaire

The data was collected from science student teachers of both Secondary Colleges of Education. A questionnaire was used to find out student teachers' views on the nature of science and the scientific method.

A questionnaire is one of the most widely used data-collection instruments (Kothari 2001: 124). According to Best and Khan (1996: 229), a questionnaire asks respondents to answer the questions asked or to respond to statements in writing.

The questionnaire compiled for this study consists of two parts – part one and part two. (The questionnaire is included in Appendix A). Part one is a profile format that gives background information on the student teachers (i.e. gender, the name of the institute they attend, year of study and the group (science as either a major or minor teaching subject). All the items in this section had to be answered by ticking the appropriate box. The background information on the respondents is used to understand if there is any association between the variables given above and observed variables such as student teachers' views of scientific knowledge, scientific observations,

scientific theories, scientific models, scientific laws, nature of science and scientific method.

Part two of the questionnaire consists of twenty-one structured statements drawn up for the specific purpose of the present study. According to McMillan and Schumacher (1993: 238), structured questions are best for obtaining information and data that can be categorised easily. The main advantages of structured questions is that they are less time-consuming, easy to complete, keep respondents focused objectively on the subject and, as far as the researcher is concerned, are easy to tabulate and analyse.

Developing the questionnaire statements required an intensive reading of the literature related to the nature of science and the scientific method. Questionnaire statements were compiled on the basis of the literature reviewed. The questionnaire statements were compiled and modified mainly from questionnaire statements developed by Deborah Pomery (1993: 273-277), Jandayala (1996) and Haidar (1999).

In order to accomplish the objectives stated in chapter 1, section 1.4 (a), statements were compiled based on observed variables such as scientific knowledge, scientific observations, scientific theories, scientific laws, scientific models and scientists' work. Statements were also compiled that related to scientific methods.

The table below presents the number of statements in each category and the rationale for employing each statement.

TABLE 2

Description of factors, variables, and number statements and rationale for each statement

Factor	Observed variables	Total no. of statements	Statement number	Rationale for employing each statement To study student teachers views on
Nature of science	Scientific knowledge	5	1	Tentative nature of scientific knowledge
			2	Generation of scientific knowledge
			3	Status of scientific knowledge - whether it corresponds directly to reality
			4	Progression of scientific knowledge in evolutionary and revolutionary manner rather cumulative manner
			5	Objective account of scientific knowledge
	Scientific Observations	1	10	Nature of scientific observations
	Nature of scientists work	5	11	Use of several methods during investigations by scientists in order to get results
			12	Factors that influence how scientists report data
			13	Factors that influence scientists' work
			14	Factors that consider the evaluation of scientific claims
		21	Discovery of absolute scientific laws by scientists	
Scientific theories		4	15	Role of theories that belong to different paradigms in scientific progress
			16	Rational & defensible ways used by scientists to decide between competing theories
			17	Validation of scientific theories by scientists based on relationship to supplementary and alternative theories

Continued

			18	Contribution of various incompatible theories to scientific progress
	Scientific models	1	19	Status and role of scientific models
	Scientific laws	1	20	Status of scientific laws
	Scientific method	4	6	Scientific investigations use range of scientific methods, depending on context of enquiry
			7	Scientific methods do not have rigid step-by-step procedures to follow
			8	Adjustment of scientific method in the middle of enquiry by scientists
			9	Contribution of various scientific methods for scientific progress

In order to accomplish the objective stated in chapter 1, section.4 (a), the statements based on observed variables of the nature of science, such as scientific observations, scientific theories, scientific laws, scientific models, scientific knowledge and nature of scientists' work and scientific method were quantified and measured by the researcher. The investigator used the Likert-type ranking scale on a five-point continuum. In this scale the respondent is asked to indicate the level of agreement with each statement contained in the instrument. The respondents had to indicate, on a five-point scale, to what extent they agreed or disagreed with each statement by drawing a tick in appropriate space provided for each statement.

Respondents receive one to five points for each statement. The student teachers who strongly agree with statements 1, 6, 7, 8 and 9, 10,11,13,15,16,17 and 18 earn five points for each statement, while only one point would be given for each ‘strongly disagree’ response. Agree, undecided, disagree would earn 4,3 and 2 points respectively. The statements 1, 3, 4, 5, 12, 14, 19, 20 and 21 are stated negatively, which means that a ‘strongly agree’ answer earns one point and a ‘strongly disagree’ response earns five points. Agree, undecided, and disagree earn 2,3 and 4 respectively. This information will be used during the scoring and analysis of the questionnaire. The table below describes the pattern of scoring.

TABLE 3

Description of factors, variables, statements and pattern of scoring

(SA= Strongly Agree; A= Agree, UN= Undecided, DA= Disagree and SDA = Strongly Disagree)

Factor	Observed variables	Statement type and number	Pattern of scoring				
			SA	A	UN	DA	SDA
Nature of science	Scientific knowledge	Positively stated 1	5	4	3	2	1
		Negatively stated 2, 3, 4 and 5	1	2	3	4	5
	Scientific observations	Positively stated 10	5	4	3	2	1
	Nature of scientists’ work	Positively stated 11 and 13	5	4	3	2	1
		Negatively stated 12,14 and 21	1	2	3	4	5
	Scientific theories	Positively stated 15,16,17 and 18	5	4	3	2	1
	Scientific models	Negatively stated 19	1	2	3	4	5
	Scientific laws	Negatively stated 20	1	2	3	4	5
	Scientific method	Positively stated 6,7,8 and 9	5	4	3	2	1

In order to accomplish the objective stated in chapter 1, section 4.1 (b), student teachers responses for each alternative of each statement are counted based on gender, type of educational institution, science major/minor teaching subject, and year of study.

3.2.4 Validity and reliability of instruments, procedure and content

Validity and reliability are important and essential to the effectiveness of any data-collection procedure.

3.2.4.1 Instrument validity

Validity is one of the most important criterion in any educational research. Groundlund and Linn (1995:46) indicate that validity refers to the “appropriateness of the interpretations made from test scores and evaluation results with particular use”. Khothari (2001:91) regarded “validity as referring to the extent to which differences found with measuring instrument reflect true differences among those being tested”. A measuring instrument is therefore said to be valid if it measures accurately what it purports to measure, if it reflects true differences of the variables being measured and if it gives results of an evaluation procedure that serve the intended purpose. In this study, cognisance will be taken of the content of the questionnaire statements.

3.2.4.2 Content validity

Gay (1987: 129) defines content validity as “ the degree to which a test measures an intended content area”. McMillan and Schumacher (1993:224) indicate that the content validity is the extent to which the content of a test is judged to be representative of some appropriate universe or domain of content. Content validity is therefore concerned with test items representing measurement in the intended content area and adequate item

samples that represent the total content area. Content validity thus gives logical evidence that the content of the items of the measurement is suitable for the purpose. In order to establish content validity, for the present study, most of the questionnaire statements were adapted from published articles. An attempt has been made to ensure that the questionnaire statements adequately represent the total content area, that is, the nature of science and the scientific method.

In order to validate the questionnaire, a pilot study was conducted on nine student teachers from Tonota College of education. Three science student teachers from each year of study were selected for the purpose of the pilot study. On the basis of the pilot study and suggestions made by experts, the questionnaire was revised. Some modifications were made in the language (i.e. to eliminate ambiguity). A deliberate effort was made to present the items in simple English, in order to avoid confusion or misunderstandings.

3.2.4.3 Instrument reliability

An instrument is reliable if it is consistent in measuring the extent to which the results are similar over different forms of the same instrument or occasions of data collecting (McMillan & Schumacher 1993: 227). In other words, reliability is concerned with the variation of the results caused by factors other than the variable being measured. A reliable instrument minimises the influence of chance or other variables unrelated to the intent of the measure. For the present study, reliability was measured by using the Cronbach alpha-coefficient.

To collect information systematically, it is necessary to carefully and systematically select the group of subjects sharing common characteristics. The following section describes the population.

3.2.5 Description of population and sample

The purpose of the investigation was to study student teachers' views of the nature of science and the scientific method. Secondary Colleges of Education offer and train student teachers for the Diploma in Secondary Education. After successful completion of the DSE, student teachers of secondary colleges of education are eligible to teach in junior secondary schools. According to Best and Khan (1996:13) a population is any group of individuals that have one or more characteristics in common and that are of interest to the researcher. Furthermore, Gay (1987: 102) defined population as having at least one characteristic that differentiates it from other groups. Therefore the population selected was junior secondary student teachers.

The present study is conducted using students registered in the course for undergraduate Diploma in Secondary Education (DSE) programme at Secondary Colleges of Education. The selection of the appropriate sample was the first step towards the achieving the research objectives stated in chapter one. The population of science student teachers in Botswana includes students from the two Colleges of Education and students from the University of Botswana. To draw the sample for this study, an attempt was made to acquire data from each and every science student teacher from Secondary Colleges of Education. To maximise the accuracy of the information, the sample includes science teachers from both colleges of education.

The present study therefore considers the entire first-year, second-year and third-year student science teachers from the Tonota and Molepolele Colleges of Education. The student teachers in both Secondary Colleges of Education share common characteristics such as same academic background, entry requirements into DSE programme and all are following the same science curriculum in teacher training. The student teachers do differ in terms of gender, the institution they attend, the year of study and whether they are offering science as a major or minor teaching subject. Approximately 40-45 students will be enrolled as major science students every year and 40- 45 students will be enrolled as minor science students in both institutions.

The Diploma in Secondary Education at Secondary Colleges of Education is a full-time programme extending over three academic years. The curriculum comprises the following subjects:

Foundations of Education, Communication and Study Skills, major and minor teaching subjects (students select one subject as major subject and one as a minor subject from a wide range of subjects, e.g. Science, Agriculture, Home economics, Business studies etc.) and Teaching Practice. The group of student teachers who select science as major teaching subject and science as minor teaching subject are referred to as science major student teachers and science minor student teachers.

The education of science major and minor student teachers (pre-service) is fundamentally centred on their integrated knowledge of science (i.e. Physics, Chemistry and Biology), and covers a wide range of topics, as well as a Professional Studies component. The Professional Studies component comprises a wide range of topics and subtopics such as science and technology today, models in science and science teaching, introduction to the use and making of effective teaching learning aids, practical work in science, approaches, styles, teaching methods and techniques, teaching practice evaluation, communication in science, and various learning theories, including constructivism, etc.

Each unit is designed to run for a half-term or (occasionally) a full term (4 x 50 minutes classes per week). In the major course, two of the periods 2x50 minutes are devoted to practical topics from the modules of the Junior Secondary Science syllabus. Some units of the Junior Secondary Science syllabus will be completed in each half term (science syllabus, 1996).

The particular unit to be done will depend on the science content and on the professional studies topics being covered in that particular half term. The lecture hours for major subjects in professional studies and content are in the ratio of approximately 1: 3 and for minors the ratio is approximately 2: 3. Post-positivist views of the nature of science and scientific method are conveyed explicitly and implicitly by professional studies and content components.

The description of the sample is given below.

TABLE 4

Distribution of sample according to gender, type of institution, years of study and science as a major / minor teaching subject

Year of study	Number of students in Tonota College of Education		Number of students in Molepolele College of Education		Total number of student teachers	
	Males	Females	Males	Females		
1 st year major	13	7	19	6	45	82
1 st year minor	12	9	8	8	37	
2 nd year major	8	9	16	12	45	87
2 nd year minor	15	11	15	1	42	
3 rd year major	14	13	14	7	48	105
3 rd year minor	16	13	19	9	57	
Total students	78	62	91	43	274	
Total Number of male student teachers: 169						
Total number of female student teachers: 105						
Total number of student teachers in Tonota College of Education: 140						
Total number of student teachers in Molepolele College of Education: 134						
Total number of science major student teachers: 138						
Total number of science minor student teachers: 136						

3.2.5.1 Diagrammatic representation and analysis of sample based on Gender, type of educational institution, year of study and science as a major or minor teaching subject

Figure 1: Diagrammatic representation of percentage of male and female student teachers in the sample

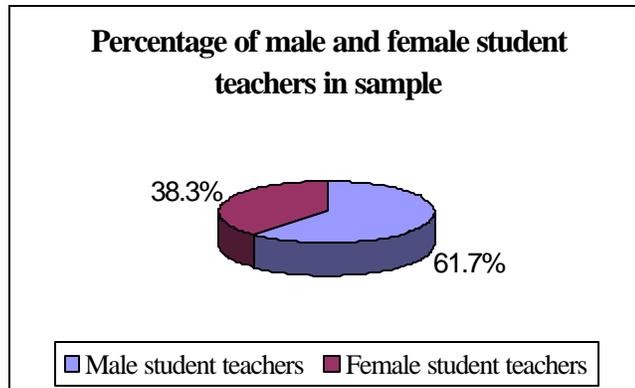


Figure 1 shows that male student teachers constitute 61.7% and female student teachers constitute 38.3% of the total sample.

Figure 2: Diagrammatic representation of percentage of Tonota and Molepolele student teachers in the sample

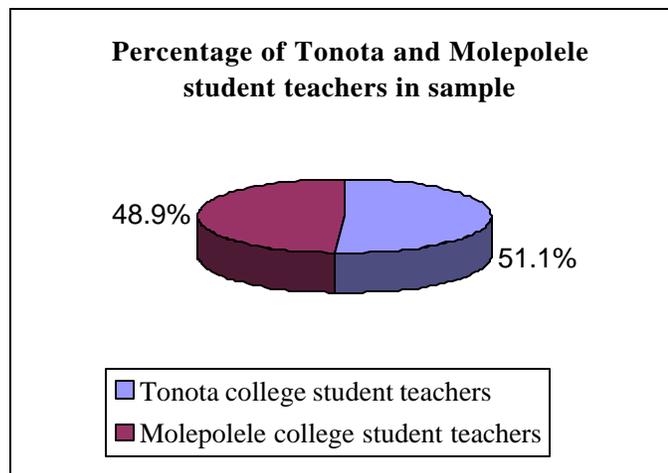


Figure 2 above shows that Tonota College of Education student teachers constitute 51.1% and Molepolele College of Education student teachers constitute 48.9% of the sample.

Figure 3: Percentage of 1st, 2nd and 3rd year student teachers in the sample

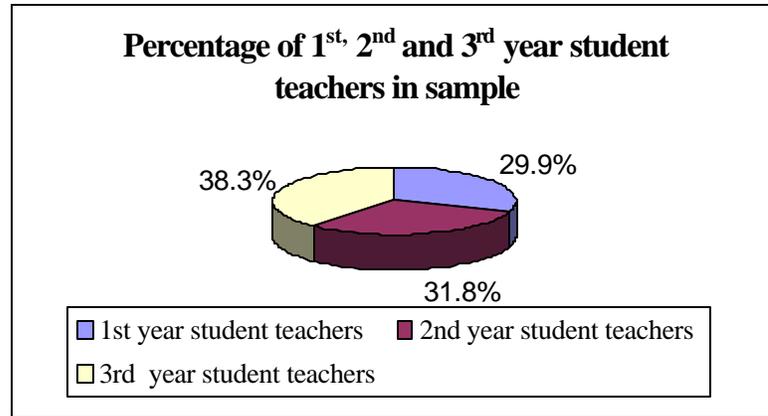


Figure 3 shows that first-year student teachers constitute 29.9%, second-year student teachers constitute 31.8%, and third-year student teachers constitute 38.3% of total sample.

Figure 4: Percentage of major and minor student teachers in the sample

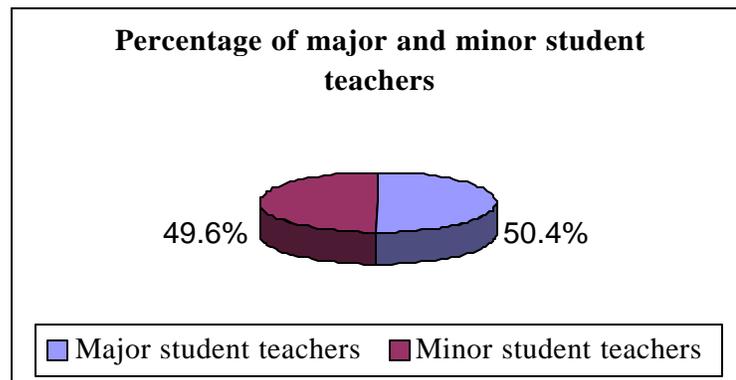


Figure 4 shows that the major student teachers constitute 50.4% and the minor student teachers constitute 49.6% of total sample.

An analysis of the above indicates that, in the sample, male student teachers outnumber female student teachers. Third-year student teachers are more numerous compared to first- and second-year student teachers.

3.2.6 Data collection

The target population of this study are student science teachers of Secondary Colleges of Education. The questionnaire was presented to 274 student teachers. The questionnaire contained a letter of introduction explaining the purpose of the research and requesting the student's cooperation. In order to ensure that the questionnaire got a high response, the questionnaire was administered personally to student teachers of the Tonota College of Education. The investigator requested lecturers from the Molepolele College of Education to administer the questionnaire. The investigator explained the purpose of the research and also explained, to respondents, how to fill in the questionnaire.

This method is convenient for two reasons:

- Further instructions and clarity can be given during the process of respondents completing the questionnaire.
- Less time will be spent waiting for the return of responses.

The data was collected from first-year student science teachers during the first term of 2003 academic year. During the first term, second- and third-year student science teachers are on teaching practice (i.e. not at college). Data was therefore collected from second- and third-year student science teachers during the second term of academic year 2003. The following hypotheses were considered for the present study.

3.2.7 Hypotheses

In chapter two, section 2.2.4, it was noted that, to date, empirical evidence on the relationship between different factors and student teachers' views on the nature of science and the scientific method is both ambiguous and conflicting. As indicated in chapter two, section 2.2.5, there is a definite scarcity of literature on the association between certain factors and student teachers' views on the nature of science and the scientific method. It is therefore difficult to predict the nature and direction of the association between different variables and student teachers' scores on the nature of science and the scientific method. However, in this study, the hypotheses are based on variables such as gender, type of educational institution, which student teachers attend, years spent in studying, whether science is a major or minor teaching subject and their scores on the nature of science and the scientific method. The following hypotheses are considered for the present study.

H₀₁: There is no association between student teachers' scores on the nature of science and gender.

H₀₂: There is no association between student teachers' scores on the scientific method and gender.

H₀₃: There is no association between student teachers' scores on the nature of science and the type of educational institution they attend.

H₀₄: There is no association between student teachers' scores on the scientific method and the type of institution they attend.

H₀₅: There is no association between student teachers' scores on the nature of science and the years spent in studying.

H₀₆: There is no association between student teachers' scores on the scientific method and the years spent in studying.

H₀₇: There is no association between student teachers' scores on the nature of science and whether student teachers are offering science as a major or minor teaching subject.

H₀₈: There is no association between student teachers' scores on the scientific method and whether student teachers are offering science as a major or minor teaching subject.

3. 2.8 Data analysis

The data for research question 1.3 (a) and objective 1.4 (a), stated in chapter 1, was analysed using descriptive statistics such as frequencies and percentages. Frequencies and percentages were calculated on the basis of student teachers' responses to each statement.

For research question 1.3 (b) and objective 1.4(b) stated in chapter 1, first analysis of part 1 of the questionnaire will be done according to the variables of gender, type of educational institution attended, year of study and whether science is offered as a major or minor teaching subject. This background information will be utilised in order to understand the association between these variables and student teachers' scores on the nature of science and the scientific method. The chi-square test will test the formulated hypotheses. Note, however, that the chi-square is not a measure of the degree of relationship, but only of the significance of association between two variables.

3.3 ANALYSIS AND DISCUSSION OF THE RESEARCH RESULTS

3.3.1 Presentation and analysis of collected data

The data included all the major and minor student science teachers responses from Tonota and Molepolele Secondary Colleges of Education. The whole sample of this investigation consisted of 274 student teachers. (See section 3.2.3.2, table 4). Out of the 274 questionnaires distributed, 213 were returned (table 5) to give a response rate of 77.7%.

TABLE 5

Analysis of the responses according to gender, type of educational institute, science as a major / minor teaching subject and years spent in studying

Student teachers	Total number of questionnaires received from respondents	Non-responses
Male	126(74.6%)	43(25.4%)
Female	86 (81.9%)	19 (18.1%)
Tonota College of Education	122(87.1%)	18 (12.9%)
Molepolele College of Education	91(67.9%)	43(32.1%)
Major	105(76.1%)	33(23.9%)
Minor	108(79.4%)	28(20.6%)
1st year	77(93.9%)	5(6.1%)
2nd Year	57(65.5%)	30(34.5%)
3rd year	79(75.2%)	26(24.8%)

The sample consisted of 169 male and 105 female student teachers. Table- 5 shows that 126 (74.6%) male and 86 (81.9%) female student teachers responded. One student teacher failed to indicate gender.

The sample consisted of 140 Tonota and 134 Molepolele student teachers. Table 5 shows that 122 (87.1%) student teachers responded from the Tonota College of Education and that 91 (67.9%) responses were received from the Molepolele College of Education.

The sample consisted of 138 major and 136 minor student teachers. Table 5 shows that 105 (76.1%) major student science teachers and 108 (79.4%) minor student science teachers responded.

The sample consisted of 82 first-year, 87 second-year and 105 third year student teachers. Table 5 shows that 77 (93.9%) first-year student teachers, 57 (65.5%) second-year and 79 (75.2%) third-year student teachers responded. The above data is presented graphically below.

Figure 5: Percentage of responded and non-responded male student teachers in sample

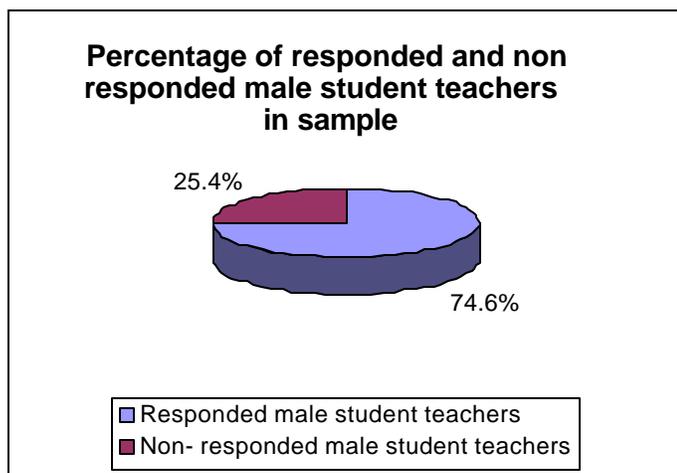


Figure 6: Percentage of responded and non-responded female student teachers in sample

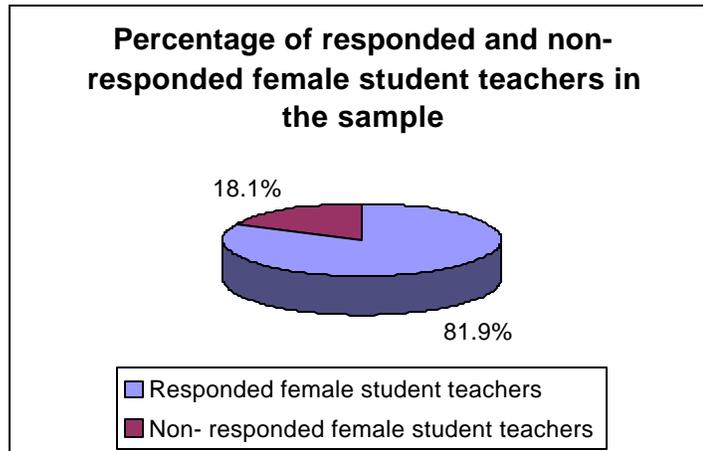


Figure 7: Percentage of responded and non-responded Tonota college student teachers in sample

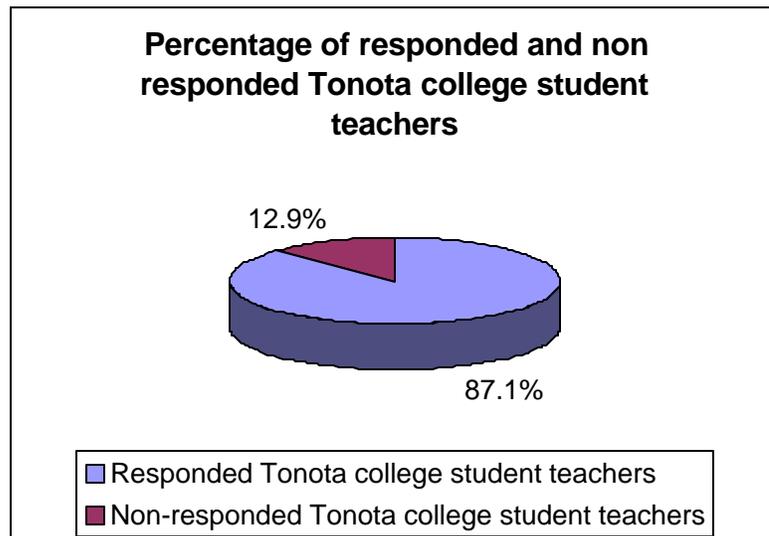


Figure 8: Percentage of responded and non-responded Molepolele college student teachers in sample

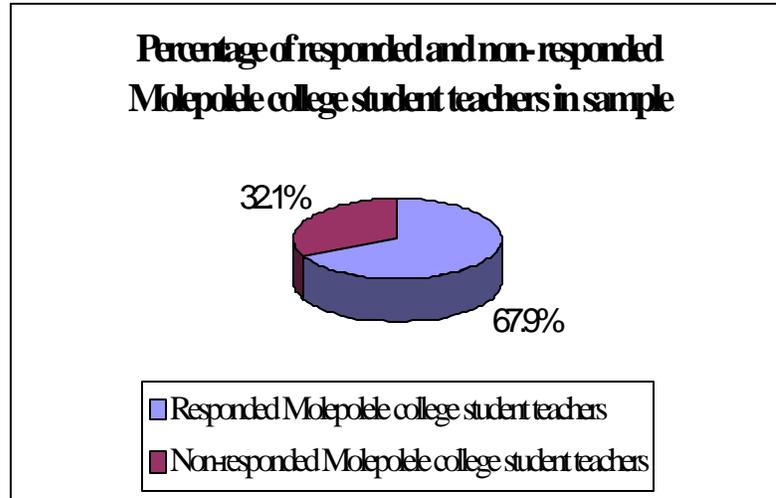


Figure 9: Percentage of responded and non-responded major student teachers in sample

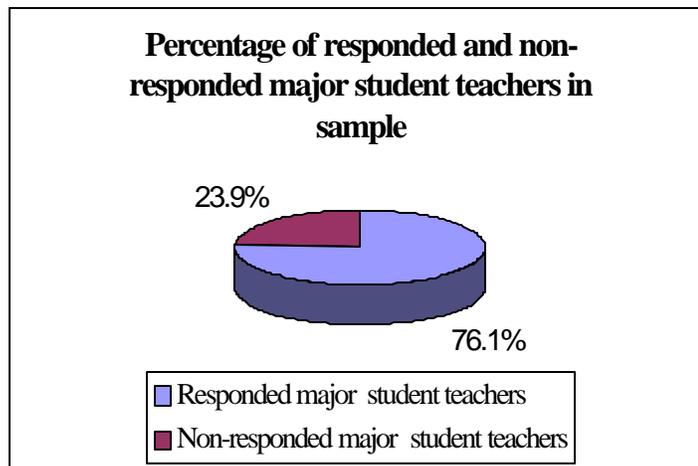


Figure 10: Percentage of responded and non-responded minor student teachers in sample

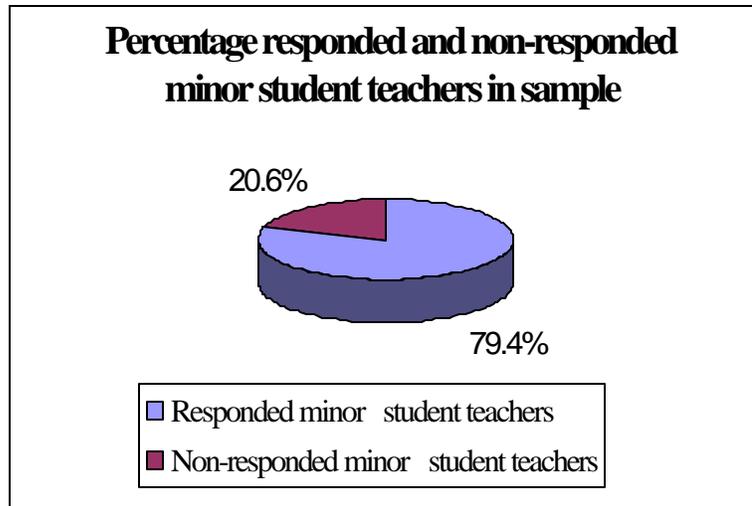


Figure 11: Percentage of responded and non-responded first-year student teachers in sample

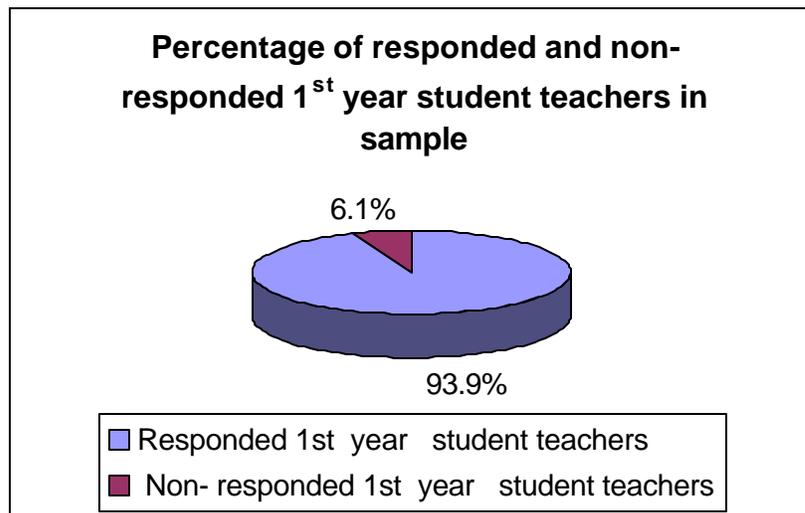


Figure 12: Percentage of responded and non-responded second-year student teachers in sample

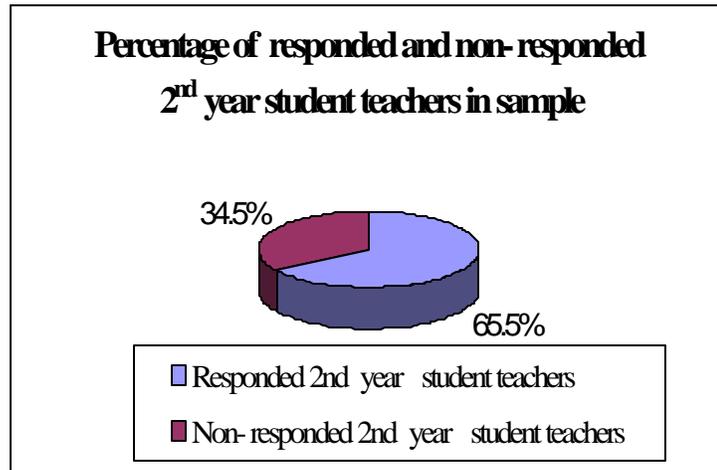
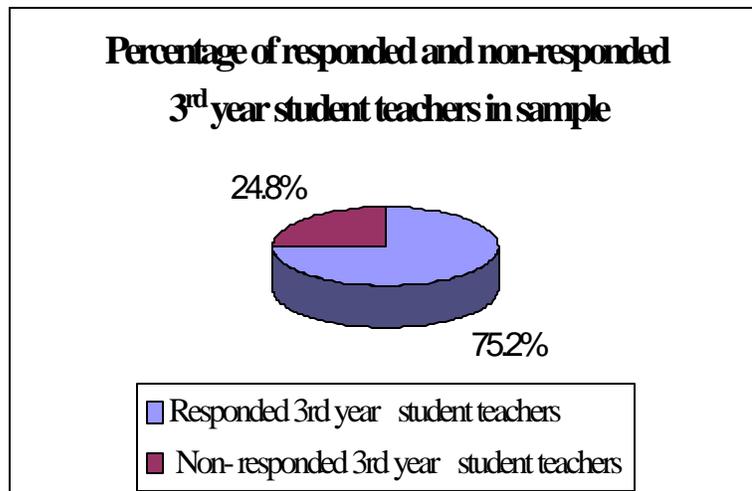


Figure 13: Percentage of responded and non-responded third-year student teachers in sample



The following section presents the item analysis of the questionnaire.

3.3.2 Item analysis

The statements on part two of the questionnaire are based on observed variables such as students' views of scientific observations, scientific theories, scientific models, scientific laws, the nature of scientists' work, scientific knowledge and the scientific method. The observed variables (also factors)¹ such as scientific theories, scientific knowledge, the nature of scientists' work and the scientific method contain more than one statement.

The aim of the above Item analysis was to determine whether each statement contributes significantly to the observed variable in which it is placed. An item analysis was therefore done for all the items of each observed variable, namely students' views of scientific theories, scientific knowledge, nature of scientists' work and the scientific method. The results are shown in table 6.

¹ Some of the observed variables are made up of many statements therefore, they can also be viewed as factors.

TABLE 6 Item analysis

SCIENTIFIC KNOWLEDGE		
Number of student teachers: 207, Number of statements: 5 Cronbach coefficient-alpha, Raw 0.490692		
	RAW	
	Correlation with total	Alpha if item is left out
Statement 1	0.139125	0.539195
Statement 2	0.302843	0.412942
Statement 3	0.258975	0.441139
Statement 4	0.478388	0.310406
Statement 5	0.221098	0.462141
NATURE OF SCIENTISTS WORK		
Number of student teachers: 183, Number of statements: 5 Cronbach coefficient-alpha, Raw 0.436416		
	RAW	
	Correlation with total	Alpha if item is left out
Statement 11	0.213919	0.399601
Statement 12	0.272360	0.346921
Statement 13	0.245738	0.375978
Statement 14	0.237220	0.376576
Statement 21	0.191760	0.407135
SCIENTIFIC THEORIES		
Number of student teachers: 211, Number of statements: 4 Cronbach coefficient-alpha, Raw 0.508731		
	RAW	
	Correlation with total	Alpha if item is left out
Statement 15	0.315524	0.422934
Statement 16	0.163003	0.545374
Statement 17	0.285992	0.450249
Statement 18	0.448178	0.281334
SCIENTIFIC METHOD		
Number of student teachers: 211, Number of statements: 4 Cronbach coefficient-alpha, Raw 0.438053		
	RAW	
	Correlation with total	Alpha if item is left out
Statement 6	0.258014	0.355790
Statement 7	0.335734	0.260816
Statement 8	0.320032	0.289839
Statement 9 *	0.064834	0.494689

*= Low correlation with total

Cronbach alpha is an estimate of internal consistency. Raw cronbach alpha values are based on item correlation. The stronger the interrelationship/co relationship between the items, the more likely it is that the test is consistent and that alpha values are higher. According to Schumacher and McMillan (1993:227) the reliability scale ranges from 0.00 to 0.99 and an acceptable range of reliability coefficient is 0.70 to 0.90. According to Fraenkel and Norman(1993:149) reliability co-efficient should be at least 0.70 and preferably higher. If the coefficient is high, that is, 0.9, the instrument had little error and was highly reliable. In exploratory research, studies can tolerate low reliability, sometimes as low as 0.50 (Schumacher and McMillan 1993:227) .

Table 6 shows that the Cronbach coefficient-alpha for scientific knowledge, nature of the scientists' work, scientific theories, and scientific method is 0.490692, 0.436416, 0.508731 and 0.438053 respectively. Generally, Cronbach coefficient-alpha values are low for the above categories especially for scientists' work and the scientific method compared with the Cronbach coefficient-alpha for scientific knowledge and scientific theories. Statements are not strongly interrelated and reliability values are therefore lower in the above categories.

The researcher decided to retain all the statements under the nature of scientists' work, because the omission of any statement will not contribute to any increase in the reliability coefficient in that section. The reliability coefficient of the nature of scientists' work is therefore lower than 0.5, that is, 0.436416. The scientific method section consists of the four statements 6,7,8 and 9. It was found that statement 9 showed a very low correlation with the total and it was therefore decided to omit statement 9. This altered the reliability from 0.438053 to 0.494689.

It is important to note that due to low cronbach coefficient alpha values, it wasn't possible to combine scores of different observed variables together in order to arrive at a combined score towards the nature of science. Because of low item correlation, in different observed variable categories, the statements are not grouped under different observed variables (i.e. scientific knowledge, scientists' work and scientific theories). As a result of the low Cronbach alpha values, a combined score couldn't be calculated and frequencies as well as the chi-square test were used for analysis and reporting on individual statements. It is important to note that results must be interpreted in context low cronbach alpha values.

The following section describes the responses to the statements contained in the questionnaire.

3.3.3 Presentation of results

Table 7 presents results for research questions 3.1(a) and (b), as stated in chapter 1. Student teachers' responses to each of the statements contained in the questionnaire are tabulated in the form of frequencies and percentages.

TABLE 7**Frequency and percentage of responses to questionnaire statements**

S. No	Strongly agree	Agree	Undecided	Disagree	Strongly Disagree	Non-response
1. Scientific knowledge is not fixed /final and is subject to change (tentative in nature).						
	87 (40.8%)	86 (40.4%)	14 (6.6%)	10 (4.7%)	12(5.6%)	4(1.9%)
2.Scientific knowledge is generated first through observation.						
	94(44.1%)	99 (46.5%)	7(3.3%)	5 (2.3%)	5 (2.8%)	2(0.9%)
3. Scientific knowledge corresponds directly to reality.						
	57(26.8%)	103(48.4%)	26(12.2%)	21(9.9%)	6 (2.8%)	0(0%)
4.Scientific knowledge increases with increasing observations.						
	106 (49.8%)	86(40.4%)	12(5.6%)	3(1.4%)	4(1.9%)	2(0.9%)
5. Scientific knowledge attempts to be an objective account of nature.						
	34(16%)	109(51.2%)	54(25.4%)	15(7%)	0 (0%)	1 (0.5%)
10. Observation and interpretation of observations are influenced by theories scientists hold.						
	39 (18.8%)	131(61.5%)	21(9.9%)	18 (8.5%)	2(0.9%)	1(0.5%)
11.The best scientists are those who use any method that might obtain favourable results.						
	42(19.7%)	80(37.6%)	35(16.4%)	33(15.5%)	23(10.8%)	0(0%)
12. Scientists report data exactly as their senses perceive them.						
	32(15%)	66(31%)	44(20.7%)	44(20.7%)	26(12.2%)	1(0.5%)
13. Scientists' work (i.e. observations, selection of data and hypothesis etc) is sometimes influenced by many factors, e.g. previous knowledge, logic and social factors.						
	50(23.5%)	120(56.3%)	28(13.1%)	10 (4.7%)	5 (2.3%)	0 (0%)
14.Scientists evaluate scientific claims exclusively through an analysis of empirical evidence.						

....Continued

	15 (7%)	82(38.5%)	79(37.1%)	27(12.7%)	10(4.7%)	0(0%)
21.Scientists strive to discover the absolute laws of nature.						
	53 (25%)	112 (53%)	34(16%)	5 (2%)	3 (1%)	5 (2%)
15.Theories fit within certain paradigms; hence if they are old, or untrue, they are helpful to scientists.						
	23 (10.8%)	77 (36.2%)	63(29.6%)	32 (15%)	15 (7%)	3 (1%)
16. When there are competing theories, and scientists want to decide between them, there are rational and defensible ways of doing so.						
	21(9.9%)	104(48.8%)	59(27.7%)	19(8.9%)	7 (3.3%)	3 (1%)
17. A theory is validated by its connections to other theories generally accepted within the scientific community.						
	35 (16.4%)	111 (52.1%)	42(19.7%)	19 (8.9%)	3 (1.4%)	3 (1%)
18.The existence of various incompatible theories is fruitful for scientific progress.						
	34 (16%)	108 (50.7%)	33(15.5%)	18 (8.5%)	15(7%)	5(2%)
19. Scientific models are copies of reality, since they describe reality as it is.						
	41(19.2%)	101(47.4%)	18(8.5%)	32(15%)	16(7.5%)	5(2.3%)
20. Scientific laws can be proven to be absolutely true.						
	70 (32.9%)	98 (46%)	22(10.3%)	15 (7%)	2 (0.9%)	6 (2.8%)
6.There is no single, universal scientific method. Scientific methods differ, depending on particular circumstances.						
	69(32.4%)	96(45.1%)	17(8%)	18(8.5%)	12(5.6%)	1(0%)
7. Scientists do not necessarily have to follow fixed sequence of steps in the scientific method.						
	29 (13.6%)	77 (36.2%)	21 (9.9%)	59(27.7%)	26(12.2%)	1(0%)
8. Scientists can adjust their method of inquiry in the middle of an investigation and still get valid results.						
	15 (7%)	100 (46.9%)	41(19.2%)	39(18.3%)	17 (8%)	1 (0.5%)

3.3.4 Analysis and discussion of results for research question and objective one

3.3.4.1 The nature of science

40.8% and 40.4% of student teachers strongly agree and agree respectively that scientific knowledge is not fixed / final and is subject to change (statement 1). This indicates that 81.2 % of student teachers hold views that are consistent with post-positivism. The results of the present study are in agreement with previous research, such as that conducted by Hassan (2001:235-250), Haidar (1999:807-822) and Abd-El-Khalick, Bell and Lederman (1998:423) (i.e. that scientific knowledge is tentative).

2.3% and 2.8 % of student teachers disagree and strongly disagree that scientific knowledge is first generated through observation (statement 2). 5.1 % of student teachers therefore hold a view that is consistent with post-positivism. The majority of student teachers held conception other than post-positivist view in that scientific knowledge is only generated first through observation and scientific knowledge is derived from only scientific observations. The previous research results of Abell and Deborah (1994:475-487) agreed with present research results and indicated that most pre-service teachers had an inadequate understanding of scientific knowledge (i.e. they believe that it originates directly from observation).

Student teachers should recognise that scientific knowledge is not only derived from observations, but is also derived from a variety of experiences, all of which constitute valid scientific discoveries. Such awareness helps student teachers to consider and encourage activities (in future classroom practice) that, in turn, encourage analysis and evaluation of multiple data sources.

9.9% and 2.8% of student teachers disagree and strongly disagree respectively that scientific knowledge corresponds directly to reality (statement 3). In other words, 12.7% of student teachers hold views that are consistent with post-positivism. These findings are consistent with the previous research findings of Haidar (1999:807-822); Mellado (1997: 331-354) and Gallagher (1991:121-133). The present empirical research results showed that the majority of student teachers held opinions that were not in accordance with post-positivism; these students believe that scientific knowledge directly corresponds to reality. Student teachers should develop a more adequate understanding of the approximate nature of scientific knowledge.

1.4% and 1.9% of student teachers disagree and strongly disagree respectively that scientific knowledge increases with increasing observations in a way that is cumulative (statement 4). Only 3.3% of student teachers, therefore, held views that are consistent with post-positivism in terms of this aspect of science. The majority of student teachers views believed, contrary to the post-positivist view, that scientific knowledge increases with the number of observations made. Abell and Deborah's research results (1994:475-487) are in agreement with present research results and indicated that most of pre-service teachers had an inadequate understanding of how scientific knowledge is established. These results show that student teachers need to develop an adequate understanding on how science progresses.

Science progresses in an evolutionary and revolutionary manner, rather than a merely cumulative one.

7% of student teachers disagree that scientific knowledge attempts to be an objective account of nature (statement 5). Their views are therefore consistent with post-positivist views on this aspect of science. Student teachers' responses revealed that most student teachers held opinions that were contrary to post-positivism and consider scientific knowledge as being absolute, real, and devoid of any element of the human imagination.

Student teacher's views are consistent with post-positivist views only in terms of the tentativeness of scientific knowledge. This finding is consistent with the previous research findings of Hassan (2001:235-250) Haidar (1999:807-822) and Abd-El-Khalick, Bell, and Lederman (1998:423).

18.8 % and 61.5% of student teachers strongly agree and agree respectively that scientific observations and interpretations are influenced by the theories scientists hold to be true (statement 10). 80.3% of student teachers, therefore, hold a view that is consistent with the post-positivist view on scientific observations. The results of the present empirical study are consistent with the research findings of Hassan (2001:235-250) and Brickhouse (1990:53-62) (i.e. on scientific observations).

19.7% and 37.6% of student teachers strongly agree and agree respectively that scientists use any method to obtain the favourable results (statement 11). In other words, 57.3% of participating student teachers' views are consistent with post-positivist views on this aspect of scientific methodology. The findings of Abd-El-Khalick, Bell and Lederman (1998:424) and King (1991: 135-141) are all in agreement with the results of the present, empirical study of this aspect of science.

20.7% and 12.2% of student teachers disagree and strongly disagree respectively that scientists report data exactly as their senses perceive data (statement 12). Only 32.9% of student teachers, therefore, held views that are consistent with post-positivism. The majority of student teachers, therefore, hold views that do not reflect post-positivism and they consider that scientist's record and report data without any bias or psychological projections. The result of the present study is in agreement with the research findings of Haidar (1999:807-822) on the above aspect of science.

23.5% and 56.3% of student teachers strongly agree and agree respectively that scientists' work is influenced by many factors (statement 13). 79.8 % of student teachers' views are therefore consistent with post-positivist views on this aspect of science. The results of the present investigation are in agreement with the findings of Abd- El-Kahlick, Bell and Lederman (1998: 417-436) on this aspect of science. Although the majority of student teachers realised that scientists' work is influenced by many factors, many of them (67.1%) also failed to recognise that there are factors that might affect scientists' reporting of data (statement 12). In other words, there seems to be confusion about the factors that influence scientists' work.

12.7% and 4.7% of student teachers disagree and strongly disagree respectively that scientific claims are evaluated exclusively by an analysis of empirical evidence (statement 14). 17.4% of student teachers' views are therefore consistent with post-positivism on this aspect of science. Majority of participating student teachers views are hold conceptions other than post-positivist views. Student teachers holds views that are not consistent with post-positivist views on the above aspect of science and their views may well interfere with any laboratory work they do. Student teachers might consider that experiments conducted in the laboratory are directly related to theory

acceptance or rejection and that this approach is based on empirical evidence. Student teachers should be aware that scientific claims are evaluated by the community of scientists and are influenced by many factors, and are not entirely dependent upon empirical evidence. Theoretical factors (logical structure, accuracy, consistency, simplicity and fruitfulness), empirical evidence, experiments, and other factors such as scientist's preferences, social, political factors etc. all play an important role in evaluating scientific claims.

Only 2% and 1% of student teachers disagree and strongly disagree that scientists discover absolute laws of nature (statement 21). In other words, only 3% of student teachers hold views that are consistent with post-positivism. These results show that the majority of student teachers' views (about scientists discovering absolute scientific laws) are not consistent with post-positivism. The majority of student teachers hold views that do not reflect post-positivists' views on scientists' reporting of data, the evaluation of scientific claims and the discovery of absolute laws.

10.8% and 36.2% of student teachers strongly agree and agree respectively that old and untrue theories fit into certain paradigms that are helpful to scientists (statement 15). 47% of participating student teachers, therefore, hold views that are consistent with post-positivism on the above aspect of science. The above result is consistent with the research findings of Haidar (1999:807-822).

9.9% and 48.8% of student teachers strongly agree and agree respectively that scientists follow rational, defensible methods when deciding between competing theories (statement 16). The results of the empirical study, therefore, also showed that 58.7% of student teachers hold views that are consistent with post-positivism on the aspect of criteria in scientific methodology.

16.4% and 52.1% of student teachers strongly agree and agree respectively that a theory is validated by its connections to other theories and should be accepted within the scientific community (statement 17). 68.5% of participating student teachers, therefore, hold views that are consistent with post-positivism on the validation and acceptance of scientific theory. The research findings of Abd- El-Kahlick, Bell and Lederman (1998: 417-436) also indicated that pre-service teachers possessed an adequate understanding of the validation of scientific theories.

16% and 50.7% of student teachers strongly agree and agree respectively that the existence of various incompatible theories contributes to scientific progress (statement 18). 66.7 % of participating student teachers, therefore, hold views that are consistent with post-positivism on this aspect of science.

The above results indicate that most of the student teachers held a view consistent with post positivist views (not strongly) on several aspects of scientific theory. At the same time significant number of student teachers were undecided about their views, 29.6% of students teachers were undecided about statement 15, 27% were undecided about statement 16, 19.7% were undecided about statement 17, and 15% were undecided about statement 18. These results clearly indicate that significant numbers of student teachers are unable to decide what they think about several aspects of scientific theory. Those who, although undecided, disagree and strongly disagree with any of these statements, may or may not hold views that are consistent with post-positivism or they may simply be confused. Student teachers hold views that do not reflect post-positivist views on the role of theories in different paradigms.

15% and 7.5% of student teachers disagree and strongly disagree respectively that scientific models are copies of reality (statement 19). In other words, only 22.5% of student teachers hold views that are consistent with post-positivism's view of scientific models. The empirical results of the present study disagree with the research findings of Haidar (1999:807-822) and Abd-El-Khalick, Bell and Lederman (1998:425), which indicated that pre-service teachers had an adequate understanding of scientific models. Student teachers need to realise that scientific models are socially constructed devices, ideas or structures designed to help our understanding of, and an imperfect attempt to describe and predict scientific phenomenon. Scientific models are not copies of reality.

7% and 0.9% of student teachers disagree and strongly disagree respectively that scientific laws are absolute. 7.9 % of student teachers, therefore, hold views that are consistent with post-positivism on this aspect of scientific laws (statement 20). The majority of the student teachers, therefore, hold views that are not consistent with post-positivism on this aspect of science. The majority of student teachers failed to recognise laws as different types of statements, and failed to distinguish between laws, theories and hypotheses (based on the degree to which scientific community has accepted them). The results of Abell and Deborah's research findings (1994:475-487) also indicated that the majority of pre-service teachers had an inadequate understanding of what constituted scientific laws. Student teachers should be aware of post-positivist views on scientific laws: scientific laws are only scientists' best efforts to explain the natural world and scientific laws are therefore neither absolute nor certain and may not be induced with any degree of certainty from empirical or experimental evidence.

3.3.4.2 SCIENTIFIC METHOD

32.4% and 45.1% of student teachers strongly agree and agree that there is no universal scientific method and scientific method depends upon circumstances (statement 6). From the present empirical study, it is clear that 77.5% of student teachers hold views that are consistent with post-positivist views on this aspect of science (i.e. that scientific methods differ, depending on circumstance). These findings are in agreement with Haider's findings (1999: 807-822).

13.6% and 36.2% of student teachers strongly agree and agree respectively that scientists do not necessarily follow a fixed sequence of steps in the scientific method (statement 7). 49.8% of participating student teachers, therefore, stated that scientists do not follow a fixed sequence of steps. Overall, student teachers hold mixed views on whether scientists follow a fixed sequence of steps. The existence of alternative views on the steps involved in the scientific method might be due to the emphasis on textbook presentation, or the teacher's steps to emphasise a particular feature of scientific method during laboratory work and class discussions. The empirical results of the present study on this aspect of science agree with the findings of Abd- El- Kahlick and Lederman (2000:1057-1097) and Haidar (1999:807-822).

7% and 46.9% of student teachers strongly agree and agree respectively that scientists can adjust their method of inquiry in the middle of an investigation and still obtain valid results (statement 8). In other words, 53.9% of student teachers held post-positivist views on this aspect of science.

3.3.5 Summary of student teachers' views on the nature of science and the scientific method

3.3.5.1 Student teachers' views on the nature of science

In summary, most of the student teachers' views are strongly consistent with post-positivism's view of the tentativeness of scientific knowledge (91.2%), influence of theory on scientific observation (80.3%), and the influence of various factors on scientists' work (79.8%).

Student teachers (68.5%) possessed an adequate understanding of the validation and acceptance of scientific theory and (66.7 %) of the contribution of incompatible theories to scientific progress.

Student teachers (57.3%) also displayed a reasonable understanding of the use of different scientific methods to obtain valid results and of the (58.7%) criteria used by scientists to decide between the incompatible theories. Student teachers have mixed views (47% post –positivist) on the usefulness of old and untrue theories to science.

Student teachers held views that did not reflect post-positivism in terms of the generation of scientific knowledge, the direct correspondence of scientific knowledge to reality, and the progression of scientific knowledge. The majority of student teachers held views that did not reflect post-positivism in terms of how they saw scientists' records and reporting of data; and how they saw the evaluation of scientific claims (exclusively through an analysis of empirical evidence).

The majority of student teachers hold views other than post-positivist views and consider that scientific laws are absolute and that scientific models are copies of reality.

3.3.5.2 Summary of student teachers' views on the scientific method

The majority of student teachers (77.5%) hold views that are strongly consistent with post-positivist views on several aspects of the scientific method, such as the existence of different scientific methods (statement 6). Student teachers (53.9%) had a reasonable understanding of the possibility of adjusting scientific method in the middle of enquiry; they (49.8%) hold mixed views about the (fixed) sequence of steps followed in the scientific method.

The possible reason for existence of views other than post-positivist views on science is the interaction of formal curriculum experiences (textbooks, teachers) and informal experiences such as books, television etc. Curriculum experiences, that is, teachers and textbooks, mainly focus on content and emphasise the learning of science through the memorisation of facts and the mastery of a technical vocabulary. It is possible that these views are formed during their time spent in primary and secondary education. Their educational orientation is mostly concentrated on content and reinforced by an evaluation system. The limited understanding of student teachers of the above-mentioned aspects of science might affect both the learning and teaching of science in the classroom (Karen & Reneto 1999:110-120).

At the same time student teachers' post-positivist views on some aspects of nature of science and scientific method resulted partially from learning experiences provided through curriculum and partially come from their own experiences of learning.

3.3.6 Analysis and discussion of results for research question and objective 2

The data for objective 1.3 (b) and research question 1.4 (b), stated in chapter 1, is analysed by the statistical technique of the chi-square test (for the individual statements of observed variables). In order to perform the chi-square test, strongly agree and agree responses for each statement are combined and numbered as 1. Undecided responses are treated as another category and numbered as 2, and disagree and strongly disagree are combined and numbered as 3.

In order to facilitate the presentation, the null hypotheses are restated.

3.3.6.1 Nature of science, scientific method and gender

a) Null hypothesis 1

H₀₁: There is no association between student teachers' scores on the nature of science and gender.

TABLE 8

Chi –square values and probability based on nature of science and gender

	Statistic	Degree of freedom	Value	Probability
Statement 1	Chi-square	2	1.1411	0.5652
Statement 2	Chi-square	2	0.6520	0.7218
Statement 3	Chi-square	2	3.3712	0.1853
Statement 4	Chi-square	2	0.1093	0.9468
Statement 5	Chi-square	2	3.5617	0.1685
Statement10	Chi-square	2	5.4901	0.0642
Statement11	Chi-square	2	3.1588	0.2061
Statement12	Chi-square	2	1.2876	0.5253
Statement13	Chi-square	2	0.5097	0.7750
Statement14	Chi-square	2	2.3838	0.3036
Statement21	Chi-square	2	0.9924	0.6088
Statement15	Chi-square	2	2.2505	0.3246
Statement16	Chi-square	2	0.5969	0.7420
Statement17	Chi-square	2	4.2383	0.1201
Statement18	Chi-square	2	0.7340	0.6928
Statement19	Chi-square	2	0.4806	0.7864
Statement20	Chi-square	2	2.7900	0.2478

(Chi-square) \leq 0.05 = 5.99147

The table value of χ^2 for 2 degrees of freedom at 5% level of significance is 5.99147. The table 8 shows that, for statements about the nature of science, the calculated χ^2 value is smaller than the table value and the p -value is thus greater than 0.05. The null hypothesis is therefore accepted and there is no association between gender and student teachers' scores on all the individual items that form part of the nature science variable or factor.

b) Null hypothesis 2

H₀₂: There is no association between student teachers' scores on the scientific method and gender.

TABLE 9

Chi –square values and probability based on scientific method and gender

	Statistic	Degree of freedom	Value	Probability
Scientific method				
Statement 6	Chi-square	2	2.6370	0.2675
Statement 7	Chi-square	2	1.5525	0.4601
Statement 8	Chi-square	2	0.2464	0.8841

(Chi-square) χ^2 0.05 = 5.99147

The table value of χ^2 for 2 degrees of freedom at 5% level of significance is 5.99147. The table 9 shows that, for statements 6,7 and 8, the calculated χ^2 value is smaller than table value and the probability value is greater than 0.05. The null hypothesis is therefore accepted and there is no association between gender and student teachers' scores on all the individual items that form part of the scientific method.

3.3.6.2 The nature of science, the scientific method and type of educational institution attended

a) Null hypothesis 3

H₀₃: There is no association between student teachers' scores on the nature of science and the type of educational institution they attend.

TABLE 10

Chi- square values and probability based on the nature of science and type of educational institution attended

	Statistic	Degree of freedom	Value	Probability
Statement 1	Chi-square	2	2.9700	0.265
Statement 2	Chi-square	2	0.8013	0.6699
Statement 3	Chi-square	2	0.5210	0.7707
Statement 4	Chi-square	2	2.1168	0.3470
Statement 5	Chi-square	2	2.2221	0.3292
Statement10	Chi-square	2	7.1537	0.0280
Statement11	Chi-square	2	0.8890	0.6411
Statement12	Chi-square	2	0.9920	0.6090
Statement13	Chi-square	2	15.3266	0.0005
Statement14	Chi-square	2	0.7772	0.6780
Statement21	Chi-square	2	10.9328	0.0042
Statement15	Chi-square	2	8.9770	0.0112
Statement16	Chi-square	2	9.1379	0.0104
Statement17	Chi-square	2	6.3728	0.0413
Statement18	Chi-square	2	1.0105	0.6034
Statement19	Chi-square	2	19.2602	<. 0001
Statement20	Chi-square	2	0.0437	0.9784

(Chi-square) $\chi^2_{0.05} = 5.99147$

The table value of χ^2 for 2 degrees of freedom at 5% level of significance is 5.99147. Table 10 shows that, for statements 1, 2, 3, 4, 5, 11, 12, 14, 18 and 20 (about the nature of science), the calculated χ^2 value is smaller than the table value and the probability value is greater than 0.05. The null hypothesis is therefore accepted. In other words, there is no association between student teachers' scores on these individual statements and type of educational institution attended.

For statements 10, 13, 21, 15, 16, 17 and 19 the calculated χ^2 value is greater than the table value and the probability value is smaller than 0.05. At 95% level of confidence, therefore, there is an association between student teachers, scores on these individual statements and type of educational institution attended.

b) Null hypothesis 4

H₀₄: There is no association between student teachers, scores on the scientific method and type of educational institution they attend.

TABLE 11

Chi-square values and probability based on the scientific method and type of institution attended

	Statistic	Degree of freedom	Value	Probability
Scientific method				
Statement 6	Chi-square	2	0.7632	0.6828
Statement 7	Chi-square	2	1.5885	0.4519
Statement 8	Chi-square	2	6.0261	0.0491

(Chi-square) $\chi^2_{0.05} = 5.99147$

Table 11 shows that, for statement 8, the calculated χ^2 value is greater than the table value and the probability value is smaller than 0.05. At 95 % level of confidence, therefore, there is an association between the score for this statement and type of institution attended.

For statements 6 and 7, the calculated χ^2 value is smaller than the table value and the probability value is greater than 0.05. In other words, there is no association between the scores for these statements and type of educational institution attended.

3.3.6.3 The nature of science, the scientific method and years spent in studying

a) Null hypothesis 5

H₀₅: There is no association between student teachers' scores on the nature of science and years spent in studying.

TABLE 12

Chi-square values and probability based on the nature of science and years spent in studying

	Statistic	Degree of freedom	Value	Probability
Statement 1	Chi-square	4	7.4160	0.1155
Statement 2	Chi-square	4	12.2539	0.0156
Statement 3	Chi-square	4	6.3731	0.1730
Statement 4	Chi-square	4	3.5160	0.4754
Statement 5	Chi-square	4	6.7724	0.1484
Statement10	Chi-square	4	4.5807	0.3331
Statement11	Chi-square	4	18.7594	0.0009
Statement12	Chi-square	4	9.1516	0.0574
Statement13	Chi-square	4	8.9671	0.0619
Statement14	Chi-square	4	3.8507	0.4266
Statement21	Chi-square	4	1.5740	0.8135
Statement15	Chi-square	4	2.4196	0.6591
Statement16	Chi-square	4	7.5190	0.1109
Statement17	Chi-square	4	2.9767	0.5617
Statement18	Chi-square	4	1.5654	0.8150
Statement19	Chi-square	4	10.8545	0.0282
Statement20	Chi-square	4	8.0784	0.0887

(Chi-square)_{0.05} = 9.48773

The table value of χ^2 for 4 degrees of freedom at 5% level of significance is 9.48773. Table 12 shows that, for statements 2, 11 and 19, the calculated χ^2 value is greater than the table value and the probability value is smaller than 0.05. At 95% level of confidence, therefore, there is an association between the scores for these individual statements and the years spent in studying.

For statements 1,3,4, 5,10, 12, 13,14,21,15,16,17,18 and 20, the calculated χ^2 value is smaller than the table value and the probability value is greater than 0.05. There is no association, therefore, between the scores of these individual statements and the years spent in studying.

b) Null hypothesis 6

H₀₆: There is no association between student teachers' scores on the scientific method and the years spent in studying.

TABLE 13

Chi-square values, probabilities based on the scientific method and years spent in studying

	Statistic	Degree of freedom	Value	Probability
Scientific method				
Statement 6	Chi-square	4	1.7720	0.7776
Statement 7	Chi-square	4	14.0142	0.0072
Statement 8	Chi-square	4	12.1385	0.0164

(Chi-square) $\chi^2_{0.05} = 9.48773$

The table value of χ^2 for 4 degrees of freedom at 5% level of significance is 9.48773. Table 13 shows that, for statements 7 and 8, the calculated χ^2 value is greater than the table value and the probability value is smaller than 0.05. At 95 % level of confidence, therefore, there is an association between the scores for this statement and the years spent in studying.

Table 13 shows that, for statement 6, the calculated χ^2 value is smaller than the table value and the probability value is greater than 0.05. In other words, there is no association between the scores for these statements and the years spent in studying.

3.3.6.4 The nature of science, the scientific method and science as a major / minor teaching subject

a) Null hypothesis 7

H₀₇: There is no association between student teachers' scores on the nature of science and whether student teachers are offering science as a major or minor teaching subject.

TABLE 14

Chi-square values and probabilities based on the nature of science and science as a major / minor teaching subject

	Statistic	Degree of freedom	Value	Probability
Statement 1	Chi-square	2	3.6289	0.1629
Statement 2	Chi-square	2	0.4004	0.8186
Statement 3	Chi-square	2	6.7309	0.0345
Statement 4	Chi-square	2	1.4547	0.4832
Statement 5	Chi-square	2	1.9714	0.3732
Statement10	Chi-square	2	4.5332	0.1037
Statement11	Chi-square	2	2.0034	0.3673
Statement12	Chi-square	2	1.6811	0.4315
Statement13	Chi-square	2	3.8084	0.1489
Statement14	Chi-square	2	3.9164	0.1411
Statement21	Chi-square	2	0.4473	0.7996
Statement15	Chi-square	2	0.4631	0.7933
Statement16	Chi-square	2	3.9663	0.1376
Statement17	Chi-square	2	3.4795	0.1756
Statement18	Chi-square	2	4.4743	0.1068
Statement19	Chi-square	2	11.8411	0.0027
Statement20	Chi-square	2	3.0404	0.2187

(Chi-square) $\geq 0.05 = 5.99147$

The table value of χ^2 for 2 degrees of freedom at 5% level of significance is 5.99147. Table 14 shows that, for statements 3 and 19, the calculated χ^2 value is greater than the table value. The probability value is smaller than 0.05. At 95% level of confidence, therefore, there is an association between the scores for these two individual statements and whether student teachers are offering science as a major or minor teaching subject.

For statements 1, 2, 4, 5, 10, 11, 12, 13, 14, 21, 15, 16, 17, 18 and 20, the calculated χ^2 value is smaller than the table value. The probability value is greater than 0.05. There is therefore no association between the scores for these individual statements and whether student teachers are offering science as a major or minor teaching subject.

b) Null hypothesis 8

H₀₈: There is no association between student teachers' scores on the scientific method and whether student teachers are offering science as a major or minor teaching subject.

TABLE 15
Chi-square values and probabilities based on the scientific method and science as a major/ minor teaching subject

	Statistic	Degree of freedom	Value	Probability
Scientific method				
Statement 6	Chi-square	2	3.4003	0.1827
Statement 7	Chi-square	2	4.3110	0.1158
Statement 8	Chi-square	2	4.5174	0.1045

(Chi-square) $\chi^2_{0.05} = 5.99147$

Table 15 shows that, for statements 6,7 and 8, the calculated χ^2 value is smaller than the table value and the probability value is greater than 0.05. There is therefore no association between the scores for these statements and whether student teachers are offering science as a major or minor teaching subject.

The above results indicate that student teachers' scores on the nature of science and the scientific method are not associated with gender. At this point it is important to note that more male student teachers responded to the questionnaire. Student teachers' scores on some of the statements (7 statements about the nature of science show more association with the type of educational institute attended than with other variables (e.g. years spent in studying). This supports King's (1991:135-141) research, that is, that the learning environment plays an important role in determining student teachers' understanding of the nature of science. As discussed in chapter 2, paragraph 2.2.5, the learning environment in formal education is influenced by many factors - for example, the personal knowledge of those doing the training, physical factors, curricular factors, learning experiences, opportunities to participate in classroom activities etc.

Student teachers' scores for some of the nature of statements (3 statements) showed association with years spent in studying and also scores of 2 nature of science statements showed association with student teachers major and minor teaching subjects. This indicates that the learning environment has more influence than the length of the exposure to classroom activities. There is no clear pattern is evident about association of certain statements with variables such as type of educational institute, years of study and science major and minor subject. However it is important to note that statement on scientific models (statement 19) showed association with 3 of the variables such type of educational institution, years spent in studying and science major and minor subject.

Scores of 1 statement of scientific method (out of 3 statements) showed association with type of educational institution, and 2 statements of scientific method (out of 3 statements) showed association with years spent in studying. At this point it is important to note that there is no association scores of scientific method statements and student teachers major / minor teaching subject. It indicates (although not clearly) the validity of Gustafson and Rowell's (1995: 589-605) finding, that is, that length of exposure to classroom activities has a certain influence on student teachers understanding.

3.3.7 Summary of results based on research question 2

The table 16 shows summary of the results based on research question 2

TABLE 16

Probability values smaller than 0.05 (S= statement)

Factor	Type of Institution	Year spent in studying	Science major/ minor teaching subject	Gender
Nature of science	Statement10=0.028 S13=0.0005 S21=0.0015 S15=0.0112, S16=0.0104 S17=0.0413 S19=0.0001	S2=0.0156 S11=0.0009 S19=0.0282	S3=0.0345 S19=0.0027	-
Scientific method	S8=0.0491	S7=0.0072 S8=0.0164	-	-

3.3.7.1 The nature of science, the scientific method and gender

Table 16 shows that there is no association between student teachers' scores on the nature of science for any of the individual statements, and gender at 5% level of significance. The same holds true for the association between the individual statements of scientific method and gender.

3.3.7.2 The nature of science, the scientific method and type of institution attended

Table 16 shows that the scores for the nature of science statements 10, 13, 21, 15, 16, 17, and 19 reflect an association with the type of institution attended at 5% level of significance (7 out of 17 statements).

Table 16 shows that the scores of only 1 scientific method statement (statement 8) show association with type of educational institution. The conclusion drawn, there appears to be no association between student teachers' scores for statements about the scientific method and the type of institution attended at 5% level of significance.

3.3.7.3 The nature of science, the scientific method and years spent in studying

Table 16 also shows that the scores for statements 2, 11 and 19 (nature of science statements) reflect an association with years spent in studying at 5% level of significance (3 out of 17 statements).

Table 16 shows that the scores of 2 scientific method statements 7 and 8 reflect an association with years spent in studying at 5% level of significance (2 out of 3 statements).

3.3.7.4 The nature of science, the scientific method and whether science is offered as a major or minor teaching subject

Table 16 shows that scores for nature of science statements 3 and 19 reflect an association with whether science is offered as a major or minor teaching subject at 5% level of significance (2 out of 17 statements).

There is no association between the individual statements of scientific method and whether student teachers offer science as a major or minor teaching subject.

3.4 SUMMARY OF CHAPTER 3

In this chapter, section 3.2 dealt with the research design and methodology. Section 3.3 handled the results of the empirical study and analysed as well as discussed such results in relation to objectives and the research questions. From the results presented in this chapter, the conclusions of research findings from literature and the current empirical study will be discussed in chapter four. The implications, suggestions and recommendations for further study will be outlined in chapter four.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

The development of the science learner's adequate understanding of the nature of science and the scientific method is recognised as a principal objective of science education at all levels. Many previous research studies reported that science learners do not have an adequate understanding of the nature of science and the scientific method. In order to find the reasons for science learners' inadequate understanding of science, researchers focused on the science curriculum and how this curriculum, in turn, is influenced by teachers' understanding of the nature of science and the scientific method. Many researchers have indicated that teachers do not have an adequate understanding of the nature of science and the scientific method. This observation may imply that teachers were not properly prepared in their training and thus there has been a great deal of interest on whether teacher training programmes provide student teachers with an adequate understanding of the nature of science and scientific method. The assumptions of the present study, therefore, are that student teachers should acquire an adequate understanding of the nature of science and the scientific method during their professional training.

Student teachers need to have an adequate understanding of how science operates and proceeds, and how the scientific community decides what to accept or reject on scientific claims. Post-positivist views on the nature of science and the scientific method provide us with valid views on the nature of science and the scientific method. Therefore, student teachers with an understanding of post-positivist or non-traditional views of the

nature of science and the scientific method might contribute to successful science learning from teacher training courses and it is hoped that would contribute to future teaching practices.

Teacher preparation programmes should help prospective teachers to develop an understanding of the nature of science and the scientific method. The purpose of this research, therefore, was to find out student teachers' views on the nature of science and the scientific method.

In the previous chapter, the research methodology was explained, and the results were presented, analysed and discussed. This chapter presents a summary of the research findings, and gives conclusions based on the literature review and on the results of this empirical study. This chapter also presents the implications of the present study and puts forward recommendations to improve student teachers' understanding on the nature of science and the scientific method. This chapter also discusses possibilities for further research.

4.2 SUMMARY OF THE RESEARCH

The present study was based on previous findings in the literature that teachers are not adequately trained in the nature of science and the scientific method. This, in turn, means that teachers often lack the necessary preparation and confidence to teach science. A literature review was done in relation to pre-service teachers' views on the nature of science and the scientific method. The literature study also included discussions on factors that might help student teachers gain an adequate understanding of the nature of science and the scientific method.

An empirical investigation was carried out to find out student teachers' views of the nature of science and the scientific method. In addition, this study aimed at finding out if there is an association between student teachers' scores on the nature of science and the scientific method and variables such as gender, type of educational institution attended, years spent in studying and whether student teachers are offering science as a major or minor teaching subject.

The following section of this chapter presents the conclusions drawn from the literature review.

4.2.1 Conclusions from the literature review

An extensive review of the literature was done in chapter 2. There is a definite lack of research studies on student teachers' understanding of the nature of science and the scientific method as far as student teachers in Botswana are concerned because the consulted sources were mainly on literature about other countries than Botswana.

Consequently, pre-service teachers' views in this research were on the nature of science and the scientific method that were conducted in other countries. The aim of these studies is to investigate, methodically, student teachers' understanding of the nature of science and the scientific method in order to improve their understanding of these aspects of science. From the literature reviewed, the variables that constitute the nature of science were identified. The observed variables such as scientific observations, scientific theories, scientific laws, scientific models, scientific knowledge and the nature of scientists' work constitute the latent factor, that is, the nature of science. However in the present study it was not possible to combine scores of different observed variables together as a score towards nature of science due to low cronbach coefficient alpha values.

An analysis of the previous research showed mixed results (reviewed in section 2.2.1). Some of the research studies indicated that pre-service teachers had an adequate understanding whereas others reported that student teachers had an inadequate understanding of what constituted scientific observations, scientific theories, scientific laws, scientific knowledge and the nature of scientists' work. Previous research reports showed that pre-service teachers had an adequate understanding of what constituted scientific models.

Some of the research studies indicated that pre-service teachers had an adequate understanding, and others reported that they had an inadequate understanding of the scientific method (reviewed in section 2.2.2).

Previous research studies reviewed mainly concentrated on elementary, primary and secondary pre-service teachers. The literature reviewed indicated that some of the previous investigations reported that elementary, primary and secondary pre-service teachers do not have an adequate understanding and others reported that they do have an adequate understanding of the nature of science and the scientific method. The previous assessment of student teachers' views on the nature of science and the scientific method was carried out with variety of instruments and at different stages of teacher training courses. Despite the fact that various research instruments were used, previous research reports contradicted each other on the whether pre-service teachers understood the nature of science and the scientific method. There is no obvious pattern emerged to show pre-service teachers' adequate understanding related to their academic backgrounds (reviewed in section 2.2.4).

The main reason for divergence in pre-service teachers' views that has been identified is the different curricular emphasis on science in the various types of teacher training courses. The specific content to be included in science courses, learning experiences provided, methods/ strategies of the

instruction, is different in various types teacher-training courses. From the literature reviewed, it was evident that many previous researchers felt that pre-service teachers inadequate understanding on the nature of science and scientific method is due to a lack of curricular emphasis. Many previous investigations, therefore, recommended the inclusion of history, sociology and philosophy of science in the teacher-training curriculum. Some previous research was conducted on the above lines and reported that pre-service teachers still had an inadequate understanding of what constituted science. They indicated that courses in, for example, the history of science may well not improve pre-service teachers understanding and recommended that direct training on the nature of science might contribute more to solving the problem. However, some previous researchers reported that including courses in the history of science in the curriculum improved pre-service teachers' understanding of science.

Reviewed literature also indicated that some previous studies reported that there are moderate changes in pre-service teachers views as result of direct instruction on the nature of science. These researchers also felt that the reason for these moderate changes is that pre-service teachers had alternative views and misconceptions about the nature of science and the scientific method as a result of previous learning experiences. The above researchers felt that short duration of direct instruction is not enough to change pre-service teachers alternative /misconceptions on nature of science and scientific method. Therefore, they expect great changes might results in pre-service teachers understanding due to lengthy exposure of activities on nature of science aspects. Some research studies suggested that the learning environment might contribute to pre-service teachers acquiring an adequate understanding of the nature of science and the scientific method.

From the literature review it is evident that there is no clear pattern about what does, and what does not, contribute to student teachers' understanding of what constitutes nature of science. This topic obviously requires more investigation. From the literature, the present study also identified the different factors such as student teachers studying in different institutions (learning environment), years spent in studying, gender, and student teachers choice of science as major teaching subject and minor teaching subject might contribute to their adequate understanding.

4.2.2 Conclusions based on the present empirical research

The first objective of this study was to find out student teachers' views on what constituted the nature of science and the scientific method. The results of the statistical analysis for the first objective are presented in chapter 3, section 3.3.4. The following conclusions have been drawn from the results of this analysis.

4.2.2.1 Student teachers' views on the nature of science and the scientific method

a) The nature of science

- Student teachers views are strongly consistent with post-positivist views on the tentative nature of scientific knowledge (statement 1), the nature of scientific observations (statement 10) and the factors influencing scientists' work (statement 13).
- Student teachers showed an adequate understanding of how scientists validate scientific theories (statement 17) and how incompatible theories contribute to scientific progress (statement 18).

- Student teachers showed a reasonable understanding of scientists' use of several methods to obtain results (statement 11), and the criteria used by scientists to decide between competing theories (statement 16).
- Student teachers' views are consistent with post-positivism only on the above aspects of science. Student teachers possessed different views from post-positivists on the generation of scientific knowledge, on the correspondence of scientific knowledge to reality, on the progress of scientific knowledge, on the recording and reporting of data by scientists, on the evaluation of scientific claims, on whether scientists discover absolute laws of nature, and on the status of scientific laws and scientific models.

In short, student teachers showed an adequate understanding of some aspects of science and inadequate understanding of others.

b) The scientific method

Student teachers' views are strongly consistent with post-positivists on the use of the range of scientific method depend upon the context of enquiry (statement 6) and displayed adequate understanding on adjustment of scientific method in the middle of enquiry (statement 8).

Student teachers therefore displayed an adequate understanding of the scientific method, apart from the step-by-step aspect of the scientific method.

4.2.2.2 Association of student teachers views on the nature of science, the scientific method with gender, type of educational institution, year of study and whether science is being offered as a major or minor teaching subject

Objective 2 and research question 2 focused on the association between student teachers' scores on the nature of science and the scientific method and variables such as gender, type of institution attended, years spent in studying and whether science was being offered as a major or minor subject. The proposed hypotheses were subject to test. The results of the statistical analysis for objective 2 and research question 2 were presented in chapter 3, paragraph 3.35. From these results, the following conclusions are drawn.

- At 5% level of significance, there is no association between student teachers' scores on the each of the individual statements of the nature of science and gender. The same holds for scientific method.
- At 5% level of significance, there is an association between scores relating to the nature of science statements (10, 13,21,15,16,17,and 19) and the type of educational institution attended (7 out of 17).
- At 5% level of significance, there is an association between the score relating to the scientific method, statement 8, (1 out of 3 statement) and the type of educational institute attended. The conclusion, therefore, is that there appears to be no association between student teachers' scores on scientific method and the type of educational institution attended.

- At 5% level of significance, there is an association between the scores relating to the nature of science, statements 2,11 and 19, and years spent in studying (3 out of 17).
- At 5% level of significance, there is an association between the scores relating to the scientific method, statements 7 and 8 (2 out of 3 statements), and the years spent in studying. The conclusion, therefore, is that there appears to be some association between the scientific method and the years spent in studying.
- At 5% level of significance, there is an association between the scores relating to the nature of science statements, 3 and 19 and whether student teachers are offering science as a major or minor teaching subject (2 out of 17).
- At 5% level of significance, there is no association between the individual statements for scientific method and whether student teachers are offering science as a major or minor teaching subject.

The conclusion therefore is that student teachers scores' on nature of science statements were more associated with the type of educational institution attended, followed by years spent in studying and whether student teachers fell into the major or minor group. Scores on scientific method statements were more associated with variable years spent in studying, followed by type of educational institution.

4.3 IMPLICATIONS AND RECOMMENDATIONS FOR IMPROVING STUDENT TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE AND THE SCIENTIFIC METHOD

Many researchers reported that an inadequate training of teachers on the nature of science and the scientific method is major constraint in attaining the objective of science education (i.e. developing, in learners, an adequate understanding of what constitutes the nature of science). The present study shows that student teachers displayed an adequate understanding on only some aspects of the nature of science and displayed an adequate understanding of several aspects of the scientific method. The present empirical study also indicated that they showed an inadequate understanding of several aspects of the nature of science.

The professional development of student science teachers is, therefore, an important issue that needs to be addressed. Based on the findings of the present study, suggestions and recommendations are put forward to improve student teachers' understanding of science in the following paragraphs. Therefore, in the following paragraphs, the need to improve the professional preparation of student teachers (pre-service teachers) is addressed.

4.3.1 The implications of, and recommendations for, future curricular development in teacher education

As said earlier in chapter 2 section 2.2.4, science curriculum plays vital role in developing adequate understanding of the nature of science and scientific method. It was also indicated that the curriculum of secondary education student teachers consists professional studies and content component. Post-positivist views of the nature of science and scientific method are conveyed to student teachers explicitly and implicitly by professional studies and content components (Presented in chapter 3, section 3.2.3.2). The results of present study highlight the importance of evaluating and reviewing curriculum i.e. content and professional studies component with regard to the nature of science and scientific method. All prospective science teachers should have ample opportunities to study modern aspects of science, including the most recent developments in scientific theory and conceptual schemes. Student teachers should have an opportunity to acquire a comprehensive knowledge and understanding of the nature of science and the scientific method. The developers of the teacher-training curriculum should emphasise a post-positivist understanding of what constitutes the nature of science. This requires in-depth studies in the history, philosophy and sociology of science. Knowledge of the history, philosophy and sociology of science will facilitate student teachers' in-depth understanding of science.

Although, at present professional studies component and science subject matter enhances the understanding on the nature of science and scientific method but it is not an alternative for instruction in philosophy, sociology and history of science. The nature of science concepts should therefore be given equal status along side the content of science and the teacher education curriculum should reflect these subjects.

Curriculum developers should identify and prioritise those topics that improve student teachers' understanding of the nature of science and the scientific method. Learning experiences that improve student teachers' understanding of the nature of science should be identified and included in the curriculum. Instructional method/ strategies that promote student teachers' understanding of the nature of science and the scientific method should be identified and included in the curriculum.

4.3.2 Suggestions and recommendations to teacher trainers

Firstly, the result of the present study suggest that science educators can't simply assume that a content and professional studies course is sufficient to help student teachers to develop the desired understanding of the nature of science and the scientific method. Teacher trainers/educators should have planned opportunities to teach the nature of science and the scientific method. Student teachers should be explicitly taught about the nature of science and the scientific method in the context of science and science education courses.

Secondly, teacher educators or trainers themselves should have an adequate understanding of the nature of science and the scientific method and should know how to teach the nature of science and the scientific method. Teacher trainers/ educators should give extensive training in teaching and in addressing the nature of science and the scientific method. The rationale behind this in-service training on the nature of science and the scientific method is to equip teacher trainers/educators with the knowledge and skills necessary to deal with the nature of science and scientific methods. The teacher trainer should be able to present various alternative views on the nature of science and the scientific method.

Thirdly, teacher trainer/ educators should provide diverse learning experiences that might carry realistic views of science and promote adequate understanding of nature of science and scientific method. Such learning experiences might be provided during the training period, followed by special workshops. Teacher educators should identify instructional strategies to teach the nature of science and scientific method.

Fourthly, teacher trainers should provide student teachers with the opportunity to reflect on their conceptions (after getting involved in various science experiences) and to become aware of their ideas. Teacher trainers should explicitly attempt to change misconceptions. Teacher trainers should also challenge pre-service teachers' ideas by providing them with learning experiences that compare their ideas with post-positivist views of education.

The results of the present study showed that student teachers' scores on several natures of science statements are associated with the type of institution attended. This clearly indicates the influence of the learning environment, that is, teaching methods, designing, organising and conducting learning experiences, teaching styles, clarity of instruction and provision of direction and feedback all influence the degree to which pre-service teachers come to have an adequate understanding of what constitutes the nature of science.

Fifthly, teacher trainers themselves help student teachers to develop an adequate understanding of the nature of science and the scientific method, and teach them the skills needed to teach these central aspects of science.

4.4 LIMITATIONS OF THE PRESENT STUDY

The present investigation studied student teachers' views on the nature of science and the scientific method. This present investigation, hopefully, contributes positively toward pre-service teacher science education in Botswana. It is important to note that this study had certain limitations.

The sample of the present study included all the science student teachers of Secondary Colleges of Education. The results of the present study should therefore be generalised to student teachers of Secondary Colleges of Education. Data collection was done by quantitative methods (questionnaires). Although questionnaires are useful in yielding data, they can produce a "halo" effect. The cronbach alpha was low for observed variables especially for scientists' work and the scientific method. Low cronbach values might indicate student teachers lack of proper understanding on the statements or statements measured multidimensional construct. Therefore, the questionnaire should be revised if necessary, for future studies.

4.5 FURTHER RESEARCH

The present study opens up avenues for future research.

The replication of present research is needed to establish the validity of the present findings. The present study utilised the quantitative data collection method. Future research should include qualitative data collection instruments such as interviews, observations etc.

Research is required on the science curriculum, to identify and include those factors that improve student teachers' understanding of the nature of science and the scientific method. Aspects such as the inclusion of particular topics, learning experience, methods and strategies that promote student teachers understanding on the nature of science and scientific method should all be investigated. Further research is also needed to evaluate the curriculum at all levels: junior secondary, senior secondary and teacher training.

Present research results indicated that student teachers' views on the nature of science statements are associated with the institution they attend. Further research is therefore required to identify institutionalised factors that either promote or hinder student teachers' understanding of what constitutes nature of science. The results also indicated scores of scientific method statements associated with years of study (duration). Further investigation also required how the duration of study gradually improves student teachers understanding.

Further research is needed on student teachers translation of their views into classroom teaching practices. Follow up research is also needed on whether student teachers' views remain consistent after training and during the in-service period.

The present research only dealt with Secondary College of Education student teachers. A comparative research is essential, and needs to take into consideration Secondary student teachers who are trained in Colleges of Education and those who are trained at universities.

Research is also needed into primary student teachers' views of the nature of science and the scientific method. A comparative research is also required between primary student teachers and secondary student teachers understanding of the nature of science and the scientific method.

The present study also suggests ways to investigate in- service teacher's views on the nature of science and the scientific method, given the dearth of studies on teachers' views in Botswana's educational context. The present study recommends the investigation into junior and senior secondary students' views on the nature of science and the scientific method.

Further research is also needed on teacher trainers' views of the nature of science and the scientific method and how teacher trainers' views are translated into classroom practice. Research is also needed to investigate the influence of different factors such as curriculum constraints, administrative policies and supplies etc while the philosophies of teacher trainers are being translated into actual classroom practice. Research is also needed on how the teachers views influences, the science learners understanding on the nature of science and scientific method.

4.6 SUMMARY OF CHAPTER 4

The objective of science education is to develop the science learner's understanding of the nature of science and the scientific method. In a country's educational system, the quality of education depends upon the quality of teacher preparation. Student teachers should therefore acquire an adequate understanding and the skills necessary to achieve the objective of science education.

The present study investigated student teachers' understanding of the nature of science and the scientific method. The results revealed that student teachers had an adequate understanding of only some aspects of the nature of science. Student teachers had an adequate understanding of several aspects of the scientific method.

The present study also revealed those student teachers' scores of some statements on nature of science is closely associated with the type of institution they attend and the years spent in studying rather than fact that they are offering science as a major or minor subject. Score of some scientific method statements associated with years spent in studying. It also reveals that there is no association between student teachers' scores on the nature of science, the scientific method and gender.

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APPENDIX A
QUESTIONNAIRE TO STUDENT
TEACHERS

Dear Respondents,

I am a student of the University of South Africa, doing MEd research on the nature of science and the scientific method. I am seeking your cooperation and ask you to answer all the questions asked in the questionnaire. I greatly appreciate your participation in this study. Please complete the questionnaire and return it to the Head of the Science Department. Your responses will be kept confidential.

Thank you in advance for your cooperation.

Instructions to respondents:

The Questionnaire consists of two parts. Part 1 contains Profile / biographical data. Part 2 contains questions on the nature of science and the scientific method. Please follow the instructions given.

QUESTIONNAIRE

THE NATURE OF SCIENCE AND SCIENTIFIC METHOD

PART 1: Profile / Biographical Data

Instructions: Please tick () appropriate box and write responses on the space provided.

•

1. **Sex:** Female Male

2. **Name of the institute:** TCE MCE

3. **Year of Study:** 1st Year 2nd Year 3rd Year

4. **Group:**

a) **Science Major:** Yes No

If you tick yes, indicate Your Minor Subject.....

b) **Science Minor:** Yes No

If you tick yes, indicate your Major subject.....

PART II

Instructions: Read the statements carefully and tick appropriate box that indicates your opinion.

KEY: Strongly Agree (SA), Agree (A), Undecided (UN), Disagree (DA) & Strongly Disagree (SDA).

1. **Scientific knowledge is not fixed /final and is subject to change (Tentative in Nature).**

SA	A	UN	DA	SDA
----	---	----	----	-----

2. **Scientific knowledge is generated first through observation.**

SA	A	UN	DA	SDA
----	---	----	----	-----

3. **Scientific knowledge corresponds directly to reality.**

SA	A	UN	DA	SDA
----	---	----	----	-----

4. **Scientific knowledge increases with increasing observations.**

SA	A	UN	DA	SDA
----	---	----	----	-----

5. Scientific knowledge attempts to be an objective account of nature.

SA	A	UN	DA	SDA
----	---	----	----	-----

6. There is no single universal scientific method. The scientific method is different based on particular circumstances.

SA	A	UN	DA	SDA
----	---	----	----	-----

7. Scientists do not necessarily have to follow fixed sequence of steps in the scientific method.

SA	A	UN	DA	SDA
----	---	----	----	-----

8. Scientists can adjust their method of inquiry in the middle of an investigation and still get valid results.

SA	A	UN	DA	SDA
----	---	----	----	-----

9. The existence of various scientific methods is fruitful for scientific progress.

SA	A	UN	DA	SDA
----	---	----	----	-----

10. Observation and interpretation of observations are influenced by theories scientists hold.

SA	A	UN	DA	SDA
----	---	----	----	-----

11. The best scientists are those who use any method that might obtain favourable results.

SA	A	UN	DA	SDA
----	---	----	----	-----

12. Scientists report data exactly as their senses perceive them.

SA	A	UN	DA	SDA
----	---	----	----	-----

13. Scientists work (i.e. observations, selection of data and hypothesis etc) some times is influenced by many factors e.g.: previous knowledge, logic and social factors.

SA	A	UN	DA	SDA
----	---	----	----	-----

14. Scientists evaluate scientific claims exclusively through analysis of empirical evidence.

SA	A	UN	DA	SDA
----	---	----	----	-----

15. Theories fit within certain paradigms; hence if they are old or untrue they are helpful to scientists.

SA	A	UN	DA	SDA
----	---	----	----	-----

16. When there are competing theories and scientists want to decide between them there are rational defensible ways of doing so.

SA	A	UN	DA	SDA
----	---	----	----	-----

17. A theory is validated by its connections to other theories, generally accepted within the scientific community.

SA	A	UN	DA	SDA
----	---	----	----	-----

18. The existence of various incompatible theories is fruitful for scientific progress.

SA	A	UN	DA	SDA
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19. Scientific models are copies of reality, since they describe reality as it is.

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20. Scientific laws can be proven to be absolutely true.

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21. Scientists strive to discover the absolute laws of Nature.

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