

**PRE-SERVICE SCIENCE EDUCATION STUDENTS' EPISTEMOLOGICAL BELIEFS ABOUT THE NATURE OF
SCIENCE AND SCIENCE TEACHING AND LEARNING**

BY

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DECLARATION

I, Nkosinathi Hezekia Ngwenya, hereby declare that “**Pre-service science education students’ epistemological beliefs about the Nature of science and science teaching and learning**” is my own investigation except for the work indicated in the references, and comments included in the text.

SIGNATURE

DATE

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ABSTRACT

This study set out to investigate beliefs held by pre service Bachelor of Education (B.Ed) students about the nature of science and science teaching and learning. The research sample comprised one hundred and eighty four (184) third and fourth year (B.Ed) students majoring in mathematics and physical sciences. Data on students' epistemological beliefs about the nature of science and science teaching and Learning were collected using two questionnaires: The Nature of Science as Argument Questionnaire (NSAAQ) and Beliefs About Reformed Science Teaching and Learning (BARSTL). Furthermore the study sought to find out if those beliefs cohered with the beliefs espoused by the National Curriculum Statement (NCS) for Physical Sciences grades 10-12.

The conceptual framework of this study was framed upon the preponderance of literature that carried the view that a teacher's classroom practices are a consequence of two main dialectic influences: (a) the teacher's epistemological beliefs about the nature of science, which may be either naïve or sophisticated; and (b) the teacher's beliefs about teaching and learning, which may be either traditional or reformed. Accordingly, the conceptual framework guiding the study opined that teachers holding naïve beliefs about the nature of science, and those holding traditional notions of teaching and learning will be characterized by teacher-centred instructional approaches, while those holding sophisticated beliefs of the nature of science and a reformed view of teaching and learning will be associated with learner-centred instructional approaches.

This study was a case study conducted at a South African university, and involved one hundred and eighty-four third and fourth year students registered for a four-year Bachelor of Education (B.Ed) degree for the Senior and Further Education and Training phase. During these two final years of the programme students are engaged in science enquiry practices in their Methods modules. The participants were registered in physical science and mathematics education. Intact groups were used, so there was no sampling undertaken to select participants. Data were collected by the use of (a) the Nature of Science as Argument Questionnaire (NSAAQ), to determine epistemological beliefs held by the participants about the nature of science, as well as the concurrence of those beliefs with the views about

science teaching and learning espoused by the NCS; and (b) the Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire, to determine the beliefs held by pre-service education students about science teaching and learning. Data analysis involved the use of both descriptive statistical methods to decipher patterns and general trends regarding the epistemological beliefs about science held by participants, and their beliefs about science teaching and learning, as well as inferential statistics to test both *a priori* and *a posteriori* hypotheses. Similarly, statistical analysis was carried out to determine whether or not third- and fourth-year pre-service science education students held beliefs about science teaching and learning that were in agreement with the pedagogical content beliefs about science teaching and learning espoused by the NCS.

The study found that pre service students held significantly more sophisticated epistemological beliefs about the nature of science at fourth year than at third year level. The results also showed that fourth year students demonstrated a significantly higher level of 'reformed oriented teaching and learning beliefs' about science than did the third year students. The results however showed that third and fourth year students held beliefs that were not in line with the beliefs espoused by the National Curriculum Statement (NCS). These results support studies which have found that student teachers become more sophisticated in their epistemological beliefs towards graduation. The findings also showed that the B.Ed programme is succeeding in developing both epistemological beliefs about the nature of science and teaching and learning. The degree to which the programme succeeded in developing these beliefs was however quite small. This study recommends that further investigations be done to determine whether students who hold sophisticated epistemological beliefs about the nature of science and 'reformed beliefs about science teaching and learning' also demonstrate superior science teaching skills.

DEDICATION

I would like to dedicate this work to my late parents who, despite their limited formal education, were always a big source of inspiration to me during the earlier years of my educational endeavours. I am certain that if they were still alive today they would have been very happy for me about this small achievement. I dedicate this work to you, Ntombi kaMbefuli and Mfo kanoNongxavu.

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CHAPTER ONE

BACKGROUND OF THE STUDY

1.1 INTRODUCTION

“Teachers are expected to play a crucial role in changing schools and classrooms. Paradoxically, however, they are also viewed as major obstacles to change due to their traditional beliefs.” (Prawat, in Savasci-Acikalin, 2009:5).

Many studies on teacher beliefs over the past few decades have, according to Savasci-Acikalan (2009), focused on beliefs in a variety of contexts such as constructivism; curriculum; the goals of science education; the nature of science; science, technology and society, as well as on various reform strands. However, a number of studies on beliefs have sought to understand teacher beliefs in relation to their classroom practices with a view to improving the structure and impact of teacher education programmes (Mahmood, 2007; Tsai, 2000). Researchers have, for example, wanted to know how teachers’ beliefs inform their instructional decisions as well as classroom management. Mahmood (2007) opines that beliefs influence the manner in which the teacher decides on his/her teaching objectives, plans a lesson and evaluates learning in the classroom.

Pajares (1992) argues that beliefs are the best indicators of the decisions that individuals make throughout their lives. Accordingly, teachers’ beliefs play a major role in teachers’ decision-making about the curriculum and instructional tasks.

Luft and Roehrig (2007) report that there is a growing body of research on beliefs in science education, where beliefs linked to the use of enquiry, national reforms, or constructivist practices in the classroom are being studied. However, Millwood and Sandoval (2006) believe that too little is known of students’ beliefs about the epistemological aspects of school science and how these beliefs relate to their beliefs about professional science.

Luft and Roehrig (2007) argue that understanding the beliefs of science teachers is essential if teacher education programmes are to support the ongoing development of science teachers. Moreover, Hashweh (1996) asserts that despite numerous changes that have happened in the curricula of many countries, science teachers, particularly in developing countries, have remained stuck in traditional practices, and their beliefs have not been affected by those curricular shifts. He argues that many studies have concluded that teachers are positivist in their views of scientific knowledge. These teachers believe that reality is stable and can be observed and described without interfering with the phenomena being studied. This Hashweh argues teachers do despite the fact that positivism contradicts the constructivist view of learning and knowledge advocated by recent educational reforms. Hashweh goes on to say that observations of classroom teaching show that lecturing and the neglect of students' ideas are the prominent methods of teaching, in spite of their contradiction of a constructivist basis of learning and teaching that focuses on the importance of students' prior ideas, and the active construction of knowledge by the learner.

This shows that teachers are neglecting curricular reforms in favour of traditional ways of teaching.

This apparent neglect of curriculum reforms by the teachers is well explained by Markic, Eilks and Valanides (2008), who attribute this problem in German schools to the fact that school teachers tend to teach the way they were taught as pupils at school, and their teacher education does not really affect their conceptions about learning and teaching. Fischler (in Markic, et al., 2008) argues that student teachers have fixed beliefs about teaching and learning that guide their behaviour and prevent them from following alternative pathways.

1.2 MOTIVATION FOR THE STUDY

The curriculum reforms that have taken place in South Africa with the introduction of the National Curriculum Statements (NCS) for Physical Sciences Grades 10-12

(Department of Education, 2003) and later through the Curriculum and Assessment Policy Statement (CAPS) for Physical Sciences Grades 10-12 (Department of Basic Education, 2011) require learners to use scientific enquiry and problem-solving skills to construct and apply knowledge in socially, technologically and environmentally responsible ways. As learners use their enquiry skills and construct knowledge they are expected to understand the nature of science and its relationship to technology, society and the environment. In particular, they are expected to understand how scientific knowledge develops.

The curriculum requires learners to develop knowledge about the scientific enterprise through enquiry. To develop this understanding teachers are expected to move learners from the awareness of their own experiences of enquiry to more generalized beliefs about science and science learning.

Science curriculum reform initiatives like the one South Africa has undertaken, according to Zeidler, Sadler, Simmons and Howes (2005), demand increased emphasis on the nature of science (NOS) and scientific enquiry, as well as the development of broad conceptual frameworks encompassing progressive visions of scientific literacy that entail a commitment to moral and ethical dimensions of science education, including the social and character development of children. Zeidler, et al., (2005) argue that in such a curriculum students are expected to develop an understanding of the epistemology of scientific knowledge, as well as the processes/methods used to develop such knowledge.

Through CAPS the South African curriculum requires teachers to adopt a broader perspective of what it means to be scientifically literate. Hodson (2008) argues that a person can only be considered scientifically literate if he/she possesses an authentic understanding of what science is, how science functions, what scientists do, and how science develops and changes over time in response to sociocultural and economic pressures. Over the past few years, the writer has been observing science education students during practice teaching sessions with a view to ascertaining whether or not they were teaching according to the principles of the new curriculum. From his

observations, the writer surmised that the student teachers held beliefs about the nature of science and science teaching and learning which suggested that they saw the overall goal of science teaching to be the acquisition of what scientists already knew. This was evident from their spending very little time, if any at all, examining and discussing the nature of the problem being investigated, developing higher level reasoning skills, engaging in argumentative discourse of science, or exploring the assumptions and beliefs held by learners in their classes as the curriculum expected them to do. The science student teachers' classes were more often than not observed to be rigidly bound in what McComas, Almazroa, and Clough (1998: 520) refer to as a "tradition of communicating the facts or end-products of science while generally neglecting how this knowledge was constructed". The students appear to be trapped in beliefs about the nature of science that make it difficult for them to move away. This approach to teaching is what Schwab (in McComas, et al., 1998: 522) refers to as "the teaching of science as unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal, and irrevocable truths." This is where student teachers present science as a "meticulous, orderly and exhaustive application of powerful, all-purpose, objective and reliable methods for ascertaining factual knowledge about the universe" (Hodson, 2008:372). Hodson further explains that in this view "scientists are portrayed as rational, logical, open-minded and intellectually honest individuals who are required to adopt a disinterested, value-free and analytical stance and readily share their procedures and findings with each other."

This view is, however, in sharp contrast to the view about science that the NCS for Physical Sciences Grades 10-12 advocates, namely that:

- Scientific knowledge is in principle tentative and subject to change as new evidence becomes available.
- Knowledge is contested and accepted, and depends on social, religious and political factors.
- The explanatory power and limitations of scientific models and theories need to be evaluated. (Department of Education, 2003:11)

According to Sampson and Benton (2006), research suggests that the role of a teacher's beliefs in the process of initiating science education reform should not be underestimated, and that the successful implementation of the current science education reform movement will require a considerable adaptation of teachers' beliefs in order to align their practices with the philosophy of the reform.

The new cadre of science teachers that will teach this new curriculum is expected to be conversant with enquiry practices, as well as hold beliefs about science which will make them able to design learning environments that engage and empower learners in the knowledge construction and evaluation of evidence needed for explanation of natural phenomena.

This new generation of science teachers advocates what Zeidler, et al., (2005:368) call a "more issues-driven STS curriculum in the form of science – technology – society – environment education (STSE) which exploits the inherent pedagogical power of discourse, reasoned argumentation, explicit NOS considerations, and the emotive, developmental, cultural or epistemological connections within the issues themselves."

However, Kruss (2009) argues that it is possible that the new curriculum expects teachers to implement a curriculum developed on epistemological and pedagogical principles that contrast sharply with their own existing and accepted commitments and practices. As Millwood and Sandavol (2006) argue, doing enquiry may be the best way to develop students' ideas about science, but students' ideas about science often interfere with their enquiry. Linn and Songer (1993) argue that students who do not already hold constructivist epistemological beliefs do not learn as much from enquiry, and according to Tobin, Tippins and Hook (2006), they even resist it. It is therefore possible that science student teachers do not engage their learners in the expected enquiry processes and knowledge construction activities because they themselves do not hold constructivist beliefs, or share in the reform-based

epistemological beliefs which, if they did, would make them believe that their learners could learn from enquiry and knowledge construction processes.

1.3 STATEMENT OF THE PROBLEM

Research on pre service teachers' epistemological beliefs about the nature of science and science teaching has been on the increase in the recent past (Yilmaz & Sahin, 2011; Chai, Teo, Lee & Cheng, 2009; Chan, Tang & Cheng, 2009). This research has been trying to determine the changes in pre service teachers' epistemological beliefs and their beliefs about teaching and learning during the course of their preparation. Research identifying pre service teachers' epistemological beliefs and their conceptions about teaching has therefore become necessary in the preparation of pre service teachers for the real world teaching environment (Yilmaz & Sahin, 2011). According to Cheng et al this has been the case because teachers' beliefs and value systems shape their conceptions and practical theories in classroom teaching, which eventually influence their instructional strategies and performance in class.

Presently there is very little, if anything, that is known about the epistemological beliefs about the nature of science and science teaching and learning that South African science student teachers hold at various levels of their study, particularly in the senior years, when they begin to be involved in practice teaching. These are critical year-levels of study because at this stage, teacher education institutions expect their student teachers to start going out to schools to practise. It is at these year- levels of study that one begins to see the interaction between the beliefs that the students hold vis-à-vis their classroom practices. Additionally, few if any research studies have examined how pre service science teachers' epistemological beliefs about science and science teaching change at various levels of their studies – and how this may influence the teaching practices of the student teachers. Such studies would have shed light on whether teacher education programmes in Higher Education Institutions (HEIs) are succeeding in changing beliefs pre service teachers' hold about science and science teaching during the course of study.

This research sought to build upon what is currently known about pre service science teachers' epistemological beliefs about science and their conceptions about science teaching and learning. It further adds to what is currently available about how the pre service teachers' epistemological beliefs about science and their beliefs about science teaching change at different levels of their studies.

1.4 CONCEPTUAL FRAMEWORK

The relationship between teachers' beliefs and the impact these beliefs have on teaching practices have been a subject of numerous research studies. Beliefs about teaching are already established by the time pre-service teachers enter teacher training institutions (Epler, 2011). On their part, pre-service teachers already hold beliefs about teaching and learning – including the belief that good teaching is highly related to one's content knowledge and one's abilities to pass that knowledge to others, when they enter teacher training institutions (Feiman-Nemser, 1996). By the same token, student teachers' beliefs related to knowledge acquisition develop before their formal entry into the teaching and learning profession (Cheng, et al., 2009). These observations suggest that knowing pre-service teachers' beliefs about knowledge, teaching and learning is important because these beliefs are crucial in their own learning and pedagogical understanding, as well as in their teaching methods and classroom practice (Uzuntiryaki & Boz, 2007).

A linear relationship between epistemological beliefs and teaching and learning conceptions has been reported in numerous research findings. Pre-service teachers with advanced epistemological beliefs have been found to use student-centred teaching practices more frequently, while participants with naïve epistemological beliefs have shown a tendency to use teacher-centred teaching practices more frequently (Epler, 2011). Literature also suggests that pre-service teachers with advanced epistemological beliefs use multiple student teaching methods including class discussions, peer teaching, collaborative groups, and also high-order questioning techniques in their science classes. On the other hand, pre-service teachers with naïve epistemological and intelligence beliefs are known to use

teacher- centred methods such as lectures, demonstrations and teacher-led discussions (Epler, 2011).

Pre-service teachers who hold naïve epistemological beliefs have been found to be fundamentally knowledge transmitters (Chai, Teo & Lee, 2010). Pre-service teachers' with behaviouralist views of teaching and learning have also been found to enjoy use of a systematic and detailed approach to planning daily lessons, as opposed to unit planning used by those pre-service teachers' with constructivist views of teaching and learning. The pre-service teachers with such views think that the detailed planning hinders their creativity, and prefer unit plans to detailed daily plans (Knobloch & Hoop, 2007).

The conceptual framework of this study was framed upon the preponderance of literature that carried the view that a teacher's classroom practices are a consequence of two main dialectic influences: (a) the teacher's epistemological beliefs about the nature of science, which may be either naïve or sophisticated; and (b) the teacher's beliefs about teaching and learning, which may be either traditional or reformed. Accordingly, the conceptual framework guiding the study opined that teachers holding naïve beliefs about the nature of science, and those holding traditional notions of teaching and learning will be characterized by teacher-centred instructional approaches, while those holding sophisticated beliefs of the nature of science and a reformed view of teaching and learning will be associated with learner-centred instructional approaches.

1.5 AIM OF THE STUDY

The aim of this study was therefore to determine pre-service science education students' epistemological beliefs about the nature of science, and teaching and learning, and how those beliefs related to each other and their coherence with the philosophical foundations of the NCS.

1.6 RESEARCH QUESTIONS

In line with the above aim, this study sought to find answers to the following main research question, and the attendant sub-questions:

1. How do pre service science teachers' beliefs change and relate to the curriculum policy as they go through the teacher education programme?
 - a) Do third- and fourth-year science education students differ in their epistemological beliefs about **science**?
 - b) Do third- and fourth-year science education students differ in their beliefs about **science teaching and learning**?
 - c) Is there a significant correlation between pre-service science education students' epistemological beliefs about the nature of science and their beliefs about science teaching and learning?
 - d) Is there a significant correlation between the epistemological beliefs about the nature of science held by third- and fourth-year pre-service science education students versus the views about the nature of science espoused by the NCS?
 - e) Is there a significant correlation between beliefs held by third- and fourth-year students about science teaching and learning, versus the pedagogical content beliefs about science teaching and learning espoused by the NCS?

1.7 RESEARCH HYPHOTHESES

The following theoretical hypotheses have been formulated for testing in this study:

- Pre-service science education students hold similar epistemological beliefs about science across levels of study.
- Pre-service science education students hold similar beliefs about science teaching and learning across levels of study.

- There is no correlation between pre-service science education students' epistemological beliefs about science and their beliefs about science teaching and learning.
- Epistemological beliefs about **science** held by pre-service science education students do not cohere with the views on **the nature of science** espoused by the NCS.
- **Science teaching and learning** beliefs held by pre-service science education students do not cohere with pedagogical content beliefs about science teaching and learning espoused by the NCS.

1.8 DEFINITION OF TERMS

In this study the following terms will mean the following:

1.8.1 **Belief**

According to Pajares (1992), a belief is an individual's judgment of the truth or falsity of a proposition, a judgment that can only be inferred from a collective understanding of what human beings say, intend, and do.

1.8.2 **Beliefs about science teaching and learning**

According to Markic, et al. (2008), beliefs about science teaching and learning are mental predispositions that teachers or student teachers hold which affect their behaviour in science classes.

1.8.3 **Epistemological beliefs**

Tutty and White (2005) define epistemological beliefs as beliefs concerning the nature of knowledge and knowing, including how knowledge is constructed and evaluated.

1.9 CONCLUSION

This chapter has outlined the importance of beliefs in science teacher education, and how these beliefs influence the teaching and learning of science in schools. The chapter has also revealed that certain epistemological beliefs function as constraints to knowledge acquisition process (Dinal-Taganahan, 2008). The chapter has highlighted the need to understand the beliefs that pre-service teachers hold about science knowledge and science teaching and learning. These conceptions about the nature of knowledge and teaching and learning are formed through many years of exposure to educational practices (Cheng, Chan, Tang & Cheng, 2009), and influence the way pre-service teachers teach science.

There is, however, very little that is known about the beliefs that pre-service science education students hold in later years of their study, and how the teacher education science programmes challenge these beliefs during the programme implementation. Studies that have attempted to investigate the pre-service teachers' belief about science knowledge and science teaching and learning in initial teacher education programmes have found the impact of these programmes on teachers' beliefs to be of great concern (Cheng, et al., 2009).

This chapter, therefore, has outlined how this study will attempt to understand the beliefs that pre-service science education hold about science knowledge and science teaching and learning. This understanding will shed light on whether the initial teacher education programme that these students go through succeeds in changing the traditional beliefs that students bring to the programme.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter addresses beliefs: what they are, and how they develop. The chapter will also make a distinction between different types of beliefs and categories into which these beliefs fall. An in-depth review of epistemological beliefs will be undertaken. An argument about the unidimensional, multidimensional and theoretical nature of epistemological beliefs will be presented. Epistemological beliefs as a critical aspect of the science teachers' classroom practice will be looked into. An argument will also be presented to show that if these beliefs are left unchallenged they could adversely affect the uptake and implementation of science curriculum reforms.

2.2 BELIEFS

According to Luft and Roehrig (2007), research has demonstrated that beliefs are personal constructions, and entities that belong to an individual. Rokeach (1969) suggests that all beliefs have three components: a cognitive component, an affective component and a behavioural component. Underlying all beliefs are the individual's intentions and subsequent performance. A cognitive component represents a person's knowledge about what is true or false, desirable or undesirable. An affective component of the belief enables an individual to take a positive or negative position in an argument, whilst a behavioural component of the belief leads to action when it is activated (Savasci-Acikalin, 2009).

According to Fishbein and Ajzen (1975:222), "a belief links an object to some attribute and the object of a belief may be a person, a group of people, an institution, a behaviour, a policy, an event, etc., and the associated attribute may be an object, quality, characteristic, outcome or event". Rokeach (1969) argues that there are five kinds of beliefs, namely types A to E. He asserts that these beliefs can

be represented by five concentric circles; at the centre of these circles are the key beliefs, while the more inconsequential beliefs are along the outside circle.

Type A beliefs (primitive beliefs) are the core beliefs, are formed early in life, and involve the nature of oneself and one's physical and social world. They are considered to be connected with societal norms, are not prone to controversy, and can hardly change. Type B beliefs are a second kind of primitive beliefs. They are private beliefs, independent of any social judgement. They are still very much resistant to change. These beliefs can either be positive (type B+) or negative (type B-). "Type B+ beliefs represent our positive self-image which guides our aspirations and ambitions to become even better, wiser, and nobler than we are, while type B- beliefs are the kind of primitive beliefs that we only wish we were rid of" (Rokeach, 1969:3). Type C beliefs (authority beliefs) are shaped through individual's acculturation, education and schooling. They are beliefs that we all have about which authority to trust and which not to trust. Rokeach argues that individuals also hold type D beliefs (peripheral beliefs), which are derived mainly from secondary sources such as books and media. Peripheral beliefs can be changed. Type E beliefs (inconsequential beliefs) are beliefs which can be changed. The change in these beliefs does not result in a change in the entire belief system.

Fishbein and Ajzen (1975), on the other hand, argue that beliefs are formed as a result of an individual's direct experience with an object. Such beliefs are called descriptive beliefs. They argue that some beliefs go beyond directly observable relationships. For example, beliefs may be formed during an interaction with another person, and result in the formation of beliefs about the unobservable characteristics, such as honesty, friendliness, intelligence, etc. of that person. These beliefs are called inferential beliefs. Fishbein and Ajzen (1975) acknowledge that not all our beliefs are formed on the basis of direct experience with the object of the belief, or by way of some inferential process. They contend that some beliefs are formed when we accept information about some object provided by outside sources such as newspapers, magazines, books, lecturers, etc. Beliefs which we form when we accept the information provided by outside sources are called informational beliefs.

Irrespective of how beliefs were formed, once they are formed they inform behaviour (Fishbein & Ajzen, 1975). As a consequence, Ajzen (1991), in his theory of planned behaviour, has put a person's beliefs into three main categories, namely behavioural beliefs, normative beliefs and control beliefs. Underlying these beliefs are the person's intentions and subsequent performance. Within the behavioural beliefs are found an individual's attitude towards behaviour. Attitudes are held by specific people about specific objects and situations (Hayden, 1998). An individual may have either a positive or a negative evaluation of the behaviour. On the basis of that evaluation an individual may decide whether to perform or not to perform that behaviour. The holder of the belief can evaluate behaviour as positive if it is behaviour of interest to him/her, or he/she can evaluate it as negative if it is behaviour of no interest to him.

The second category of beliefs deals with normative prescriptions, where an individual holds beliefs that are either socially acceptable or not socially acceptable. If the behaviour is supported by the society an individual may label that behaviour as positive, and negative if it is not supported by the society.

Control beliefs are beliefs that one holds about one's ability to perform the behaviour of interest. When factors make it easy to perform it, the behaviour is labelled as positive, and negative when factors do not make it easy to perform it.

Ackermann (in Savasci-Acikalin, 2009) also identified beliefs as behavioural, but he further categorized them into unconscious beliefs, conscious beliefs and rational beliefs. He described unconscious beliefs as longstanding beliefs that can influence behaviour over a long period of time. Unconscious beliefs are not recognized by the holders, while conscious beliefs are any beliefs a person has explicitly formulated and is aware of. Rational beliefs are defined as a "philosophical idealization of actual belief structures" (Savasci-Acikalin, 2009:2).

2.3 DEVELOPMENT OF EPISTEMOLOGICAL BELIEFS ABOUT SCIENCE

The area of study concerned with the origin, nature, limits, methods and justification of human knowledge is known as personal epistemology (Hofer, & Pintrich, 2002). Sandoval (2005), however, contends that psychologists define personal epistemology as a set of beliefs that individuals hold about the nature of science knowledge and its production. According to Hofer (2001), these beliefs include beliefs about the definition of knowledge, how knowledge is constructed, how it is evaluated, where it resides, and how it occurs. In line with this categorization, Jackson (2010) has conceptualized epistemological beliefs as core beliefs about the nature of knowledge and the nature of knowing, and peripheral beliefs about learning.

There has been a growing need to discover features describing epistemological belief developments over the past few decades (Sormunen, 2008). Hofer (2001) contends that research on personal epistemology has over the years been developmental in nature, where a systematic progression in the development of one's ideas has been highlighted. Personal epistemology has also been looked at as a system of more or less independent beliefs (Hofer, 2001). William Perry pioneered research on the development of epistemological beliefs in 1976 (Brownlee, Purdie & Boulton-Lewis, 2001). In this developmental model, "individuals move through some specified sequence in their ideas about knowledge and knowing, as their ability to make meaning evolves" (Hofer, 2001:356). Considering knowledge through a continuum, Perry found that students' epistemological beliefs moved through four positions which he described as dualism, multiplism, relativism and commitment. In his research Perry discovered that individuals who held dualistic beliefs about the nature of knowledge believed that absolute truths (right/wrong) existed, and could be transmitted to an individual from an authority or expert. When individuals held a multiplistic view of knowledge they conceded that there were some things that could not be known with certainty. Such individuals believed that knowledge comprised both personal opinions and ultimate truth, and therefore relied less and less on authority for absolute truths while they still considered personal opinions

and truths to be right or wrong. In this study Perry found that a major shift in epistemological thinking was observed in those individuals who held a relativist position. These individuals considered knowledge as actively and personally constructed in some context. For these individuals, absolute truths could no longer exist because they considered truth to be relative to an individual's personal interpretations of experiences. In their final position, relativistic thinking was still a feature, but they valued particular beliefs more than others, and were committed to them in a flexible manner. As Perry's study was based on students in a four-year university programme, he emphasized that the dualistic view of knowledge was challenged and transformed over a four-year period. He argued that when students entered university they tended to believe in simple, certain knowledge that is handed down by authority, but when they reached their senior years of study they believed in tentative, complex knowledge obtained through observation and reasoning (Epler, 2011). Perry's study demonstrated that epistemological beliefs develop and become more sophisticated, where an individual moves from relying on experts to provide knowledge to relying more on self-constructed processes to develop understanding (Jackson, 2010). This, according to Bromme (2005), shows an individual moving from a dualistic view of knowledge to a relativistic view. As he/she embraces the relativistic view, he/she moves away from being a passive recipient of knowledge to being an active constructor of his own knowledge (Bromme, 2005). Perry's findings and many others similar to his – for example, women's ways of knowing, epistemological reflections, reflective judgement and the skills of argument (Hofer, 2001) – are, however, based on the premise that personal epistemologies develop in parallel with individual cognitive development (Topcu & Yilmaz-Tuzun, 2009).

Perry's work on developmental epistemological beliefs received widespread condemnation for advocating what Brownlee, et al., (2001) called its stage-like, unidimensional characteristics when researchers' interest in epistemological beliefs was rekindled in the 1990s. At this point researchers were not just interested in identifying epistemological beliefs, but more in illustrating how epistemological beliefs impacted on aspects of learning (Epler, 2011). In Jackson's terms (2010),

researchers were more interested in identifying core beliefs about the nature of knowledge and nature of knowing, and peripheral beliefs about learning.

A pioneer of the study on personal epistemology as a system of independent beliefs was Schommer (1989). Schommer, having identified some shortcomings in the conception of epistemological beliefs by Perry, that personal epistemology is unidimensional and develops in a fixed progression of stages, conceptualized “a more plausible conception that personal epistemology is a belief system that is composed of several more or less independent dimensions” (Schommer, 1989:2). She argued that beliefs were too complex to be captured in a single dimension, and proposed five dimensions of epistemological beliefs that included omniscient authority (beliefs in the source of knowledge), certain knowledge (beliefs in the certainty of knowledge), simple knowledge (beliefs in the structure of knowledge), quick learning (beliefs in the speed of learning), and innate ability (beliefs in the stability of knowledge). However, using exploratory factor analysis, evidence of all factors except omniscient authority were found by Schommer. In this study Schommer established the multidimensional nature of epistemological beliefs.

The multidimensional nature of epistemological beliefs suggests that individuals may hold both sophisticated (more relativistic) and naïve (more dualistic) views about the nature of knowing at the same time. According to Tickle, Brownlee and Nailon (2005:6), a person holding naïve epistemology along the different dimensions may believe that:

- knowledge is simple, clear and specific
- knowledge resides in authorities and is therefore unchanging
- concepts are learned quickly or not at all, and
- learning ability is innate

This is in contrast to a person who holds sophisticated epistemology along the different dimensions who generally believes that:

- knowledge is complex and uncertain

- knowledge can be learned gradually through reasoning processes, and
- knowledge can be constructed by the learner

Tickle, et al.(2005) argue that the multiplicity dimensions suggest that epistemological beliefs do not necessarily develop in synchrony.

Within this research tradition of the multidimensional nature of personal epistemologies has emerged numerous different dimensions. Hofer and Pintrich's (1997) four general epistemological dimensions include certainty of knowledge (stability), simplicity of knowledge (structure), source of knowing (authority), and justification for knowing (evaluation of knowledge claim) (Conley, Pintrich, Vekiri, & Harrison, 2004). Conley et al. argue that the first three of these dimensions parallel those of Schommer's, while the last dimension is often proposed by those who take a developmental perspective on epistemological development.

In his study of pre-service teachers' epistemological beliefs and their conceptions about teaching and learning, Chan (2004) found that the results of his study differed from Schommer's in that in his study the dimension "authority/expert knowledge" was extracted. This dimension is similar to the dimension "omniscient authority" which was absent from Schommer's study. The findings of this study were similar to the findings of Elliott and Chan (1998) conducted within the Chinese culture where the omniscient authority was reported. Similarly, the dimension "justification of knowledge" did not emerge as a distinct dimension of physics-related epistemological beliefs in Stathopoulou and Vosniadou, (2007) study of epistemological beliefs in the Greek context. Like Chinese students, Greek secondary school students may pay more attention to the role of authority in the source and justification of knowing than American students because of the intense teacher-centeredness of physics instruction in Greece (Stathopoulou & Vasniadou, 2007). This suggested cultural influence in the development of epistemological beliefs. With respect to the development of the omniscient authority in Chinese culture, Elliott and Chan (1998) argue that the development of this dimension may be because "authority is usually respected in Asian

cultures, and there is a tendency not to query or criticize the viewpoints of authority figures” (Elliott & Chan, 1998:6).

Likewise, using qualitative methodologies to investigate epistemological beliefs held by 7th grade learners, Sormunen (2008) found that the justification, certainty and sources of knowledge dimensions emerged strongly from his data analysis. However, the dimension “simplicity of knowledge” was not recognized in the data (Sormunen, 2008).

The development of multidimensional epistemological beliefs has been confirmed by a number of research findings. The results of Yilmaz-Tuzun and Topcu’s study (2008) suggested that pre-service science teachers’ epistemological beliefs developed more or less independently. “While pre-service science teachers’ developed sophisticated beliefs in some epistemological dimensions (e.g. innate ability), they developed less sophisticated beliefs in other epistemological dimensions (e.g. certain knowledge)” (Yilmaz-Tzun and Topcu, 2008:80). Stathopoulou and Vosniasdou (2007) suggest that beliefs can also be conceptualized as theory-like structures. They argue that this conceptualization can “help us understand better how epistemological beliefs can be acquired and changed, how they can influence individuals’ learning in areas such as physics, and how it is possible to differentiate epistemological beliefs in different disciplines” (Stathopoulou & Vosniasdou, 2007:146). Conceptualizing epistemological beliefs as theories may also help in representing epistemological thinking in ways that enhance our understanding of mechanisms of acquisition and change (Hofer, 2001).

The model of epistemological theories consists of “dimensions suggested by a review of both the developmental model and the independent beliefs model” (Hofer, 2001:361). This, according to Stathopoulou and Vosniadou (2006), implies that regardless of the conceptualization of the epistemology construct, changes in epistemological thinking have to be conceptualized as involving an upward movement from dualistic views to more relativistic, subjectivist, contextual, constructivist and evaluative perspectives of knowledge and knowing.

2.4 EPISTEMOLOGICAL BELIEFS AND THEIR RELATION TO SCIENCE LEARNING

Jehng, Johnson and Anderson (1993), in their study of students' epistemological beliefs about learning, found that students' beliefs about learning may evolve as they are exposed to more advanced education. They found that students with more advanced education in a domain tended to believe that "the nature of knowledge is uncertain, learning is not a totally orderly process, and independent learning is crucial" (Jehng, Johnson & Anderson, 1993:32)

Chan and Sachs (2001), who investigated children's beliefs about learning, found that children who viewed learning as meaning construction were better than those holding shallow conceptions on reading. This is because students who see learning as involving the completion of routine activities are less likely to apply deep processing strategies to tackle problems of understanding. Constructivist-oriented students have also been found to employ more meaningful learning strategies, while those less constructivist have been found to use rote memorization when acquiring scientific knowledge (Tsai, 200). Similar findings were also made by Chan (2002) regarding the relationship between students' epistemological beliefs and the learning strategies they use to learn science. He found that students who believed that learning requires effort, and is also a process, would probably use a deep strategy to understand instead of relying on rote. On the other hand, a student who believed that knowledge was handed down by authority or experts would not bother much about understanding, and would use a surface strategy (Chan, 2002). Chan also found that Chinese students tended to be deep and achieving-oriented in their learning approaches.

Sahin (2009), in his study of epistemological beliefs by physics students attending a problem-based introductory physics, found that some students believed learning physics to be memorizing formulas and problem-solving algorithms, while others thought of learning physics as developing a deeper conceptual understanding. Similarly, Schommer (in Chan & Sachs, 2001) found that students who viewed learning as involving problem solving applied a constructive learning strategy and engaged in deeper processing as

opposed to those who believed that learning involved reproduction and completion of routine activities. These tended to employ a surface-learning strategy.

Songer and Linn (1991) also found an influence of epistemological beliefs on students' cognitive development processes and their academic achievement. They found that students who believed in a rich, integrated view of science outperformed others in scientific understanding. Qian and Alvermann (1994), on the other hand found, that students who held beliefs about simple- certain knowledge and quick learning performed poorly on conceptual change tasks. Chan and Sachs (2001), in their research where they examined the relationship between epistemological beliefs and quality of learning outcomes, found that children with more sophisticated beliefs about learning were likely to employ deep-processing strategies, resulting in better performances than those with naïve beliefs.

Epistemological beliefs have also been linked to students' study techniques by researchers such as Hofer and Pintrich (1997), who found that students who believed that the structure/content of knowledge consisted of unrelated pieces of information may use memorization as a study technique instead of a deeper process such as elaboration or integration. They also found that students who viewed science as stable and unchanging tended to memorize scientific facts. This is in contrast with the students who viewed science as dynamic, and who always attempted to understand the information. The same results were also found in the study by Stathopoulou and Vosniadou (2006), where students with constructivist physics-related epistemology, and who showed evidence of in-depth physics understanding, adopted a deep approach to learning. The opposite was true for those with less constructivist physics epistemology and who showed evidence of poor conceptual physics understanding. They relied on memorization of what had been learnt, and rote learning (Stathopoulou & Vosniadou, 2007). Sahin (2009), however, did not find any link between the academic performance of the physics students and their beliefs about physics learning. He found that those who believed that learning physics was about receiving information and taking what was given by authorities without evaluation had similar grades to those who believed that learning science involved an active process of reconstructing one's own understanding.

Tsai (2000), on the other hand, found that there was a relationship between students' epistemological beliefs and their perception of the learning environment. He found that students with epistemological beliefs that tended towards a more constructivist view of science tended to prefer constructivist- oriented learning environments.

Tickle, Brownlee and Nailon (2005) have argued that epistemological beliefs can help distinguish between what they call transactional and transformational leadership behaviour. A transformational leader is the one who engages in the coaching and facilitation of subordinates, and creates a supportive work environment in which subordinates are encouraged to explore alternative solutions to problems (Tickle, et al., 2005). This leader's behaviour is similar to that of a teacher who believes that knowledge can be constructed by a learner and gained through reasoning. On the other hand, the behaviour of a transactional leader, who believes in clarifying the roles of subordinates and initiating work structure, precludes the construction of knowledge by subordinates, since subordinates are not encouraged to question authority and develop their own knowledge or meaning (Tickle, et al., 2005).

The relationship between epistemological beliefs and conceptual understanding of physics concepts has been extensively investigated. According to Dinal-Taganahan (2008), students develop mature beliefs about physics as their physics knowledge develops. Stathopoulou and Vosniadou (2007) found that students who held constructivist physics epistemologies achieved a conceptual change in dynamics, whilst students who held less constructivist physics epistemologies did not achieve deep conceptual understanding in dynamics. Similarly, Hammer (1994) found that physics students who believed that physics consisted of weakly connected pieces of information which required to be learned separately, employed surface-learning strategies, while those who considered it to be a coherent set of ideas to be learned together employed deep-learning strategies.

Ravert and Evans (2007), working within the multidimensional paradigm, found that undergraduates in their earlier years of study demonstrated a decided preference for absolute instruction and class discussion flowing from instructor to student. They also

found that students had a decided preference for knowledge that is factual and unambiguous, and questions with a single correct answer.

2.5 SCIENCE TEACHERS' EPISTEMOLOGICAL BELIEFS AND THEIR RELATION TO SCIENCE TEACHING AND LEARNING

Mansour (2009) believes that beliefs become personal pedagogies or theories to guide teachers' practices. Collins, Selinger and Pratt, (2003), argue that these beliefs act as filters through which new messages concerning teaching and learning are reconciled with previously held information. Nespor (1987) asserts that teachers rely on their core belief systems rather than academic knowledge when determining classroom actions. Similarly, Pajares (1992) contends that beliefs are the best indicators of the decisions individuals make throughout their lives. He argues that there is a strong relationship between teachers' educational beliefs and their planning, instructional decisions and classroom practice. From this point of view, like Nespor, he sees beliefs as being far more influential than subject knowledge in determining how individuals organize and define tasks and problems, and are stronger predictors of behaviour.

According to Ozdemir (2007), science teachers have been found to hold both naïve and sophisticated epistemologies about science. Naïve epistemologies indicate a positivist perspective, and they describe science knowledge that is true, real and existing independently of personal experience; whereas those who hold sophisticated beliefs understand the relationship between events, and are able to apply their science knowledge to novel situations with enjoyment. Teachers who hold naïve epistemological beliefs have been found to hold pedagogical beliefs that have been classified broadly under the knowledge transmission category, and those who hold sophisticated beliefs have been found to hold pedagogical beliefs that have been classified broadly under the knowledge- construction category. Depending on their epistemological beliefs, teachers' classroom practices can be put under either one of the two categories. Knowledge transmitters have been found to stress the objectivity and reproducibility of knowledge. According to Ozdemir (2007:358-364) these teachers "see the purpose of activities as

being to follow the directions given in the textbook to reach predetermined right answers.” He argues that these teachers

- Stress the product rather than the process of knowledge in their instruction.
- Stress the objectivity and reproducibility of science knowledge, and in the process make their learners develop an understanding that science knowledge is out there, and everybody can reach the same truth by following the same experimental procedure.
- Use teacher-directed instructional approaches with closely controlled activities which emphasize the transmission of knowledge, and consider students as simple receptors of knowledge.
- Use traditional assessment methods such as quizzes, unit tests, multiple choice, true/false, matching, drawing and labelling, fill in the blank, etc.
- Do not consider scientific theories in their instructional tasks. They develop their instruction within scientific facts and truths.
- Make students accept scientific knowledge without reasoning and questioning. They make students accept existing knowledge coming from the textbook and from teachers, even if the scientific knowledge conflicts with their everyday experiences.
- They reinforce and retain misconceptions by teaching scientific knowledge as disconnected from everyday experiences, which leads to the familiar conclusions, memorizations and meaningless learning. (Ozdemir, 2007:365-366)

On the other hand, knowledge constructors have been found to emphasize meaningful learning, and

- See learning as a productive process in which learners actively construct their own meaning with social interaction.
- Teach the process of science, which leads them to pay more attention to their students’ interpretations.
- Use formative assessment formats, and focus on students’ interpretations rather than those of their textbooks. (Ozdemir, 2007:365-366)

Pajares (1992) also confirmed that the knowledge transmission category is characterized by teacher-centred, content-driven didactic teaching practices that emphasize passive reception of knowledge by students; whereas the knowledge construction category is a learning-oriented, student-centred constructivist teaching that encourages students to actively make sense of their experiences. In accordance with this classification, Pajares (1992) found that teachers who held knowledge constructivist beliefs were more likely to detect students' alternative conceptions, and had a richer repertoire of teaching strategies. These teachers used effective teaching strategies for inducing student conceptual change.

These research findings also concur with the research findings reported by Tickle, et al. (2005) who found that holders of sophisticated epistemological beliefs adopt constructive approaches to teaching, and demonstrate more innovative, democratic and emphatic behaviour, whereas those who hold naïve epistemological beliefs are linked to transmissive approaches to teaching, and consider knowledge as absolute and learnt from experts. Tickle, et al. (2005) argue that individuals who hold more sophisticated epistemological beliefs are more likely to engage in personal reflection and analysis about their understandings and use of knowledge. Similar findings were also reported by Brickhouse (1990). Brickhouse found that teachers' instructions portrayed an image of science consistent with their own views. In three different studies that she conducted she found that teachers who saw science primarily as generative tended to do more inquiry activities so that students could generate knowledge. Those who saw science as a body of knowledge to be used to solve problems generally planned instruction in which students used science in this way.

She further found that the science teachers she studied who held understandings that were congruent with logical positivism used examples which included the usefulness of a step-by-step scientific method, the objectivity of knowledge and the superiority of observational data over theoretical data in class.

Similarly, in a study on the effects of epistemological beliefs about science on classroom practice, Hofer (2004:143) studied two chemistry teachers' teaching. She observed that

one course offered the view that students are “cognitive apprentices who can rise to the challenge of constructing knowledge much as scientists do, within a discipline in which knowledge continues to evolve”. This teacher saw his role as a facilitator who allowed students to reconstruct, extend or replace their existing knowledge. She also observed the other teacher presenting a view that knowledge in chemistry consisted of facts and formulas, and that knowing chemistry meant “remembering formulas and applying these formulas and recognizing appropriate contexts for their particular use”. This teacher, she concluded, saw his role as an expert in his subject who presented the information on it directly to his students in a logical sequence. Brickhouse (1990) had a similar experience, and described how teachers who held different beliefs about science theories approached the science lesson, where the one who viewed theories as truths wanted his students to know the major theories, while the one who considered science theories as tools insisted that his students should be able to use them to solve problems.

The difference in epistemological beliefs among teachers holding different levels of qualifications were found not significant by Lee, Zhang, Song and Huang (2013). Teachers with different qualifications, however, held slightly different views about teaching and learning, with teachers holding qualifications above the bachelor degree more likely to accept constructivist conceptions of teaching and learning, and those with qualifications below bachelor endorsing traditional conceptions about teaching and learning (Lee, et al., 2013).

2.6 PRE-SERVICE TEACHERS’ EPISTEMOLOGICAL BELIEFS AND THEIR RELATION TO THEIR BELIEFS ABOUT TEACHING AND LEARNING

According to Chai, Khine and Teo (2007), research findings show that student teachers hold a range of epistemological beliefs, but become more relativistic towards graduation. This finding was confirmed by Deng, Chai, Tsai and Lee (2014), who found that teachers become relativistic in their epistemological beliefs when they enter the service. Chai, et al., (2007), studying the Singapore pre- service teachers, found that pre-service teachers were homogenous in their epistemological beliefs. They found that

they seemed to believe that knowledge is uncertain, and comes from experts and authorities. Cheng, Chan, Tang and Cheng's study (2009) confirmed these findings when they found that student teachers believed that teachers or experts have a certain degree of accuracy in their knowledge. These student teachers were, however, found to hold stronger constructivist views about teaching and learning. These findings contradict those of Deng, et al. (2014), who found that pre-service teachers in China are not inclined to rely on authorities and experts as sole sources of knowledge.

Pre-service teachers have also been found to hold sophisticated beliefs in some areas of the nature of science, but not in others. Mihladiz, Dunan and Dogan (2011) found that pre-service science students held sophisticated beliefs about the tentativeness of scientific knowledge, the scientific approach for researchers, public influence on scientists, and on precision and uncertainty in scientific knowledge. Pre-service science teachers were found to hold naïve beliefs on scientific theories, laws and hypotheses, and on the status and nature of scientific models. Similarly, Tuzun and Topcu (2013) found that pre-service teachers had less sophisticated beliefs in the quick learning dimension of epistemological beliefs, and sophisticated epistemological beliefs in the simple knowledge dimension.

Tanriverdi (2012) found that pre-service teachers who believe that learning depends on innate ability were likely to use a surface strategy in their learning, while those who believe that learning depends on effort adopt deep study strategies. Tanriverdi's results were contradicted by Chan (2002), who found that students who believed that learning requires effort used surface strategy to understand instead of relying on rote. Chan however found that pre-service students who believed that knowledge is handed down from an authority or expert would also use surface learning strategy.

Studying the pre-service teachers' epistemological beliefs and conceptions about teaching and learning, Chan (2004) found that epistemological beliefs held by Hong Kong teacher education students were related to their conceptions about teaching and learning.

In their study of the structural relationship between pre-service students' epistemological beliefs and their conceptions of teaching and learning, Otting, Zwaal, Tempelaar and Gijssels (2010: 12-13)

- Found that a significant positive path was established between the learning effort/process dimension and the constructivist conception of teaching and learning, and a significant negative path was found from learning effort/process to the traditional conception of teaching and learning.
- Established a significant path from expert knowledge to the traditional conception of teaching and learning, and a significant negative path from expert knowledge to the constructivist conception of teaching and learning.
- Did not establish a significant path from innate ability to either the traditional or the constructivist conception of teaching and learning.
- Established a positive significant path from certainty of knowledge to the traditional conception of teaching and learning. No significant path could be established between certainty of knowledge and the constructivist conception of teaching and learning.

A similar study was conducted by Yilmaz-Tuzun and Topcu (2008:76) with pre service teachers, and found that pre-service teachers

- Developed their epistemological beliefs as a set of more or less independent beliefs.
- Held less sophisticated beliefs about omniscient authority, and believed that the scientific knowledge discovered by scientists is transferred to students.
- Who believed that their students would do well in science tended to feel confident about influencing their achievement only when that scientific knowledge is certain knowledge (knowledge is unchanging).
- Who believed in the effectiveness of student-centred teaching approaches in student learning tended to feel that science may be taught when students are memorizing the isolated facts or the body of scientific knowledge (simple knowledge).

- Who believed in the effectiveness of student-centred approaches in teaching tended to see their students' learning ability as not fixed.

2.7 CHANGES IN PRE-SERVICE TEACHERS' EPISTEMOLOGICAL BELIEFS AND THEIR CONCEPTION OF TEACHING AND LEARNING

Drawing on Stathopoulou and Vosniadou's conceptualization (2007) of epistemological beliefs as theory-like structures, one can also explain how teachers' epistemological beliefs can change, and in the process positively affect their classroom practice. "Conceptualizing epistemological beliefs as theory-like structures helps in understanding how epistemological beliefs can be acquired and changed, how they can influence individuals' learning in areas such as physics, and how it is possible to have different epistemological beliefs in different disciplines" (Stathopoulou & Vosniadou, 2006: 146). According to Hofer (2001), educational experiences play a role in fostering development or belief change.

Kwak (2001), who in his study monitored and identified changes in the ontological and epistemological characteristics of pre-service science teachers during the first three quarters of a teacher education programme, found that the pre-service teachers' ontological and epistemological beliefs changed throughout the period of study, and in turn caused changes in their conceptions of science teaching and learning. "With the influence of constructivist epistemology, the pre-service teachers' conceptions of science teaching and learning evolved and were refined over time as they incorporated various constructivist ideas" (Kwak, 2001:248). Teachers, however, expressed their concerns about the constraints on implementing their beliefs about science teaching and learning they acquired in the course.

Similarly, Chai, Teo and Lee (2008) when they investigated changes in Singaporean pre-service teachers' epistemological beliefs and beliefs about teaching and learning over a course of a teacher preparation programme, found that the pre-service teachers' epistemological beliefs had become relativistic in nature. They attributed the change towards a relativistic stance to teaching experiences during the teaching

practicum period. They contend that the changes could have been caused by the teaching challenges that pre-service teachers had to face during the teaching practicum period, and the uncertainties in their roles which did not have clear right or wrong answers (Chai, et al., 2008).

In their study of teacher candidates' epistemological beliefs and their views on teaching as persuasion, Sinatra and Kardash (2004:483) found that teacher candidates who believed that:

- Knowledge is constructed and modified over time were supportive of the notion of persuasion as a means of restructuring beliefs
- Knowledge is complex and constructed by learners also tended to believe that learning involves both thinking deeply about new ideas and relating them personally and affectively to new information.

Mansour (2009) argues that the development of progressive epistemological and teaching and learning beliefs occurs in stages after students have experienced both theoretical and practical components of the course. However, he contends that the development of progressive epistemological and teaching beliefs can be achieved if teachers are first made aware of their own beliefs and then challenged to change them by providing them with opportunities to examine them. This awareness of one's beliefs leads to one becoming dissatisfied with them (Saka, et al., 2007:22). Saka, et al., (2007:22) argue that pedagogical dissatisfaction occurs when a teacher recognizes the "mismatch between his /her teaching beliefs, instructional practices, goals and student learning outcomes". Brownlee, et al., (2001) suggest, therefore, that teacher education programmes need to help students to be "more meta-cognitive and focus explicitly on their epistemological beliefs in order to promote belief change" (Brownlee, et al, 2001).

After finding that epistemological beliefs only correlated with innate ability and quick learning, Topcu and Yilmaz-Tuzun (2009) made the same suggestion that the students' epistemological beliefs needed to be developed in all dimensions for better science achievement. They argued that teachers and policy makers should

give the necessary importance to developing students' epistemological beliefs throughout their formal education. Southerland, Sowell, Blanchard and Granger (2011), on the other hand, found that teachers with a combination of pedagogical discontentment and high self-efficacy were likely to be more receptive to reform initiatives within professional development.

Conley, Pintrich, Vekiri and Harrison (2004), in their study of the changes in beliefs in elementary science learners, found that young children's epistemological beliefs about science changed over time. They argued that the changes they observed were not large, but students became more sophisticated in their beliefs about the source of knowledge over the period of instruction.

Bromme, Kienhues and Stahl (2008), however, argue that there is some research evidence that suggests that gaining factual knowledge on different topics sometimes results in less sophisticated epistemological beliefs. Their observations are confirmed by Stathopoulou and Vosniadou (2007), who, while exploring the relationship between physics-related epistemological beliefs and the physics understanding of Greek secondary school students, found that all students who showed a deeper understanding of Newtonian dynamics were those with naïve epistemological beliefs, and those with sophisticated epistemological beliefs were found to have a shallow understanding of Newtonian dynamics. When individuals study a certain discipline, "their growing knowledge base may lead to the assumption that knowledge in the discipline is stable, secure and absolute, as the learner gets to the world of facts and well established theories" (Bromme, et al., 2008:11).

Collins, Selinger, and Pratt (2003) also found that some subjects are more responsible for developing certain teaching and beliefs than others. For example, when they studied student teachers' perspectives on teaching across disciplinary majors they found that prospective teachers in both life sciences and mathematics/sciences scored significantly higher on the transmission perspective than those that were in languages, arts, expressive arts and technical sciences. They

attributed this to content that was taught in subjects like mathematics/science and life sciences, which was well defined and made a lot of assumptions of single right or wrong answers. They argued that the students saw their task in those subjects as that of delivering this authorised form of knowledge. This, they argue, is in contrast with the languages, arts and social studies students, who saw their role as that of “engendering deeper understanding and promoting critical thinking skills” (Collins, et al., 2003: 5). A similar observation was also made by Yilmaz and Sahin (2011), who found that pre-service teachers from English language programmes preferred traditional teaching methods compared to students from other programmes.

2.8 CONCEPTUAL FRAMEWORK

Science teachers, who are very much involved in substantial efforts of reform, are, however, known to rely on their personal beliefs to guide their thinking and practice of science teaching and learning instead of on the policy guidelines (Sampson & Benton, 2006). These shortcomings of science teachers are blamed on education programmes that teachers go through when they are being prepared for their teaching challenges. Yilmaz-Tuzun and Topcu (2008) consider that teacher education programmes ought to prepare better teachers who can improve their schools according to the changing characteristics of the world. They therefore argue that teachers need to understand their beliefs and the relationship of those beliefs with their classroom practice. They blame teacher education programmes for lack of focus on epistemological beliefs. To address the problem teacher education programmes should evaluate their programmes and take action to enhance student teachers’ epistemological beliefs and conceptions of teaching (Yilmaz & Sahin, 2011). Some studies go as far as suggesting that teachers’ epistemological and teaching beliefs can be addressed just by making teacher education programmes constructivist oriented. This, they argue, happens because constructivist teaching and learning approaches that are advocated in constructivist teacher education programmes not only challenge teachers’ beliefs but also provide them with exemplary role models for learning to teach in a constructivist manner (Kwak, 2001). The argument presented is that in order for pre-service and in-service teachers to

perceive alternative beliefs to be credible they have to be presented with evidence that challenges their currently held beliefs (Epler, 2011). The advocates of this strategy contend that naïve epistemological beliefs that teachers hold can be challenged through explicit reflection in an environment that endorses advanced beliefs. They argue that failure to reflect on and the inability to change teacher beliefs could lead to a problematic and unconscious cycle of perpetual poorly developed practice (Markic & Eilks, 2007). Yilmaz- Tuzun and Topcu (2008), on the other hand, believe that since teachers' beliefs have been shaped over a long time, and it is therefore difficult for pre- service teachers to change them during teacher education programmes, they propose that pre-service teachers must be taught several courses such as nature of science, philosophy and history of science throughout their teacher education programme to develop their epistemological beliefs.

Recognizing that teacher beliefs play such a huge role in mediating educational change, this study has focused on the beliefs that pre-service science education students hold about science knowledge and science teaching and learning. The study has sought to find out if pre-service science education students have demonstrated different beliefs about science and science teaching and learning at third- and fourth-year levels of study. Comparing students' beliefs at these critical levels of study is done to learn if the programme that the students go through is effective in addressing their beliefs. This comparison is done despite the fact that there is research evidence that suggests that even where teacher education curricula address teachers' beliefs, teachers' experiences that they bring to the learning environment have a sustained influence on their learning during their training, and on their later behaviour as practising teachers in schools (Markic & Eilks, 2007).

Another reason is that there is very little if anything that is known about the beliefs that pre-service science education students hold about science and teaching and learning in South Africa at various levels of study. This study hopes to make a small contribution in this area of knowledge.

Figure 2.1 provides a visual model of the conceptual frame work for this study.

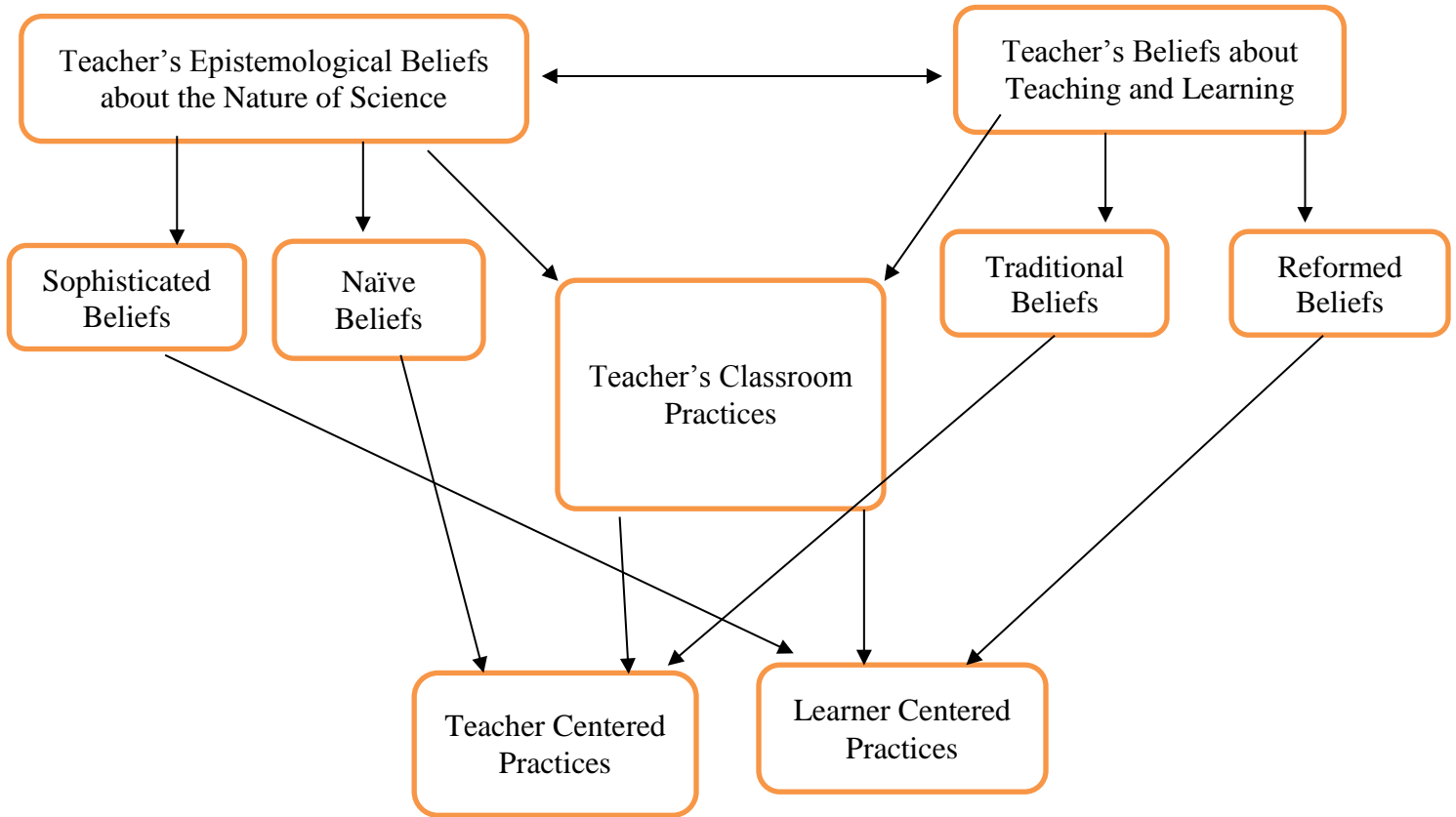


Figure 2.1. Conceptual framework of this study

Figure 2.1 summarises the various aspects that comprised the conceptual framework of this study, coming out of the literature reviewed above. According to this figure, a teacher's classroom practices are consequent upon two main dialectic influences: (a) the teacher's epistemological beliefs about the nature of science, which may be either naïve or sophisticated; and (b) the teacher's beliefs about teaching and learning, which may be either traditional or reformed. Accordingly, it is abstracted from the foregoing literature review that teachers holding naïve beliefs about the nature of science, and those holding traditional notions of teaching and learning will be characterised by teacher-centred instructional approaches, while those holding sophisticated beliefs of the nature of science and a reformed view of teaching and learning will be associated with learner-centred instructional approaches.

Accordingly, one may also add that student teachers holding naïve beliefs about the nature of science may also be likely to be associated with traditional notions of science teaching, while those holding sophisticated notions about the nature of science would exhibit alignment with the reformed view of science teaching and learning. This double dialectic, then, constituted the conceptual framework of the study.

2.9 CONCLUSION

This chapter has demonstrated that there is a strong link between the teachers' epistemological beliefs about science and their beliefs about teaching and learning. This link has enabled researchers to categorize science teachers who hold naïve beliefs about science as science knowledge transmitters, while those who hold sophisticated views about science have been categorized as knowledge constructors because they have been found to engage their learners in knowledge construction activities when they teach. Constructivist teachers are responsible for creating a learning environment in which students interact with peers and the teacher, and provide students with opportunities to use previous knowledge to construct new knowledge (Yilmaz & Sahin, 2011). Some studies, however, dispute the existence of this simple relationship between the quality of epistemological beliefs and practice, and have shown that as science students' knowledge improves, the students are found to hold naïve beliefs about science. These contradictory findings do not suggest a weakness in the research methods, but that more still needs to be known about the sophistication of epistemological beliefs (Bromme, et al., 2008). This chapter has also revealed that the development of pre-service science educators' epistemological beliefs depends on the level of study. The student teachers' teaching and learning beliefs have been found to develop as the epistemological beliefs develop. However, these sophisticated beliefs have been found not to directly translate into constructivist teaching. This anomaly is attributed to the conflict that student teachers face between their beliefs in knowledge acquisition and learning and the realities of teaching, such as the pressure to keep up with the scheduled teaching progress (Cheng, et al., 2009).

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This study is essentially a descriptive study. It has sought to describe how pre-service teachers' epistemological beliefs are related to their beliefs about teaching and learning. In this chapter a description and selection of data sources will be made. The procedures for data analysis for each research question will be presented.

3.2 RESEARCH DESIGN

Kumar (2005) sees a research design as a procedural plan that is adopted by the researcher to answer questions validly, objectively, accurately and economically. The function of a research design is to ensure that the evidence obtained enables the researcher to answer the initial questions as unambiguously as possible (De Vaus, 2007). This study used a cross-sectional design. According to De Vaus (2007), cross-sectional design studies have three distinctive features, namely: no time dimensions; reliance on existing differences rather than change following intervention; and groups based on existing differences rather than by random allocation. Thus this study collected data at a particular point in time, and the data was analysed focusing on the existing differences in beliefs about teaching and learning, and the epistemological beliefs about science, between the two groups (third- and fourth-year science education students) at a particular point in time.

3.3 RESEARCH SAMPLE

3.3.1 Target population

The study was conducted at a South African university with one hundred and eighty-four 184 students registered for a four-year Bachelor of Education (B.Ed) degree for the Senior and Further Education and Training phase. Hundred and twenty two 122 of these students were in their fourth year of study, and sixty-two 62 were in their third year. During their last two

years the students were engaged in science enquiry practices in their Methods modules. The two groups did their methods in physical science and mathematics education.

3.3.2 Sampling

This study had two sample cohorts (B.Ed 3 and B.Ed 4 students). The design did not require any sampling to be done as data collected involved intact cohorts. Two sets of data (students' beliefs about teaching and learning and their epistemological beliefs about science) were collected at the end of the second semester for each group. The B.Ed 4 cohort consisted of hundred and twenty two (n=122) respondents while the B.Ed 3 cohort had only sixty two (n=62) respondents.

3.3.3 Instrumentation

The Nature of Science as Argument questionnaire (NSAAQ)

The Nature of Science as Argument questionnaire (NSAAQ) was used to determine epistemological beliefs held by pre-service science education students about science as well as the concurrence of those beliefs with the views about science teaching and learning espoused by the NCS. The NSAAQ was administered to the third- and fourth-year pre-service science Bachelor of Education students at the end of the second semester. According to Sampson and Clark (2006), the design of the NSAAQ is modelled after the Contrasting Alternatives Design (CAD) format used by Halloun (In Hashweh, Z. 1996). The CAD format requires respondents to choose between two contrasting viewpoints using a five-point scale. One viewpoint represents a naïve epistemological belief about the nature of science, while the other represents a viewpoint that is consistent with the view of science as a process of explanation and argument. Respondents can indicate that they agree with either viewpoint exclusively (option 1 or 5), or a weighted combination of the two (options 2, 3, and 4). According to Sampson and Clark (2006), Halloun (2001) has demonstrated that the CAD format is significantly more reliable for assessing epistemological beliefs than more traditional assessment formats that use open-ended, multiple choice or

rating scale items. This instrument captures the views about science that are articulated by the National Curriculum Statements (grades 10-12).

The NSAAQ is divided into four subscales which distribute a total of 26 items around four topics, namely (a) the nature of scientific knowledge (six items); (b) the method that can be used to generate scientific knowledge (six items); (c) what counts as reliable and valid scientific knowledge (seven items); and (d) the social and cultural embedded nature of scientific practices (seven items). The possible scores range from 26 to 130 points, with higher scores reflecting a view of the nature of science that is consistent with the view of science as a process of explanation and argument (Sampson and Clark, 2006).

The NSAAQ instrument

Developers of the NSAAQ instrument validated it by administering it to a group of two hundred and three (203) secondary school students enrolled in science during the second half of the academic year. The sample of students consisted of sixty seven (67) students enrolled in biology, one hundred and one (101) enrolled in Chemistry and thirty five (35) enrolled in Physics. Of the 203 students 110 were female and 93 were male (Sampson & Clark, 2006).

Validity

According to Sampson and Clark (2006), the face validity of the item was examined by determining how often students were able to make valid interpretations of the two statements found in each item. To test the hypothesis that students were able to understand the statements found in the NSAAQ, a group of students were asked to write each statement found in the NSAAQ in their own words. Their interpretations were analyzed to determine if they understood the statements found in the NSAAQ. The analysis found that the cohort of students (n=12) was able to make valid interpretations of the statements 95% of the time. The high frequency of valid interpretations produced by the cohort indicated that secondary school students were able to comprehend the NSAAQ which confirmed the face validity of the NSAAQ (Sampson & Clark, 2006).

Validation of questionnaires is often quite difficult, unlike tests. One reason for this is that questionnaires usually solicit opinions, which tend to change and vary extensively from one person to another. Two people observing the same event could have different opinions about what they have just witnessed. Thus, opinions tend to be quite personal and not generalizable. As Howard (2008: 2) observes, “a questionnaire can have one kind of validity but not another” because “each type of validity is distinct.” One way to validate questionnaires is check the extent to which similar questions are answered similarly. However, this is only possible in situations where there is pairing of questions, such that each question has an equivalent “other”. In the present study, no validation test was done for the research sample, save for face validity which was done by both the researcher and his supervisor – paying particular attention to the language difficulty. Both the supervisor and the researcher were satisfied that the respondents would understand and interpret the questions correctly.

Reliability of the NSAAQ

Assessment of the reliability of the NSAAQ using Cronbach alpha resulted in a reliability score of 0.70 (n=203), which indicated that the instrument had sufficient internal consistency. The test-retest reliability analysis (n=67) resulted in a reliability score of 0.88 ($p=0.01$). Taken together these values indicated that the NSAAQ had adequate reliability, when compared to other survey instruments that have been developed to measure the multi-dimensional nature of epistemological beliefs (Sampson & Clark, 2006).

Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire

To determine the beliefs held by pre-service education students about science teaching and learning, the Beliefs about Reformed Science Teaching and Learning (BARSTL) questionnaire was administered to the third- and fourth-year pre-service B.Ed science education students at the end of the second semester.

According to Sampson and Benton (2006), the Beliefs about Reformed Science teaching and Learning (BARSTL) questionnaire was designed as a survey instrument that can be used to assess the degree to which science teachers' pedagogical content beliefs about teaching and learning are "reformed" in accordance with the recommendations and standards for teaching of science that have been articulated by professional societies of scientists and science educators. They argue that the design of the BARSTL is based on the assumption that teachers with different pedagogical beliefs about the teaching and learning of science will respond differently to statements describing either reformed or traditional perspectives of science teaching and learning.

The BARSTL questionnaire consists of 32 items which are divided into four subscales: (1) how people learn about science, (2) lesson design and implementation, (3) characteristics of teachers and the learning environment, and (4) the nature of the science curriculum. Each subscale consists of eight items. Four of these items are worded to be consistent with a reformed perspective of science education, while the remaining four are designed to represent a traditional perspective. Science education students indicated the degree to which they agreed or disagreed with each of the items using a Likert-type response scale. The items that represented a traditional perspective of science education scored 1 and 2, whilst a reformed perspective of science education scored 3 and 4 for the responses Strongly Disagree (SD), Disagree (D), Agree (A), and Strongly Agree (SA) respectively. The items that represent a traditional perspective were scored in reverse. The possible score ranged from 32 to 128 points, with higher scores reflecting pedagogical content beliefs about the teaching and learning of science that are more consistent with the current school curriculum reforms (Sampson and Benton, 2006).

Validation of a BARSTL instrument

Construct validity

According to Sampson and Benton (2006), construct validity refers to the theoretical integrity of an instrument. To determine the construct validity of the BARSTL the interrelationships among the constructs in the instrument were to give rise to empirical correlations that mirrored the theoretical coherence (Sampson and Benton, 2006). Because the BARSTL is a quantitative measure of the degree to which a teacher's beliefs about teaching and learning is in accord with the current science reform movement, each of the dimensions measured by subscales had to be positively correlated to each other because they were measuring different aspects of the same theoretical framework. Although the BARSTL consisted of 4 different subscales, it was expected that underlying each of these subscales was going to a single construct of **reformed pedagogical content beliefs about teaching and learning**. To test the hypothesis that reformed pedagogical content beliefs about teaching and learning was the single underlying construct in design of the BARSTL a correlation analysis was performed on each of the four subscales. Overall the results suggested that the four subscales were good predictors of the overall score. The construct reformed pedagogical content beliefs about teaching and learning, produced an internal coherence across the 32 items and the four dimensions of the construct as measured by each of the subscales. This analysis suggested that the BARSTL had a good construct validity Sampson and Benton (2006).

Reliability of the BARSTL instrument

According to Sampson and Benton (2006), two internal consistency estimates of reliability were computed for the BARSTL namely a split half coefficient expressed as a Spearman-Brown correlation and coefficient alpha. For the split –half coefficient, the scale was split into two halves such that the two halves would be equivalent as possible (Sampson & Benton, 2006). In splitting the items the researchers took into account the sequencing of items as if they were worded to represent a traditional or reformed perspective of science education. The value for the split-half coefficient was 0.80 and the value of coefficient alpha was 0.77, indicating that the BARSTL had a satisfactory internal consistency Sampson & Benton, 2006).

3.3.4 Permission to use the questionnaires from the originators

Sampson and Benton (2006) developed the BARSTL questionnaire. They based the questionnaire on the literature dealing with science education reforms in the United States. The literature was used to generate a content matrix which was also used to define the content of BARSTL items in terms of the construct reformed pedagogical content beliefs. The items of this construct measured the four dimensions namely a) how people learn, b) lesson design and implementation, c) characteristics of teachers and learning environment, and d) the nature of the science curriculum (Sampson and Benton, 2006). The content matrix was then used to develop the four subscales and help ensure construct validity and content validity of the BARSTL (Sampson and Benton, 2006).

According to Sampson and Benton (2006), few studies have examined how teachers' beliefs about teaching and learning align with the philosophy of the current reform movement. They go on to say that the BARSTL could be a valuable tool for science teacher educators working in practical and research settings to assess the beliefs of prospective teachers concerning the teaching and learning of science.

The Nature of Science as Argument Questionnaire (NSAAQ) was developed by Sampson and Clark 2006. According to Sampson and Clark (2006) the NSAAQ was developed as a response to the criticism concerning the validity of survey instruments that were designed to measure epistemological beliefs. "Criticisms of the survey instruments focused on the fact that respondents often did not interpret items in the same ways as the developer, survey instruments usually only measured a respondent's level of agreement with the researchers' predefined theoretical position, and the realization that students may hold inconsistent and incoherent views of the nature of science that are cued in different contexts" (Sampson and Clark, 2006:3).

Sampson and Clark (2006) sought to maximize the construct validity and criterion validity by basing the content of the instrument on a sound theoretical framework by employing the definition of the construct **science as a process of explanation and**

argument. To generate the two contrasting viewpoints represented in each item of the NSAAQ, they used literature dealing with what students should know about the nature of science and the identification of students' epistemological beliefs about the nature of science. From the literature they came up with the content matrix which they used to define the content for the NSAAQ in terms of the construct. The aspects of the construct adopted by the researchers defined the characteristics they used to discriminate between alternative epistemological beliefs and epistemological beliefs that are consistent with a view of science as a process of explanation and argument. The content matrix was then used to develop items, the four subscales, and to help ensure content validity of the NSAAQ (Sampson and Clark, 2006).

According to Sampson and Clark (2006), the NSAAQ questionnaire is likely to be a useful tool for researchers who wish to measure the degree in which an individual's epistemological beliefs are consistent with a view of science as a process of explanation and argumentation. Sampson and Benton (2006) also suggested that the BARSTL could be a valuable tool for science teacher educators working in practical and research setting to assess the beliefs of prospective teachers concerning the teaching and learning of science. These pronouncements by Sampson and Clark (2006) and Sampson and Benton (2006) taken together suggest that these instruments have been developed for the use by researchers who want to research science teachers' epistemological and teaching and learning beliefs about science. These instruments have been widely used by different researchers (Rice, 2012, Karaman and Karaman, 2013, Sexton, 2015) since they were developed and made public in 2006. This confirms that they were developed and made available to be used by researchers involved in teacher education.

3.3.5 Adaptation of research instruments

The literature reviewed for this study has revealed that curriculum reforms taking place in other countries are similar to reforms taking place in South Africa. It was also pointed out earlier that the instruments used in this study capture the views about science and science teaching and learning that are articulated by the NCS and

CAPS. Because of the similarity between the concepts and beliefs of the NCS/CAPS and concepts of the research instrument, students were considered to be familiar with the concepts from the original scales. The two research scales were therefore considered suitable for the new setting on the familiarity of the students with the concepts of the scales. The university at which this research took place is an English medium university. While the majority of the participants were second language speakers of English, their proficiency in the use of English was considered sufficient to enable them to understand the language used in these questionnaires. The language used in the questionnaires was considered to be at the same level as the language used to set the question papers at the university. There was therefore no difference between the original language and the language of the target population. Having considered these two critical validation (language and concepts) issues and also having satisfied himself that they were the similar internationally and locally, the researcher decided that the two instruments accurately reflected what the questionnaires were supposed to measure.

3.3.6 Data analysis

The NSAAQ consisted of a total of 26 items. The lowest possible score on this scale would be $26 \times 1 = 26$, and the highest possible score would be $26 \times 5 = 130$. The BARSTL questionnaire consisted of 32 items. The lowest possible score on this scale would be $32 \times 1 = 32$, and the highest possible score would be $32 \times 4 = 128$. Descriptive statistics were used to describe patterns and general trends regarding the epistemological beliefs about science held by pre-service science education students and their beliefs about science teaching and learning. From the statistical analysis those who held either naïve views about science or views about science as a process of explanation and argument were determined. Statistical analysis was used to assist in determining whether the epistemological beliefs about science held by science education students concurred with the views espoused by the NCS, and also whether students held pedagogical content beliefs about science teaching and learning that concurred with the views espoused by the NCS.

Most research studies which have evaluated student views and beliefs about science have used survey instruments similar to the NSAAQ and BARSTL questionnaires. Sahin (2009) used the Maryland Physics Expectations Survey (MPEX) to determine students' expectations, attitudes and epistemological beliefs about physics and physics learning. Chan and Sachs (2001) used the Implicit Learning questionnaire to study schoolchildren's beliefs about learning and their understanding of science text. Perkins, Adams, Pollock, Finkelstein, and Wieman (2004) used the Colorado Learning Attitudes about Science Survey (CLASS) to examine the relationship between students' beliefs about physics and other educational outcomes such as learning and student retention. In all these studies, correlation analysis has been used to determine the relationship between the beliefs, views or attitudes and some learning outcomes. To address the broad aim of the study and to answer the question if was there any correlation between pre-service science education students' **epistemological beliefs about science** and their beliefs about **science teaching and learning** students responses were first coded as S1 for student no. 1, S2 for student no. 2, and so on. Correlation was conducted to test the hypothesis **that there was no correlation between pre-service science education students' epistemological beliefs about science and their beliefs about science teaching and learning.**

Correlation was conducted at third and fourth year levels on the overall scores for teaching and learning beliefs and the overall scores for epistemological beliefs. Correlations were further conducted on fourth year level teaching and learning subscale scores and epistemological beliefs subscale scores. Lastly correlations were conducted on fourth year level overall teaching and learning beliefs scores and epistemological beliefs subscale scores.

To answer the research question how third and fourth year science education students differ in their epistemological beliefs about science and to test the hypothesis **that pre-service students hold similar epistemological beliefs about science across levels of study**, a series of t-tests were used to determine whether the means of two groups were statistically different from each other at a significance

level .05. To answer the question how third and fourth year science education students differ in their beliefs about teaching and learning and to test the hypothesis **that pre-service students hold similar beliefs about science teaching and learning across levels of study**, a series of t-tests were used to determine whether the means of two groups were statistically different from each other at a significance level .05. Trochim (2006) argues that a t- test is appropriate whenever one wants to compare the means of two groups.

To answer the question if there is any agreement between the epistemological beliefs about science held by third and fourth year pre service science education with the view about science espoused by the NCS and to test the hypothesis that **epistemological beliefs about science held by the pre-service science education students do not cohere with the nature of science views espoused by the NCS**, mean scores from student responses were calculated. A mean score below 3.5 on a question constituted a naïve view, while a mean score above 3.5 constituted a sophisticated view. A percentage of respondents who indicated 1,2 and 3 or 4 and 5 for each question was also calculated to get an indication of the percentage of students who held naïve versus sophisticated epistemological beliefs about science. Furthermore, the number of questions on which pre-service science teachers held sophisticated beliefs on each subscale was used to determine whether or not the respondents' beliefs were in agreement with the nature of science views espoused by the NCS. A minimum of four questions within a subscale demonstrated an agreement with the views espoused by the NCS, while less than four questions within a subscale demonstrated disagreement with the nature of science views espoused by the NCS.

To answer the question if there is any agreement between the science teaching and learning beliefs held by third and fourth year students with the pedagogical content beliefs about science teaching and learning espoused by the NCS and to test a hypothesis that **science teaching and learning beliefs held by the pre-service science education students do not cohere with pedagogical content beliefs about science teaching and learning espoused by the NCS**, mean scores from student

responses were calculated. Responses from each question of the BARSTL scale were scored in such a way that a response of 1 or 2 was taken as representing a traditional view, while a response of 3 or 4 was taken as representing a reformed view on each of the 32 questions. An average score below 2.5 on a question constituted a traditional view, while an average score of 2.5 and above constituted a reformed view. A percentage of respondents who indicated 1 or 2 and 3 or 4 on each question was calculated to get an indication of the percentage of respondents who held traditional and reformed pedagogical beliefs about science teaching and learning respectively. Averages were calculated to identify questions where, on average, teachers held traditional versus reformed pedagogical beliefs about science teaching and learning. The percentage calculations were also done to help determine a fraction of students who held traditional or reformed views in situations where average scores seemed either too high or too low because of outliers. If respondents who indicated 1 or 2 and 3 or 4 on each question were found to be more than 50%, the mean score was discarded in favour of the percentage score to determine whether the respondents held traditional and reformed pedagogical beliefs about science teaching and learning. The final determination whether third- and fourth-year pre-service science education students held beliefs about science teaching and learning that are in agreement with the pedagogical content beliefs about science teaching and learning espoused by the NCS was based on the number of questions representing reformed beliefs that students held on each of the four subscales of the BARSTL scale.

3.3.7 Ethical issues

According to De Vaus (2007), the researcher using a cross-sectional design needs to attend to matters of confidentiality, privacy, avoidance of harm to participants and informed consent.

3.3.7.1 *Confidentiality and privacy of information*

Confidentiality and privacy of information was ensured by making sure that information obtained through this study remained confidential. To protect students who participated in this study, the writer ensured that at all times he did not reveal the identity of the source of information, and that the information obtained was used only for the purpose of the study. However, as this study interrogated science students' beliefs which are likely to impact on their practice, it is very important that students receive feedback on the views they hold. This will again be done in such a way that students will not be associated with any expressed view when feedback is given.

3.3.7.2 *Avoidance of harm to participants*

The study ensured that participants were not physically, emotionally or spiritually harmed. Any situation that threatened to expose participants to harm of whatever nature was avoided.

3.3.7.3 *Informed consent*

Students' permission to participate in the study was sought before any data were collected. Participants were informed about their rights not to participate, or to withdraw when they did not feel like continuing.

3.8 **CHAPTER OUTLINE**

The research report contains five chapters organized as follows:

Chapter 1: Introduction. This chapter focuses on the rationale for doing the study, the statement of the problem, research objectives and research questions.

- Chapter 2: This chapter focuses on the literature review and conceptual framework.
- Chapter 3: This chapter focuses on the research design and methods.
- Chapter 4: This chapter focuses on the presentation of results.
- Chapter 5: This chapter focuses on the discussion of results, implications for the findings, limitations of the study and recommendations for further study. It will provide an evaluative summation of the investigation's findings.

3.9 CONCLUSION

This chapter has attempted to describe how data were collected and analysed in this study. In the main the chapter has described the appropriate methods and instruments as well as suitable data analysis techniques that are used to collect and analyse data when studying beliefs. In this study two instruments were used to collect data. Data analysis was done at a scale and subscale level to determine the correlation between teachers' epistemological beliefs about science and the beliefs about science teaching and learning. The computed Pearson (r) correlation coefficient was used to determine whether there was a significant relationship among the two scales and the subscales of epistemological beliefs and teaching and learning beliefs (Tranriverdi, 2012).

CHAPTER FOUR

PRESENTATION OF RESULTS

4.1 INTRODUCTION

This chapter presents the results of the Nature of Science as Argument questionnaire (NSAAQ) which was used to investigate science teachers' epistemological beliefs about science, and the results of the Beliefs about Reformed Science Teaching and Learning questionnaire (BARSTL), which was used to investigate the pre-service teachers' beliefs about science teaching and learning. These research instruments were administered to third- and fourth-year students studying towards a Bachelor of Education (B.Ed) degree in science education. The results shed some light on whether the students' level of study affected their beliefs about the nature of science as well as their beliefs about science teaching and learning. Descriptive statistics were used to determine (a) the differences in the mean scores of third- versus fourth-year students' epistemological beliefs about science versus their beliefs about science teaching and learning; (b) correlation between the third and fourth year students' epistemological beliefs about science and their beliefs about science teaching and learning; and (c) differences between mean scores of third- versus fourth-year students regarding their epistemological beliefs using the t-test statistic.

4.2 THE EPISTEMOLOGICAL BELIEFS HELD BY THIRD- AND FOURTH-YEAR PRE-SERVICE SCIENCE EDUCATION STUDENTS ABOUT SCIENCE

To address this research question the NSAAQ was administered to the two respective research samples (i.e. third- and fourth-year pre-service science education students). The respondents were asked to choose between two contrasting viewpoints using a five-point Likert scale. One viewpoint represented a naïve epistemological belief about the nature of science while the other represented a viewpoint that is consistent with the view of science as a process of explanation and argument (Sampson and Benton, 2006).

Table 4.1 shows that the overall scores on the NSAAQ survey ranged between 51 and 94 for third-year students and between 64 and 105 for fourth-year students.

Table 4.1: Summary of group scores of third- and fourth-year students on the NSAAQ scale

Year level	No of respondents	NSAAQ score
Third	62	51-94
Fourth	122	64-105

The overall epistemological beliefs mean score of third-year students was 77.71, with a standard deviation of 7.43, while an overall epistemological beliefs mean score of fourth-year students was 82.61 with a standard deviation of 7.59 (see table 4.2 below). This shows that on average, fourth-year pre-service science students' epistemological beliefs are superior to third-year students' beliefs.

Table 4.2: The NSAA questionnaire mean scores and standard deviation of third- and fourth-year students.

Third Year			Fourth Year	
Beliefs about science	Mean	Std deviation	mean	Std deviation
	77.71	7.43	82.61	7.59

The NSAAQ is divided into four subscales and distributes a total of 26 items around four topics, namely (1) the nature of scientific knowledge (6 items); (2) the method that can be used to generate scientific knowledge (6 items); (3) what counts as reliable and valid scientific knowledge (7 items); and (4) the socially and culturally embedded nature of scientific practices (7 items). Descriptive statistics were used to determine the mean scores and standard deviations of subscales for the third- and fourth-year students.

Table 4.3 shows that the mean score of the third-year students was 17.40, with a standard deviation of 3.160 on subscale 2, while the mean score of the fourth-year students was 19.69, with a standard deviation of 3.17.

Table 4.3: The NSAAQ mean subscale scores

Subscale	Third Year		Fourth Year	
	Mean score	Std Dev	Mean score	Std Dev
Subscale1	16.67	3.16	16.55	3.04
Subscale 2	17.40	3.160	19.69	3.17
Subscale 3	20.25	4.016	20.90	4.01
Subscale 4	20.75	4.090	20.34	4.22

The table shows that fourth-year students' epistemological beliefs are slightly superior to third-year students' on the methods used to generate scientific knowledge. The table also shows that fourth-year students' epistemological beliefs are slightly superior to third-year students' beliefs on what counts as reliable and valid scientific knowledge (subscale 3). There was, however, no apparent difference in the science students' beliefs on subscales 1 and 4. In subscale 1 the mean score of third-year students was 16.67, with a standard deviation of 3.16, while the mean score of fourth-year students was 16.55, with a standard deviation of 3.04. This suggests a similar level of sophistication between the two groups of students in their epistemological beliefs regarding the nature of scientific knowledge. In subscale 4 the mean score was 20.75, with a standard deviation of 4.090 for third-year students; the mean score of fourth-year students was 20.34, with a standard deviation of 4.22. Again, this suggests a similar level of sophistication between the two groups in their epistemological beliefs about the socially and culturally embedded nature of scientific practices.

In addressing this research question further, the t-test statistic was used to determine whether or not significant differences existed between the two research samples on (a) their overall mean scores on the NSAAQ, and (b) the various

subscales of the NSAAQ. Leven’s test for equality of variance was conducted, and the t-test values corresponding to equal variance and the four subscale scores were used to analyse the effect of a year of study on the epistemological beliefs about science.

Table 4.4 compares the overall and subscale epistemological beliefs mean scores with respect to year levels. According to Table 4.4, the difference in the overall epistemological beliefs mean scores for third- and fourth-year pre service science students was significant: [t(183)= 4.192, p=0.000].

This suggests that pre-service students’ epistemological beliefs are significantly higher at fourth-year level.

Table 4.4: Comparison of epistemological belief mean scores with respect to year levels

Scale	Third Year			Fourth Year			t	df	p-value
	Mean	Std deviation	N	Mean	Std deviation	N			
Overall	77.71	7.428	63	82.61	7.588	122	4.192	183	0.000*
Subscale 1	16.67	3.162	63	16.55	3.035	122	0.246	183	0.806
Subscale 2	17.40	3.160	63	19.69	3.173	122	4.662	183	0.000*
Subscale 3	20.25	4.016	63	20.90	4.005	122	1.041	183	0.299
Subscale 4	20.78	4.090	63	20.34	4.218	122	0.682	183	0.496

P<0.05*

Further analysis of epistemological beliefs mean scores per subscale shows that the difference in epistemological beliefs mean scores for subscale 2 was significant: [t(183)=4.662, p=0.000]. **This indicates that fourth-year students held superior epistemological beliefs with regard to the methods used to generate scientific knowledge.** However, the difference in mean scores of the two research samples in subscale 1 [t(183) = 0.246, p=0.806], subscale3 [t(183)=1.041,p=0.299] and subscale 4 [t(183)=0.682, p=0.496] were not statistically significant. **This suggests that fourth-year pre-service science students do not differ from third-year students in the**

epistemological beliefs they hold about the nature of scientific knowledge, the socially and culturally embedded nature of scientific practices, and what counts as reliable and valid scientific knowledge.

4.3 BELIEFS HELD BY THIRD- AND FOURTH- YEAR PRE-SERVICE SCIENCE EDUCATION STUDENTS ABOUT SCIENCE TEACHING AND LEARNING

As already stated, in answering this research question, the BARSTL questionnaire was used to measure the reformed pedagogical science beliefs for third- and fourth-year pre-service science education students. The BARSTL is a four-point Likert scale which operationalizes questions on a traditional – reformed pedagogical content belief continuum (Khan, 2012).

Table 4.5 presents a summary of third- and fourth-year respondent’s minimum and maximum BARSTL scores.

Table 4.5: Summary of group scores for BARSTL

Year level	No of respondents	of	BARSTL score
Third	62		66-88
Fourth	122		59-104

Table 4.5 shows that the overall scores on the BARSTL ranged between 66 and 88 for third- year students while the overall mean score for fourth-year students ranged between 59 and 104.

Table 4.6 presents BARSTL mean scores and standard deviations for third- and fourth-year respondents.

Table 4.6: The BARSTL mean scores and standard deviation for third- and fourth-year students.

		Third Year		Fourth Year	
Teaching	and	Mean	Std	mean	Std
Learning			deviation		deviation
		79.32	4.24	81.20	6.44

The means and standard deviations were calculated for overall scores for each group of pre- service science teachers. The overall teaching and learning beliefs (BARSTL) mean score for third-year students was 79.32 with a standard deviation of 4.24 (see table 4.6 above). The overall teaching and learning mean score for fourth-year students was found to be 81.20 with a standard deviation of 6.44. This statistic shows that both groups of respondents held traditional teaching and learning beliefs about science. Fourth-year respondents’ beliefs about science teaching and learning were, however, marginally superior to third-year students’ beliefs.

Descriptive statistics were further employed to determine the subscale mean scores and standard deviations for third- and fourth-year students. This was done to try and understand how the students’ beliefs about science teaching and learning differed on the different components of the BARSTL scale.

The BARSTL questionnaire consists of 32 items which are divided into four subscales as follows: subscale 1: how people learn about science; subscale 2: lesson design and implementation; subscale 3: characteristics of teachers and the learning environment; and subscale 4: the nature of science curriculum. Each subscale consists of eight items. Table 4.7 shows the mean scores and standard deviations on the subscales for the two respective research samples.

Table 4.7 shows the BARSTL mean scores for third- and fourth-year respondents.

Table 4.7: mean subscale scores –teaching and learning

Third Year			Fourth Year	
Subscale	Mean score	Std.Dev	Mean score	Std.Dev
Subscale 1	19.22	2.43	19.82	2.52
Subscale 2	19.19	2.147	19.80	2.73
Subscale 3	20.60	2.433	21.57	2.41
Subscale 4	20.10	1.316	19.95	2.88

Table 4.7 shows that the third-year students had a mean score of 19.22 with a standard deviation of 2.43, while the fourth-year students had a mean score of 19.82 with a standard deviation of 2.52 in subscale 1. This demonstrated that students at fourth-year level held beliefs that were slightly superior to third years on the characteristics of teachers and learning environment (subscale 3). On subscale 2 third-year students had a mean score of 19.19 and a standard deviation of 2.147, while fourth-year students had a mean score of 19.80, with a standard deviation of 2.73. These scores also show a slight difference in beliefs between the third- and fourth-year students on the lesson design and implementation (subscale2). This marginal difference in mean scores between third- and fourth-year students is also demonstrated in subscale 3, where third-year students had a mean score of 20.60 with a standard deviation of 2.433, while fourth-year students had a mean score of 21.57 with a standard deviation of 2.41. This again showed that fourth-year students had a slightly better understanding of the characteristics of teachers and the learning environment than did third-year students.

On subscale 4, the mean scores showed that third-year students' beliefs were superior to fourth-year students' beliefs – suggesting that third-year pre-service science students' beliefs were slightly better than those held by their fourth-year counterparts.

In addressing this research question further a t-test was conducted to determine whether or not the difference between the overall teaching and learning beliefs

scores for third- and fourth-year pre-service science education students was statistically significant. The t-test statistic was also run to determine if statistically significant differences existed between the mean scores of the third- and fourth-year students on the BARSTL subscales. Leven’s test for equality of variance was conducted, and the t-test values corresponding to ‘equal variance assumed’ row for the three subscales were used to analyse the effect of a year of study on the respondents’ beliefs regarding teaching and learning about science. The same effect was also tested by using the t-test values corresponding to equal variance not assumed row for overall teaching and learning about science, with regard to the scores for subscale 4. The results of these analyses are presented in table 4.8.

Table 4.8 compares the teaching and learning mean scores for third- and fourth-year respondents.

Table 4.8: Comparison of teaching and learning mean scores with respect to the two research samples.

Scale	Year level 3			Year level 4			t- value	df	p-value
	mean	Std deviation	N	mean	Std deviation	N			
Overall	79.32	4.238	63	81.20	6.435	122	2.378	172.344	0.019*
Subscale 1	19.22	2.426	63	19.82	2.516	122	1.549	183	0.123
Subscale 2	19.19	2.147	63	19.80	2.729	122	1.551	183	0.123
Subscale 3	20.60	2.433	63	21.57	2.412	122	2.564	183	0.011*
Subscale 4	20.10	1.316	63	19.95	2.787	122	0.478	181.883	0.633

P<0.05*

According to table 4.8 the difference in the overall mean scores of the two research samples concerning their beliefs about teaching and learning was statistically significant: [t(172.344)= 2.378, p=0.019]. **This suggests that pre-service students held significantly higher reformed oriented science teaching and learning beliefs at fourth-year level.**

Further analysis of teaching and learning beliefs about science per subscale shows that the difference in the mean scores of the two research samples was significant on subscale 3 [$t(183)=2.564$, $p=0.011$], **suggesting that fourth-year students ($\bar{x} = 21.57$) demonstrated a significantly higher level of “reformed oriented teaching and learning beliefs” about science than did the third-year students ($\bar{x} = 20.60$) on the characteristics of teachers and the learning environment.** There were no significant differences between the two research samples with regard to subscales 1, 2 and 4. **This means that the two research samples held the same beliefs about (a) how people learn about science (subscale 1), (b) learning design and implementation (subscale 2), and (c) the nature of the science curriculum (subscale 4).**

4.4 THE CORRELATION BETWEEN STUDENTS’ EPISTEMOLOGICAL BELIEFS ABOUT SCIENCE AND THEIR BELIEFS ABOUT SCIENCE TEACHING AND LEARNING

The Pearson product-moment correlation coefficient was used to determine if there was a statistically significant relationship between the respondents’ epistemological beliefs about science and their beliefs about science teaching and learning at third- and fourth-year levels. **The results showed that there was no significant correlation between the third-year respondents’ epistemological beliefs about science versus teaching and learning beliefs** (see table 4.9). However, there was a small but statistically significant correlation between epistemological beliefs about science and science teaching and learning beliefs for the fourth-year respondents ($r=0.290$, $p<0.01$). This shows that fourth-year pre-service science teachers’ epistemological beliefs about science were moderately associated with their beliefs about science teaching and learning. This moderate relationship between these two variables indicates that respondents who held superior epistemological beliefs about science were likely to hold superior beliefs about science teaching and learning.

Table 4.9: Correlation matrix for teaching and learning beliefs and the epistemological beliefs scores (of third- and fourth-year students)

Group	Scale		BARSTL- Scale	NSAAQ- Scale
Level 3	1. BARSTL- Scale	Pearson	1	0.106
		Correlation		
		Sig	-	.409
	2. NSAAQ-Scale	N	63	63
		Pearson	0.106	1
		Correlation		
Level 4	1. BARSTL- Scale	Sig	0.409	
		N	63	63
		Pearson	1	0.290*
	2. NSAAQ-Scale	Correlation		
		Sig	-	.001
		N	122	122
2. NSAAQ-Scale	Pearson	0.290*	1	
	Correlation			
	Sig	0.001	-	
		N	122	122

*P<0.01

Table 4.9 shows that a **significant correlation existed between fourth-year respondents' epistemological beliefs about science vis-à-vis their beliefs about science teaching and learning.**

Further analysis per subscale shows that there was a correlation between epistemological beliefs about science subscales and the science teaching and learning beliefs subscales at fourth-year level. The correlation test was done to determine if there was any relationship between any subscale of the BARSTL scale and any subscale of any NSAAQ scale. From the table we can see a weak but statistically significant correlation between subscale 1 of BARSTL and subscale 2 of NSAAQ. BARSTL subscale 1 measures beliefs about how people learn science, and

NSAAQ subscale 2 measures epistemological beliefs about how scientific knowledge is generated. This correlation demonstrates that fourth-year students who held superior beliefs about how scientific knowledge is generated were likely to hold superior beliefs about how people learn science. There was no other significant correlation that was observed between the subscales of epistemological beliefs about science and science teaching and learning beliefs subscales (see table 4.10).

Table 4.10 presents correlation matrix for teaching and learning and epistemological beliefs subscale scores for fourth-year students. Correlations were also tested to determine if there was a significant relationship between the overall science teaching and learning (BARSTL scale) scores and the epistemological beliefs about science (NSAAQ) subscales. A statistically significant correlation ($r=0.203$, $p < 0.05$) was found between the science teaching and learning beliefs (BARSTL) scale and the epistemological beliefs about science (NSAAQ) subscale 2. This correlation shows that fourth-year pre-service science teachers who held superior beliefs about science teaching and learning were likely to hold superior beliefs about how scientific knowledge is generated.

Table 4.10: Correlation matrix for teaching and learning beliefs and the epistemological beliefs subscale scores (of fourth-year students)

Group	Scale		BARSTL- subscale1	NSAAQ- subscale1
Level 4	BARSTL- subscale1	Pearson	1	-0.003
		Correlation		
		Sig	-	0.972
	NSAAQ- subscale1	N	122	122
		Pearson	-0.003	1
		Correlation		
		Sig	0.972	-
		N	122	122

BARSTL- subscale1	Pearson	1	0.192**
	Correlation		
	Sig	-	.034
	N	122	122
NSAAQ- subscale2	Pearson	0.192**	1
	Correlation		
	Sig	0.034	-
	N	122	122
BARSTL- subscale1	Pearson	1	0.078
	Correlation		
	Sig	-	0.394
	N	122	122
NSAAQ- subscale3	Pearson	0.078	1
	Correlation		
	Sig	0.394	-
	N	122	122
BARSTL- subscale1	Pearson	1	0.099
	Correlation		
	Sig	-	0.277
	N	122	122
NSAAQ- subscale4	Pearson	0.099	1
	Correlation		
	Sig	0.277	-
	N	122	122

** P<0.05

There were no statistically significant correlations that were observed between the teaching and learning beliefs scale and other epistemological beliefs subscales (see table 4.11). This observation and the observations prior to this one (namely BARSTL subscale 2 mean score, correlation between BARSTL subscale with NSAAQ 1 subscale) points to a very important conclusion: that BARSTL subscale 2 seems to

have contributed significantly to the increase in the fourth-year students' beliefs about science teaching and learning.

Table 4.11: Correlation matrix for teaching and learning beliefs scale and the epistemological beliefs subscale scores (of fourth-year students)

Group	Scale		BARSTL	NSAAQ- subscale1
Level 4	BARSTL	Pearson	1	0.006
		Correlation		
		Sig	-	0.945
		N	122	122
	NSAAQ- subscale1	Pearson	0.006	1
Correlation				
Sig		0.945	-	
N		122	122	
	BARSTL	Pearson	1	0.203**
Correlation				
Sig		-	0.025	
N		122	122	
	NSAAQ- subscale2	Pearson	0.203**	1
Correlation				
Sig		0.025	-	
N		122	122	
	BARSTL-	Pearson	1	-0.018
Correlation				
Sig		-	0.845	
N		122	122	
	NSAAQ- subscale3	Pearson	0.018	1
Correlation				
Sig		0.845	-	
N		122	122	
	BARSTL	Pearson	1	0.110
Correlation				
Sig		-	0.227	

	N	122	122
NSAAQ-	Pearson	0.110	1
subscale4	Correlation		
	Sig	0.227	-
	N	122	122

** P<0.05

Further correlations were conducted to determine if there were significant relationships between the epistemological beliefs about science (NSAAQ scale) and the science teaching and learning (BARSTL) subscales (see table 4.12). The epistemological beliefs about science (NSAAQ) scale had a positive and statistically significant relationship ($r=0.248$, $p<0.01$) with the beliefs about how people learn science (BARSTL subscale 1). This suggested that fourth-year respondents who held superior beliefs about science also held reformed beliefs about how people learn science. There was also a significant relationship between the NSAAQ scale and the BARSTL subscale 2 ($r= 0.203$, $P<0.05$) suggesting that fourth year respondents who held superior epistemological beliefs about science also held sophisticated beliefs about the design and implementation of a lesson. Another positive and significant relationship was observed between the NSAAQ scale and the BARSTL subscale 4 ($r=0.224$, $p<0.05$), which suggested that fourth-year respondents who held sophisticated beliefs about science also held reformed beliefs about the nature of the science curriculum. There was no significant relationship between the epistemological beliefs about science scale and the science teaching and learning subscale 3 (characteristics of teachers and the learning environment).

Table 4.12: Correlation matrix for the epistemological beliefs overall score and the teaching and learning beliefs subscale scores (of fourth-year students)

Group	Scale		1NSAAQ	BARSLT- subscale1	
Level 4	NSAAQ	Pearson	1	0.248**	
		Correlation			
		Sig	-	0.006	
		N	122	122	
		BARSTL- subscale1	Pearson	0.248**	1
			Correlation		
	Sig		0.006	-	
	N		122	122	
	NSAAQ		Pearson	1	0.203*
			Correlation		
		Sig	-	0.025	
		N	122	122	
BARSTL- subscale2		Pearson	0.203*	1	
		Correlation			
	Sig	0.025	-		
	N	122	122		
	NSAAQ	Pearson	1	0.026	
		Correlation			
Sig		-	0.776		
N		122	122		
BARSTL- subscale3		Pearson	0.026	1	
		Correlation			
	Sig	0.776			
	N	122	122		
	NSAAQ	Pearson	1	0.224*	
		Correlation			

	Sig	-	0.013
	N	122	122
BARSLT-	Pearson	0.224*	1
subscale4	Correlation		
	Sig	0.013	-
	N	122	122

* P<0.05

**p<0.01

4.5 RESPONDENTS EPISTEMOLOGICAL BELIEFS ABOUT SCIENCE VERSUS THE VIEWS ABOUT SCIENCE ESPOUSED BY THE NCS

This question was answered by scoring the NSAAQ scale in such a way that a response of 1, 2 or 3 was taken as representing a “naïve view”, while responses of 4 and 5 were taken as representing an “informed view” on each of the 26 questions. According to Rice (2012), participants who select 3 in their responses to any question on the NSAAQ are deemed to be unable to make a distinction between a naïve view and an informed view, which indicates a limited understanding of the nature of science that is acceptable internationally. An average score below 3.5 on a question constituted a naïve view, while an average score from 3.5 constituted a sophisticated view. A comparison of mean scores for third- and fourth-year students on each question was made to establish whether their epistemological beliefs were naïve or sophisticated. A percentage of respondents who indicated 1,2 and 3 or 4 and 5 on each question was also calculated to get an indication of the percentage of students who held naïve versus sophisticated epistemological beliefs about science. The percentage calculations were also done to help determine a fraction of students who held naïve or sophisticated views in situations where average scores seemed either too high or too low because of outliers. If respondents who indicated 1,2 and 3 or 4 and 5 on each question were found to be more than 50%, the mean score was discarded in favour of the percentage score to determine whether the respondents held naïve and sophisticated beliefs about science. The final determination whether third- and fourth-year pre-service science education students held epistemological

beliefs about science that are in agreement with the nature of science views espoused by the NCS was based on the number of questions representing sophisticated beliefs that students held on each of the four subscales of the NSAAQ scale. A minimum of four questions out of six within a subscale demonstrated an agreement with the views espoused by the NCS, whilst less than four questions out of six within a subscale demonstrated disagreement with the nature of science views espoused by the NCS.

NSAAQ Subscale 1

Table 4.13 presents a comparison of the epistemological beliefs of the two research samples on the first NSAAQ subscale.

Table 4.13: Mean and percentage scores for the Epistemological beliefs questions of third and fourth year respondents (subscale 1)

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	%participants responding 1,2 or 3	%participants responding 4 or 5	M(SD)	%participants responding 1, 2 or 3	%participants responding 4 or 5
Question1-6	What is the nature of scientific knowledge						
1	Scientific knowledge represents only one possible explanation or description of reality	1.60(0.943)	96.8	3.2	1.65(0.989)	90.2	9.8
2	Scientific knowledge should be considered tentative	3.17(1.199)	55.5	44.5	3.79(1.100)	37.7	62.3
3	Scientific knowledge is subjective	3.10(1.201)	71.4	28.6	3.41(1.341)	50.8	49.2
4	Scientific knowledge usually changes over time as a result of new research and perspective	3.33(1.48)	47.7	52.3	4.11(1.221)	23.7	76.3
5	The concept of species was invented by scientists as a way to describe life on earth	3.19(1.203)	61.9	38.1	3.23(1.198)	57.4	42.6
6	Scientific knowledge is best described as an attempt to describe and explain how the world works	3.08(0.972)	73.1	26.9	3.26(0.892)	62.5	37.5
		2.91			3.24		

According to Table 4.13 third year students demonstrated naïve views on five out of six questions of this subscale and had a mean score of 1.60 and a standard deviation of 0.943 on the belief that scientific knowledge represents only one possible explanation or description of reality. Fourth year students demonstrated naïve views on four out of six questions on **the nature of scientific knowledge** subscale with a mean score of 1.65 and a standard deviation of 0.989 on the belief that scientific knowledge represents only one possible explanation or description of reality. Fourth year respondents however held sophisticated beliefs on question 2 (scientific knowledge should be considered tentative) with a mean score of 3.79 and a standard deviation of 1.100 and on question 4 (scientific knowledge usually changes over time as the result of new research and perspective) with a mean score of 4.11 and a standard deviation of 1.22.

NSAAQ Subscale 2

The epistemological beliefs of two research samples were compared on the second subscale of the NSAAQ (see table 4.14)

Table 4.14: Mean and percentage scores for the Epistemological beliefs questions of third and fourth year respondents (subscale 2)

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	%participants responding 1,2 or 3	%participants responding 4 or 5	M(SD)	%participants responding 1, 2 or 3	%participants responding 4 or 5
Question7-12	How is scientific knowledge generated						
7	Experiments are important in science as they can be used to generate reliable evidence	3.30(0.909)	71.4	28.6	3.30(0.942)	64.8	35.2
8	The methods used by scientists vary based on the purpose of the research and the discipline	3.63(1.418)	38.1	61.9	4.11(1.239)	18.8	81.2
9	The methods used to generate scientific values are based on a set of values rather than a set of techniques	3.14(1.176)	60.3	39.7	3.51(1.374)	44.3	55.7
10	Science is best described as a process of explanation and argument	2.49(1.105)	81	19	2.20(1.004)	91.8	8.2
11	An experiment is used to test an idea	3.10(1.073)	71.4	28.6	3.18(1.164)	64.8	35.2
12	Within the scientific community debates and discussions that focus on the context, processes and products of inquiry are common	3.35(1.034)	57.2	42.8	3.42(1.309)	45	55
		2.61			2.74		

Table 4.14 shows that third year students held naïve beliefs on five out of six questions regarding **how scientific knowledge is generated** (subscale2). The third year students obtained a mean score of 3.30 and a standard deviation of 0.909 on the belief that experiments are important in science because they can be used to generate reliable evidence; a mean score of 3.14 and a standard deviation of 1.176 on the belief that the methods used to generate scientific knowledge are based on a set of values rather than a set of techniques. They also obtained a mean score of 2.49 and a standard deviation of 1.105 on the belief that science is best described as a process of explanation and argument; a mean score of 3.10 and a standard deviation of 1.073 on the belief that an experiment is used to test an idea; a mean score of 3.35 and standard deviation of 1.034 on the belief that within the scientific community debates and discussions that focus on the context, processes, and products of inquiry are common. Third year students however demonstrated a sophisticated view on the belief that the methods used by scientist vary based on the purpose of the research and the discipline thereby securing a mean score of 3.63 on this question with a standard deviation of 1.418.

With reference to the fourth year students table 4.14 shows that they held the naïve beliefs that: experiments are important in science because they can be used to generate reliable evidence. They obtained a mean score of 3.30 and a standard deviation of 0.942 on this question; on the belief that science is best described as process of explanation and argument they obtained a mean score of 2.20 and a standard deviation of 1.004. On the belief that an experiment is used to test an idea they secured a mean score of 3.18 and a standard deviation of 1.164.

Further analysis of data, however, showed that 55% of fourth-year students held sophisticated views on question 12. While the average score caused the fourth-year students to be categorized as naïve on this question, percentage analysis shows that the majority of students held sophisticated views on this question. Therefore on subscale 2 fourth-year students' beliefs were found to be sophisticated on questions 8, 9 and 12, implying that they are sophisticated on the beliefs that the methods used by scientists vary based on the purpose of the research and the discipline; that the methods used to generate scientific knowledge are based on a set of values rather than a set of techniques; and that science is best described as a process of explanation and

argument. This is in contrast to the third-year respondents who demonstrated sophistication on one belief only (question 8) in this subscale.

NSAAQ Subscale 3

Table 4.15 presents a comparison of the epistemological beliefs of the two research samples on the third NSAAQ subscale.

Table 4.15: Mean and percentage scores for the epistemological beliefs questions of third- and fourth-year respondents (subscale 3)

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	% participants responding 1,2 or 3	% participants responding 4 or 5	M(SD)	% participants responding 1, 2 or 3	% participants responding 4 or 5
Question 13-19	What counts as reliable and valid scientific knowledge						
13	Scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued	2.70(1.057)	84.1	15.9	2.40(1.144)	83.6	16.4
14	It is impossible to gather enough evidence to prove something true	2.24(1.254)	81	19	2.54(1.415)	71.3	28.7
15	The reliability and trustworthiness of data should always be questioned	2.92(1.168)	74.6	25.4	3.21(1.294)	56.6	43.4
16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles	3.22(1.361)	58.7	41.3	3.30(1.156)	57.4	42.6
17	Biases and errors are unavoidable during a scientific investigation	2.62(1.475)	73	27	2.92(1.541)	61.5	38.5
18	A theory can still be useful even if one or more facts contradict that theory	3.06(1.176)	68.3	31.7	2.97(1.414)	61.4	38.6
19	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked with that chemical	2.84(1.153)	76.2	23.8	2.98(1.237)	68	32
		2.80			2.90		

According to Table 4.15, third-year students held naïve beliefs on all the seven questions on this subscale. They obtained a mean score of 2.70 and a standard deviation of 1.057 on the belief that scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued; about 84.1% believed that scientific knowledge could be considered trustworthy if it was well supported by evidence. On the belief that it is impossible to gather enough evidence to prove something true, a mean score of 2.24 with a standard deviation of 1.254 was recorded, and the majority (81%) of the students believed that the scientific method could provide absolute proof. Further on the belief that biases and errors are unavoidable during a scientific investigation, third-year students obtained a mean score of 2.62, with a standard deviation of 1.475; most (73%) of them believed that when a scientific investigation is done correctly errors and biases are eliminated.

Concerning fourth-year students, table 4.15 shows that they also held naïve beliefs on all the seven questions of this subscale. They obtained a mean score of 2.40 and a standard deviation of 1.144 on the belief that scientific knowledge can only be considered trustworthy if the methods, data and interpretations of the study have been shared and critiqued; about 83.6% believed that scientific knowledge could be considered trustworthy if it was well supported by evidence. On the belief that it is impossible to gather enough evidence to prove something true, a mean score of 2.54 with a standard deviation of 1.415 was recorded, and the majority (71.3%) believed that the scientific method could provide absolute proof. Further on the belief that biases and errors are unavoidable during a scientific investigation, the fourth-year students scored a mean of 2.92 with a standard deviation of 1.541. This demonstrates that most of them (61.4%) believed that when a scientific investigation is done correctly errors and/or biases are eliminated.

NSAAQ Subscale 4

Table 4.16 presents a comparison of the epistemological beliefs of the two research samples on the fourth NSAAQ subscale.

Table 4.16: Mean and percentage scores for the epistemological beliefs questions of third- and fourth-year respondents (subscale 4)

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	% participants responding 1, 2 or 3	% participants responding 4 or 5	M(SD)	% participants responding 1, 2 or 3	% participants responding 4 or 5
Question 20-26	What role do scientists play in the generation of scientific knowledge?						
20	In order to interpret data they gather, scientists rely on their prior knowledge, logic and creativity	3.29(1.211)	54	46	3.79(1.166)	34.5	65.5
21	Scientists are influenced by social factors, their personal beliefs and past research	2.90(1.266)	63.5	36.5	3.43(1.413)	39.4	60.6
22	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists	2.71(1.197)	76.2	23.8	2.83(1.202)	70.5	29.5
23	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions	3.21(1.034)	65.1	34.9	3.17(1.380)	51.7	47.3
24	A scientist's personal beliefs and training influences what they believe counts as evidence	2.97(1.218)	65.1	34.9	3.29(1.221)	54.1	45.1
25	The observations made by two different scientists about the same phenomenon can be different	3.32(1.242)	57.1	42.9	3.64(1.217)	41	58.2
26	A scientist's conclusions may be wrong even though scientists are experts in their fields	3.22(1.263)	58.7	41.3	3.40(1.410)	43.5	56.5
		3.09			3.36		

Table 4.16 shows that the third-year students were naïve on seven out of seven questions on **the role scientists play in generating scientific knowledge** (subscale 4). On the belief that in order to interpret data they gather scientists rely on their prior knowledge, logic and creativity, third-year students scored a mean of 3.29 and a standard deviation of 1.211. Third-year students also scored a mean score of 2.90 and a standard deviation of 1.266 on the belief that scientists are influenced by social factors, their personal beliefs, and past research; whilst on the belief that scientists' personal beliefs and training influences what they believe counts as evidence, third-year students had a mean score of 2.94 and a standard deviation of 1.218. Furthermore, the third-year students scored a mean of 3.32 and a standard deviation of 1.242 on the belief that the observation made by two different scientists about the same phenomenon can be different, while on the belief that a scientist's conclusions can be wrong even though scientists are experts in their fields they obtained a mean score of 3.22 and a standard deviation of 1.263.

Further, table 4.16 shows that fourth-year students demonstrated sophisticated beliefs on four out of the seven questions of subscale 4. The fourth-year students were found to hold a sophisticated belief that in order to interpret data they gather scientists rely on their prior knowledge, logic and creativity with a mean score of 3.79 and a standard deviation of 1.166. On the belief that scientists are influenced by social factors, their personal beliefs and past research, and the belief that a scientist's conclusions can be wrong even though scientists are experts in their fields, the fourth-year students obtained a mean score of 3.43 and a standard deviation of 1.413, and a mean score of 3.40 and standard deviation of 1.410 respectively.

Further analysis revealed that 60.6% fourth-year students' beliefs were sophisticated on the view that scientists are influenced by social factors, their personal beliefs and past research, whilst 56.5% were sophisticated on the belief that a scientist's conclusions can be wrong even though scientists are experts in their fields. They were also sophisticated on the belief that the observations made by two different scientists about the same phenomenon can be different; they scored a mean of 3.64 and a standard deviation of 1.217. Fourth-year students were, however, naïve on the

belief that two scientists (with the same expertise) reviewing the same data will often reach different conclusions; they obtained a mean score of 3.17 and a standard deviation of 1.380; and on the belief that scientists' personal beliefs and training influence what they believe counts as evidence, they secured a mean score of 3.29 and a standard deviation of 1.221.

The analyses on tables 4.13, 4.14, 4.15 and 4.16 have been an attempt to answer the research question about whether or not the epistemological beliefs about science held by pre-service science education students at the third- and fourth-year levels of their studies are in agreement with the nature of science views espoused by South Africa's NCS.

According to the physical sciences NCS grades 10-12 (2003:11), it is important for learners in physical sciences to understand:

- ❖ The scientific enterprise and, in particular, how scientific knowledge develops
- ❖ That scientific knowledge is in principle tentative and subject to change as new evidence becomes available
- ❖ That knowledge is contested and accepted, and develops on social, religious and political factors
- ❖ That the explanatory power and limitations of scientific systems and theories need to be evaluated

Rice (2012) argues that the NSAAQ subscales were developed to address the internationally accepted concepts of the nature of science, and to provide a tool that could be used to discriminate between the views on the nature of science held by respondents. To this end, the NSAAQ subscales can be linked to the views about science advocated by the physical sciences NCS document. Subscale 2 of the NSAAQ scale (how scientific knowledge is generated) can be linked to the understanding of the scientific enterprise and how scientific knowledge develops in the NCS. Subscale 1 (what is the nature of scientific knowledge?) can be linked to the understanding that scientific knowledge is tentative and subject to change as new evidence

becomes available. Subscale 3 (what counts as reliable and valid scientific knowledge?) can be linked to the understanding that the explanatory power and limitations of scientific systems and theories need to be evaluated. Finally, subscale 4 (the role scientists play in the generation of scientific knowledge) can be linked to the NCS's understanding that knowledge is contested and accepted, and develops on social, religious and political factors.

The analyses done earlier on the third- and fourth-year respondents' epistemological beliefs about science reveal that third-year students were found to hold a sophisticated view on only one question on the NSAAQ scale, namely that the methods used by scientists vary based on the purpose of the research and the discipline. This demonstrates that third-year pre-service science education students held epistemological beliefs about science that are not in agreement with the nature of science views espoused by the NCS in all the subscales of the NSAAQ. Fourth-year students were, however, found to hold sophisticated beliefs on a number of questions on three subscales of the NSAAQ scale. On **the nature of scientific knowledge** (subscale 1), fourth-year students were found to hold sophisticated beliefs on two questions. In this scale 62.3% believed that scientific knowledge should be considered tentative, and 76.3% believed that scientific knowledge usually changes over time as a result of new research and perspectives. On **how scientific knowledge is generated** (subscale 2), fourth-year students were found to hold sophisticated beliefs on three questions. On this subscale 81.2% believed that the methods used by scientists vary based on the purpose of the research and the discipline, 55.7% believed that the methods used to generate scientific values are based on a set of values rather than a set of techniques, and 55% believed that within the scientific community, debates and discussions that focus on the context, processes and products of inquiry are common. On **the role played by scientists in the generation of knowledge** (subscale 4), fourth-year students were found to hold sophisticated beliefs on four questions: about 65.5% held the view that in order to interpret data they gather, scientists rely on their prior knowledge, logic and creativity, 60.6% believed that scientists are influenced by social factors, their personal beliefs and past research, 58.2% believed that the observations made by

two different scientists about the same phenomenon could be different, and 56.5% believed that a scientist's conclusions may be wrong, even though scientists are experts in their fields. These sophisticated views held by fourth-year pre-service science students are in line with the views espoused by the NCS.

While fourth-year students held some sophisticated beliefs in subscales 1 and 2, a conclusion can, however, be drawn that the fourth-year pre-service science education students held epistemological beliefs about science that were not in agreement with the views about science espoused by the NCS on **the nature of scientific knowledge** (subscale 1), and on **how scientific knowledge is generated** (subscale 2).

Fourth-year students were also found to be naïve on all the questions of subscale 3 of the NSAAQ scale. This demonstrates that the fourth-year students held epistemological beliefs about science that were not in agreement with the views about science espoused by the NCS on **what counts as reliable and valid scientific knowledge** (subscale 3). However, the fourth-year pre-service science education students were found to hold epistemological beliefs about science that were in agreement with the views about science espoused by the NCS on **the role played by scientists in the generation of knowledge** (subscale 4).

On the basis of the above analyses the researcher can conclude that (a) the third-year respondents did not hold beliefs that were consistent with the science views espoused by the NCS, while (b) the fourth-year research sample partially held beliefs that were in consonance with those espoused by the NCS.

4.6 CORRELATION BETWEEN THE SCIENCE TEACHING AND LEARNING BELIEFS HELD BY RESPONDENTS WITH THE PEDAGOGICAL CONTENT BELIEFS ESPOUSED BY THE NCS.

The fifth and final research question sought to find out if there was an agreement between the beliefs held by respondents about science teaching and learning with the pedagogical content beliefs espoused by the NCS.

The scores from the (BARSTL) scale were used to answer this research question. The BARSTL scale is a 32-item scale. According to Sampson and Benton (2006), the BARSTL scale draws on the philosophy of the current national science education reform efforts in order to define a traditional--reformed pedagogical content belief continuum. Responses from each question of the BARSTL scale were scored in such a way that a response of 1 or 2 was taken as representing a traditional view, while a response of 3 or 4 was taken as representing a reformed view on each of the 32 questions. An average score below 2.5 on a question constituted a traditional view, while an average score of 2.5 and above constituted a reformed view. A percentage of respondents who indicated 1 or 2 and 3 or 4 on each question were calculated to get an indication of the percentage of respondents who held traditional and reformed pedagogical beliefs about science teaching and learning respectively.

Averages were calculated to identify questions where, on average, teachers held traditional versus reformed pedagogical beliefs about science teaching and learning. The percentage calculations were also done to help determine a fraction of students who held traditional or reformed views in situations where average scores seemed either too high or too low because of outliers. If respondents who indicated 1 or 2 and 3 or 4 on each question were found to be more than 50%, the mean score was discarded in favour of the percentage score to determine whether the respondents held traditional and reformed pedagogical beliefs about science teaching and learning.

The final determination whether third- and fourth- year pre-service science education students held beliefs about science teaching and learning that are in agreement with the pedagogical content beliefs about science teaching and learning espoused by the NCS was based on the number of questions representing reformed beliefs that students held on each of the four subscales of the BARSTL scale. The mean scores were the main determinants of the beliefs held by the respondents. However, to address the problem of outliers in some questions, percentage calculations were used to pronounce on the beliefs held by the respondents, as explained earlier. If respondents scored a total of five reformed beliefs out of eight

on each subscale, the score constituted beliefs that are in agreement with the pedagogical content beliefs about science teaching and learning on that subscale.

BARSTL Subscale 1

Table 4.17 presents mean scores and percentage scores of third- and fourth-year respondents on the teaching and learning beliefs for subscale 1 of BARSTL.

Table 4.17: Mean and percentage scores for the Teaching and Learning beliefs questions (of third and fourth year respondents) subscale 1

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	%participants responding 1or2	%participants responding 3 or 4	M(SD)	%participants responding 1or2	%participants responding 3or 4
Question1-8	How people learn about science						
1	Students develop many beliefs about the world before they even study about science in school	3.05(0.682)	14.3	85.7	3.05(0.726)	15.6	84.4
2	Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences	2.86(0.667)	20.6	79.6	2.87(0.771)	25.4	74.6
3	People are either talented at science or they are not, therefore students achievement in science is a reflection of their natural abilities.	2.74(0.895)	65.1	34.9	2.37(0.947)	53.3	46.7
4	Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand	1.48(0.644)	92	8	1.35(0.544)	96.7	3.3
5	Frequently, students have difficulty learning scientific concepts in school because their beliefs about how the world works are often resistant to change	2.71(0.876)	42.8	57.2	2.39(0.818)	59.9	40.1
6	Learning science is an orderly process; students learn by gradually accumulating more information about the topic over time	1.90(0.670)	84.1	15.9	1.93(0.729)	80.3	19.7
7	Students know very little about science before they learn it in school	1.71(0.876)	81	19	2.17(0.968)	62.3	37.7
8	Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction	3.53(0.824)	6.4	93.6	3.70(0.573)	24.6	75.4
		2.50			2.50		

Table 4.17 shows that third-year respondents held reformed pedagogical beliefs about science teaching and learning on five out of eight questions of subscale 1. The mean score for question one was 3.05, with a standard deviation of 0.682, showing that third-year students held “reformed” beliefs, and that students develop many beliefs about the world before they study science, while in question 2 the mean score was 2.86, with a standard deviation of 0.667. The mean score was 2.74 for question 3, with a standard deviation of 0.895; in question 5 the mean score was 2.71, with a standard deviation of 0.876, and the mean score for question 8 was 3.53, with a standard deviation of 0.824. However, percentage analyses for question 3 resulted in the discarding of an average score of 2.74 as the percentage analysis showed that about 65.1% of third-year respondents had chosen a response of 1 or 2, which rendered them traditional in their beliefs on this question. This analysis therefore reduced questions on which third-year respondents held reformed beliefs from five to four in this subscale.

The mean scores in Table 4.17 show that fourth-year students held reformed beliefs on three questions out of eight on subscale 1. On question 1 the mean score was 3.05, with a standard deviation of 0.726. The mean score was 2.87, with a standard deviation of 0.771 for question 2, whilst the mean score for question 8 was 3.70, with a standard deviation of 0.573.

On the basis of the above analyses it can be concluded that third-year respondents held partially reformed beliefs on **how people learn about science** (subscale 1), while fourth-year respondents were found to hold traditional beliefs on this subscale.

BARSTL Subscale 2

Table 4.18 presents mean scores and percentage scores of third- and fourth-year respondents on the teaching and learning beliefs for subscale 2 of BARSTL.

Table 4.18: Mean and percentage scores for the teaching and learning beliefs questions (of third- and fourth-year respondents) – subscale 2

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	% participants responding 1 or 2	% participants responding 3 or 4	M(SD)	% participants responding 1 or 2	% participants responding 3 or 4
Question-16	Lesson design and implementation						
9	During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concept with them	2.68(0.930)	41.3	58.7	2.45(0.573)	54.1	45.9
10	During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students	2.63(0.989)	44.5	55.5	2.39(0.876)	61.5	38.5
11	Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instruction for students to follow in order to prevent confusion, and to make sure students get the correct results	1.41(0.710)	93.7	6.43	1.46(0.746)	92.6	7.4
12	Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class	1.56(0.642)	95.2	4.8	1.46(0.751)	90.2	9.8
13	Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading or demonstration	3.18(0.764)	14.3	85.7	3.22(0.801)	15.5	84.5
14	During a lesson, students need to be given opportunities to test, debate and challenge ideas with their peers.	3.45(0.645)	4.8	95.2	3.54(0.706)	4.9	95.1
15	During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem	2.64(0.964)	55.6	44.4	2.79(0.916)	32.5	67.5
16	Assessment in science classes should be given after instruction is completed; that way the teacher can determine if the students have learned the material covered in class	1.97(0.740)	84.1	15.9	2.41(0.994)	57.3	42.7
			2.44			2.47	

According to Table 4.18, the mean scores show that third-year students held five reformed beliefs out of eight in subscale 2. They demonstrated that they held “reformed” beliefs on question 9, where the mean score was 2.68, with a standard deviation of 0.930. On question 10 the mean score was 2.63, with a standard deviation of 0.989. On question 13 the mean score was 3.18, with a standard deviation of 0.764, on question 14 the mean score was 3.45, with a standard deviation of 0.645, and on question 15 the mean score was 2.64, with a standard deviation of 0.964. Percentage analyses resulted in the mean score of 2.64 being discarded on this question because it was found that 65.1% of third-year respondents were found to subscribe to this traditional belief. Third-year students therefore held reformed views on four questions out of eight on **lesson design and implementation** (subscale 2).

According to table 4.18, the mean scores show that fourth-year students held reformed beliefs on three out of eight questions comprising subscale 2. The table shows that they held reformed beliefs on question 13, with a mean score of 3.22, and a standard deviation of 0.801; on question 14, where the mean score was 3.54 with a standard deviation of 0.706; and on question 15, where the mean score was 2.79, with a standard deviation of 0.916.

The analyses show that third-year respondents held partially reformed beliefs on the **lesson design and implementation** (subscale 2), while fourth-year respondents were found to hold traditional beliefs on this subscale.

BARSTL Subscale 3

Table 4.19 presents mean scores and percentage scores of third- and fourth-year respondents on the teaching and learning beliefs for subscale 3 of BARSTL.

Table 4.19: Mean and percentage scores for the teaching and learning beliefs questions (of third- and fourth-year respondents) – subscale 3

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	% participants responding 1 or 2	% participants responding 3 or 4	M(SD)	% participants responding 1 or 2	% participants responding 3 or 4
Question 17-24	Characteristics of teachers and the learning environment						
17	Students should do most of the talking in science classrooms	2.84(0.827)	33.4	66.6	2.75(0.894)	36.9	63.1
18	Students should work independently as much as possible so they do not learn to rely on other students to do their work for them	2.38(0.888)	54	46	2.68(0.929)	37.7	62.3
19	In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say	3.32(0.820)	11.1	88.9	3.37(0.683)	6.6	93.4
20	Teachers should allow students to help determine the direction of a lesson	3.08(0.829)	12.7	87.3	2.84(0.866)	25.7	74.3
21	Students should be willing to accept the scientific ideas and theories presented to them during science class without question	2.84(0.902)	35	65	3.29(0.857)	15.6	84.4
22	An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands	1.57(0.712)	92.1	7.9	1.79(0.849)	80.2	19.8
23	The teacher should motivate students to finish their work as quickly as possible	1.73(0.865)	84.1	15.9	2.20(0.833)	69.6	30.4
24	Science teachers should primarily act as a resource person, working to support and enhance students' investigations rather than explaining how things work	2.84(0.884)	26.9	73.1	2.68(1.014)	41.8	58.2
		2.56			2.70		

According to table 4.19, the mean scores show that third-year students held reformed beliefs on five out of eight questions on the **characteristics of teachers and the learning environment** (subscale 3). On question 17 the mean score was 2.84, with a standard deviation of 0.827. On question 19 the mean score was 3.32, with a standard deviation of 0.820, whilst on question 20 the mean score was 3.08, with a standard deviation of 0.829. The mean score was 2.84 on question 21, with a standard deviation of 0.902, and on question 24 the mean score was 2.84 with a standard deviation of 0.884.

Table 4.19 also shows that fourth-year respondents held reformed beliefs on six out of eight questions on the **characteristics of teachers and the learning environment** (subscale 3). On question 17 the respondents' mean score was 2.75 with a standard deviation of 0.894. On question 18 the mean score was 2.68, with a standard deviation of 0.929, whilst on question 19 the mean score was 3.37, with a standard deviation of 0.683. On question 20 the mean score was 2.84, with a standard deviation of 0.866, on question 21 the mean score was 3.29 with a standard deviation of 0.857, and the mean score for question 24 was 2.68, with a standard deviation of 1.014.

The analyses showed that on the subscale 3, both groups of respondents held reformed beliefs on the **characteristics of teachers and the learning environment**. However, fourth-year respondents' beliefs were superior to third-year respondents' beliefs on this subscale.

BARSTL Subscale 4

Table 4.20 presents mean scores and percentage scores of third- and fourth-year respondents on the teaching and learning beliefs for subscale 4 of BARSTL.

Table 4.20: Mean and percentage scores for the teaching and learning beliefs questions (of third- and fourth-year respondents) – subscale 4

Question number	Question informed view statement	Year level 3			Year level 4		
		M(SD)	% participants responding 1 or 2	% participants responding 3 or 4	M(SD)	% participants responding 1 or 2	% participants responding 3 or 4
Question 25-32	The nature of the science curriculum						
25	A good science curriculum should focus on only a few scientific concept a year, but in great detail	2.67(0.880)	41.2	58.8	2.30(0.787)	63.1	36.9
26	The science curriculum should focus on the basic facts and skills of science that students will need to know later	1.94(0.716)	81	19	1.99(0.787)	77	23
27	Students should know that scientific knowledge is discovered using the scientific method	1.67(0.576)	98.8	3.2	1.70(0.626)	92.6	7.4
28	The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving	3.29(0.633)	6.4	93.6	3.32(0.742)	8.2	91.8
29	In order to prepare students for future classes, college, or a career in science the science curriculum should cover as many different topics as possible over the course of a school year	1.94(0.738)	79.4	20.6	1.92(0.723)	80.3	19.7
30	The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science	3.32(0.563)	4.8	95.2	3.30(0.724)	8.1	91.9
31	Students should learn that all science is based on a single scientific method, a step-by-step procedure that begins with defining the problem and ends with reporting the results	1.98(0.751)	82.5	17.5	2.31(0.980)	59	41
32	A good science curriculum should focus on the history and nature of science, and how science affects people and societies	3.32(0.758)	14.3	85.7	3.11(0.893)	20.5	79.5
		2.52			2.49		

Table 4.20 presents the mean scores which show that the third-year students held reformed beliefs on four out of eight questions on the **nature of science curriculum** (subscale 4). On question 25 the mean score was 2.67, with a standard deviation of 0.880. On question 28 the mean score was 3.29, with a standard deviation of 0.633, on question 30 the mean score was 3.32, with a standard deviation of 0.563, and the mean score was 3.32 for question 32, with a standard deviation of 0.758.

Concerning the fourth-year respondents, table 4.20 also shows that they held three out of eight reformed beliefs on the **nature of science curriculum** (subscale 4). On question 28 the mean score of fourth-year respondents was 3.32, with a standard deviation of 0.742; on question 30 the mean score was 3.30, with a standard deviation of 0.724; and on question 32 the mean score was 3.11, with a standard deviation of 0.893.

These results demonstrate that third-year respondents held partially reformed beliefs on the **nature of science curriculum**, while fourth-year respondents held traditional beliefs on this subscale.

4.7 SUMMARY OF THE FINDINGS

The aim of the study was to investigate the pre service science education students' epistemological beliefs about science and science teaching and learning. This chapter reported the findings.

One of the research questions in this study sought to find out if pre-service science education students held beliefs that were in agreement with the reformed science teaching and learning beliefs espoused by the NCS. Data analysis showed that as far as **how people learn about science** was concerned, 85.7% of third-year and 84.4%

of fourth-year students believed that students develop many beliefs about the world before they even study science in school, whilst 79.6% of third-year and 74.6% of fourth-year students believed that students learn in a disorderly fashion: they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences. Likewise 93.6% of third-year students and 75.4% of fourth-year students believed that students learn the most when they are able to test, discuss and debate many possible answers during activities that involve social interaction. However, 57.2% of third-year and 40.1% of fourth-year students held the view that students frequently have difficulty in learning scientific concepts because their beliefs about how the world works are often resistant to change. The above analysis shows that third-year students held four reformed beliefs versus three reformed beliefs held by fourth-year students on **how people learn about science** (subscale 1). Third- and fourth-year pre-service science education students therefore held pedagogical content beliefs about science teaching and learning that were not in agreement with the views espoused by the NCS on subscale 1.

On **lesson design and implementation**, 58.7% of third-year students believed that during a lesson students should explore and conduct their own experiments with hands-on materials before the teacher discusses the related scientific concepts with them, while 45.9% of fourth-year students held the same view. The view that during a lesson teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students was held by 55.5% of third- year students and 38.5% of fourth-year students. An observation that lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, reading or demonstration was supported by 85.7% of third- and 84.5% of fourth-year students, whilst 95.2% of third-year and 95.1% of fourth-year students believed that during a lesson students need to be given opportunities to test, debate and challenge ideas of their peers. A belief that during the lesson students should

explore and conduct their own experiments with hands-on materials before the teacher discusses the pertinent scientific concepts with them was held by 58.7% of third-year and 45.9% of fourth-year students, while 44.4% of third-year and 67.5% of fourth-year students disagreed with the belief that during a lesson all the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.

One can therefore conclude that third- and fourth- year pre-service science education students held pedagogical content beliefs about science teaching and learning that are not in agreement with the views espoused by the NCS on **lesson design and implementation** (subscale 2).

The results, however, showed that third- and fourth- year pre-service science education students held pedagogical content beliefs about science teaching and learning that were in agreement with the views espoused by the NCS on the **characteristics of teachers and the learning environment** (subscale 3). On this subscale 66.6% of third years and 63.1 % of fourth years held the view that students should do most of the talking in science classrooms, and a view that in science classrooms students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say was held by 88.9% of third-year students and 93.4% of fourth years. The view that teachers should allow students to help determine the direction of a lesson was held by 87.3% of third and 74.3% of fourth-year students, while 73.1% of third- and 58.2% of fourth-year students believed that a science teacher should primarily act as a resource person, working to support and enhance students' investigations rather than explaining how things work. However, 46% of third- and 62.3% of fourth-year students disagreed with the view that in science students should work independently as much as possible so that they do not learn to rely on other students to do their work for them; 65% of third- and 84.4% of fourth- year

students disagreed with the view that students should be willing to accept the scientific ideas and theories presented to them during science class without question.

On the **nature of science curriculum** 58.8% of third-year students and 36.9% of fourth years believed that a good science curriculum should focus on only a few scientific concepts per year, but in great detail; the view that the science curriculum should encourage students to learn and value alternative modes of investigation or problem- solving was held by 93.6% of third-year students and 91.8% of fourth years. Likewise, 95.2% of third years and 91.9% of fourth years believed that the science curriculum should help students develop reasoning skills and habits of mind necessary to do science, while 85.7% of third years and 79.5% of fourth years believed that a good science curriculum should focus on the history and nature of science and how science affects people and societies. This shows that third- and fourth-year pre-service science education students held pedagogical content beliefs about science teaching and learning that were not in agreement with the views espoused by the NCS on the **nature of science curriculum** (subscale 4).

Research Questions 1 and 2 addressed the epistemological beliefs about science of third- versus fourth-year pre-service science education students and their beliefs about science teaching and learning. The study found that fourth-year pre-service science students held epistemological beliefs about science that were superior to those of third-year students, while on their beliefs about science teaching and learning, the study found that fourth-year respondents also held beliefs that were marginally superior to third-year students' beliefs. The t-test found that the overall epistemological beliefs mean scores of third- and fourth-year pre-service science students were significant [$t(183)= 4.192$, $p=0.000$]. The t-test also found a significant [$t(183)=4.662$, $p=0.000$] difference

on epistemological beliefs mean scores on subscale 2. A test was also conducted to find if there was a significant difference in the mean scores of third- and fourth-year pre-service science students' teaching and learning. A statistically significant difference [$t(172.344)= 2.378, p=0.019$] was found on the overall mean scores, and on subscale 3 a significant difference [$t(183)=2.564, p=0.011$] was found.

Regarding the third research question, correlations indicated a statistically significant relationship between epistemological beliefs about science and science teaching and learning beliefs. The study found no significant correlations at third-year level. A significant correlation between epistemological beliefs about science and science teaching and learning beliefs ($r=0.290, p<0.01$) was found to exist at fourth-year level. A statistically significant correlation ($r=0.203, p< 0.05$) was also found between the science teaching and learning beliefs (BARSTL) scale and the epistemological beliefs about science (NSAAQ) subscale 2. Another statistically significant relationship ($r=0.248, p<0.01$) was found between the NSAAQ scale and the beliefs about how people learn science (BARSTL subscale 1). There was also a significant relationship between the NSAAQ scale and the BARSTL subscale 2 ($r= 0.203, p<0.05$). Another positive and significant relationship was observed between the NSAAQ scale and the BARSTL subscale 4 ($r=0.224, p<0.05$).

On whether or not the epistemological beliefs about science held by the third- and fourth-year pre-service science education students agreed with the views about science espoused by the NCS, third-year pre-service science education students were found to hold epistemological beliefs about science that were not in agreement with the views about science espoused by the NCS on all the subscales of the NSAAQ, while fourth- year students were found to hold epistemological beliefs about science that were not in agreement with the views

about science espoused by the NCS on the **nature of scientific knowledge** (subscale 1), **how scientific knowledge is generated** (subscale 2), and **what counts as reliable and valid scientific knowledge** (subscale 3). However, fourth-year pre-service science education students were found to hold epistemological beliefs about science that were in agreement with the views about science espoused by the NCS on **the role played by scientists in the generation of knowledge** (subscale 4).

On the final research question dealing with whether third- and fourth-year students held teaching and learning beliefs that were in agreement with the pedagogical content beliefs about science teaching and learning espoused by the NCS, the study found that third- and fourth-year pre-service science education students held pedagogical content beliefs about science teaching and learning that were not in agreement with the views espoused by the NCS on **how people learn about science** (subscale 1), **lesson design and implementation** (subscale 2), and on the **nature of science curriculum** (subscale 4). Both groups were, however, found to hold pedagogical content beliefs about science teaching and learning that were in agreement with the views espoused by the NCS on the **characteristics of teachers and the learning environment** (subscale 3).

4.8 CONCLUSION

The main findings of this study were that third- and fourth-year science education students held naïve epistemological beliefs about science. However, the findings of the study confirmed that fourth-year students were superior to third-year students in their epistemological beliefs about science. Nonetheless, taking the findings as a whole, it appears students exit the pre-service teacher education programme with epistemological beliefs that are not aligned with a view of science as a process of explanation and argument, thereby suggesting

that they may not realize that claims about the underlying causes of events are open to challenge and refutation, and therefore need the support of empirical evidence (Sampson & Clark, 2006). The study also found that third- and fourth-year students held traditional beliefs about science teaching and learning. Fourth-year students, however, demonstrated superior beliefs about science teaching and learning. The implications of the study findings are, however, that those teachers who are a target of current reform efforts will enter the teaching profession still embracing a transmission model of teaching (Sampson & Benton, 2006).

CHAPTER FIVE

DISCUSSION, IMPLICATIONS, LIMITATIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter discusses the findings of the study and compares them with previous research conducted in the domain of this research. The chapter will also highlight implications and the methodological limitations of the study, and how the findings of the study should be interpreted within the broader context of the current literature. Recommendations for future research and classroom practice will be presented in the last section of this chapter.

5.2 DISCUSSION OF RESEARCH FINDINGS

5.2.1 Epistemological beliefs about science

According to Khan (2012), contemporary reforms in science education are based on constructivism, which is a philosophy which sees learning as a social process that serves as a catalyst for cognitive development. When students learn science they “describe objects and events, ask questions, construct explanations about the natural phenomena, test those explanations in many different ways, and communicate their ideas to others” (Khan, 2012:55). The physical sciences NCS (2003) requires students to conduct scientific investigations, collect data, seek patterns and trends in the information collected, and communicate information and conclusions with clarity and precision. The NCS also suggests that students should explain relationships between concepts and be able to apply scientific knowledge to familiar, everyday life contexts. As they engage in all these activities, students get to know that learning science is something students do, not what is done to them (Khan, 2012).

The overall epistemological beliefs mean score of third-year students was found to be ($\bar{x} = 77.71$), with a standard deviation of 7.43, while an overall epistemological beliefs mean score of fourth-year students was ($\bar{x} = 82.61$), with a standard deviation of 7.59. A difference in the overall epistemological beliefs mean scores for third- and fourth-year pre-service science students was found to be significant [$t(183) = 4.192, p = 0.000$]. The results demonstrate that fourth-year pre-service science students held superior epistemological beliefs about science to those of third-year students. This significant difference between third- and fourth-year students' epistemological beliefs suggests that the development of epistemological beliefs can be strongly related to the students' educational levels. These results agree with the findings by Jehng, et al. (1993), who found that postgraduate students had a more sophisticated epistemological belief than undergraduate students. Chai, et al. (2007) also found that student teachers become more sophisticated in their epistemological beliefs towards graduation. A significant difference between the mean scores of first-year students ($M = 3.60$) and senior students ($M = 3.68$) was also found by Otting, et al. (2010). These research findings show that students at fourth-year level had "gained a stronger sense of knowledge as being constructed by themselves" (Chai, et al., 2007:287). The findings of this study, however, contradict the research findings of Ali and Ammar (2005), who found that pre-service teachers still held naïve epistemological beliefs when they reached the highest educational level.

The superiority of fourth-year students' epistemological beliefs in this study can be explained by analysing the B.Ed curriculum at fourth-year level. As physical science teachers these students did chemistry and physics throughout the four-year programme to enable them to qualify as physical science teachers. Subject matter has been found to shape personal epistemology (Chai, et al., 2007). According to Dinal-Taganahan (2008), students develop mature beliefs about physics as their physics knowledge develops. It is possible that the physics

content that the students did over a period of four years helped them develop sophisticated epistemological beliefs regarding how scientific knowledge is generated.

A significant difference [$t(183)=4.662, p=0.000$] between epistemological beliefs mean scores on subscale 2 for third- and fourth-year respondents indicated that fourth-year students held superior epistemological beliefs to third-year students with regard to how scientific knowledge is generated. However, the difference in mean scores of the two research samples on subscale 1 [$t(183)=0.246, p=0.806$], subscale 3 [$t(183)=1.041, p=0.299$] and subscale 4 [$t(183)=0.682, p=0.496$] were not statistically significant. These results suggested that fourth-year pre-service science students did not differ from third-year students, and were also naïve in their epistemological beliefs about the nature of scientific knowledge (subscale 1), the social and culturally embedded nature of scientific practices (subscale 3), and what counts as reliable and valid scientific knowledge (subscale 4). These results also showed that students at fourth-year level held sophisticated beliefs on some dimensions of the scale, and naïve beliefs on others. This finding speaks to the multidimensional nature of epistemological beliefs, and suggests that students may hold both sophisticated (more relativistic) and naïve (more dualistic) views about the nature of knowing at the same time. The findings indicate that “personal epistemology is a belief system that is composed of several more or less independent dimensions” (Schommer, 1989:2). This finding is also in agreement with that of Mihaladiz, et al. (2011), who found that pre-service science students held sophisticated beliefs in some areas of nature of science, but not in others. Yilmaz-Tuzun and Topcu (2013) also found that pre-service students were better in expressing their epistemological beliefs in some dimensions at various levels of study. In a study similar to this one conducted by Cetin, Erduran and Kaya (2010), it was reported that fourth-year students’ epistemological beliefs were superior to third-year students’ beliefs on subscales

2, 3 and 4. The mean scores on subscale 1 were similar for third- and fourth-year physics students. Even though Cetin, et al.'s results are different from the findings of this study in that they found the fourth-year students to hold superior beliefs to third-year students on subscales 3 and 4, and similar beliefs on subscale 1, both studies agree on students holding sophisticated and naïve beliefs at the same time.

5.2.2 Teaching and learning beliefs about science

The overall mean score on teaching and learning beliefs (BARSTL) for third-year students was ($\bar{x} = 79.32$), with a standard deviation of 4.24, while the overall mean score for teaching and learning for fourth-year students was found to be ($\bar{x} = 81.20$), with a standard deviation of 6.44. Both these results show moderate support for reformed views. In a similar study, Karaman and Karaman (2013) also found the overall mean scores for pre-service teachers to indicate moderate support for reformed ideas. Cheng, et al. (2009), on the other hand, found that pre-service students had significantly stronger support of reformed views than traditional views in a similar study.

In this study the difference in the overall mean scores of the two research samples was statistically significant [$t(172.344)=2.378$, $p=0.019$]. This demonstrated that fourth-year respondents held a higher level of “reformed oriented teaching and learning beliefs” about science, compared to third-year students.

When the subscale mean scores of both groups of respondents were compared, the results showed that the difference in the mean scores of the two research samples was significant on subscale 3 [$t(183)=2.564$, $p=0.011$], suggesting that fourth-year students ($\bar{x} = 21.57$) demonstrated a higher level of reformed-

oriented teaching and learning beliefs about science than did the third-year students on the characteristics of teachers and the learning environment ($\bar{x} = 20.60$). These findings are similar to those of Karaman and Karaman (2013), who, in a similar study, also found that teacher candidates' beliefs were reformed-oriented on the characteristics of teachers and the learning environment. The results of both studies indicate that science students graduate from the B.Ed programme with a superior knowledge about the learning environment that must prevail in their classes, and the kind of teachers they must be if they are to be successful as science teachers. However, superior knowledge of the learning environment and the characteristics of the teachers they ought to be is not enough to make them good science teachers. This knowledge must be complemented by knowledge on (a) how people learn about science (subscale 1), (b) learning design and implementation (subscale 2), and (c) the nature of the science curriculum (subscale 4). Fourth-year students were, however, found to hold traditional beliefs in three subscales (subscale 1, subscale 2 and subscale 4). This shows that as students exit the programme they still hold positivist beliefs about how people learn science. They also believe in designing and implementing lessons that are teacher-centred, and describing science knowledge that is true, real and existing independently of personal experience (Ozdemir, 2007). This indicates a positivist curriculum perspective.

5.2.3 Correlation findings

On investigating the relationship between the pre-service science teachers' epistemological beliefs about science and their beliefs about science teaching, the study found that there was no significant correlation between the third-year respondents' epistemological beliefs about science versus teaching and learning beliefs. This result was found to be inconsistent with the existing research findings as the expectation was that since the third-year students were found to

hold naïve epistemological beliefs about science, their beliefs would correlate with the traditional beliefs about science teaching and learning.

Fourth-year pre-service science teachers' epistemological beliefs about science were, however, found to be moderately positively associated with their beliefs about science teaching and learning ($r=0.290$, $p<0.01$). This moderate relationship between these two variables indicated that respondents who held superior epistemological beliefs about science were likely to hold superior beliefs about science teaching and learning. The findings of this study are in agreement with the existing research findings. Chan (2004), studying pre-service teachers' epistemological beliefs and conceptions about teaching and learning, found that epistemological beliefs held by Hong Kong teacher education students were related to their conceptions about teaching and learning. Yilmaz and Sahin (2011) argued in their study that traditional conceptions correlated positively with naïve epistemological beliefs, while constructivist practices correlated positively with sophisticated epistemological beliefs. Thus for the fourth-year respondents, the findings of this study are in agreement with the literature.

A significant relationship ($r=0.203$, $P<0.05$) was also found to exist between the NSAAQ scale and the BARSTL subscale 2, suggesting that fourth-year respondents who held superior epistemological beliefs about science were likely to believe that :

- during a lesson students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.
- During a lesson teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concepts to students.

- Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, reading or demonstration.
- During a lesson students need to be given opportunities to test, debate and challenge ideas with their peers.

Another positive and significant relationship was observed between the NSAAQ scale and the BARSTL subscale 4 ($r=0.224$, $p<0.05$), which suggested that fourth-year respondents who held sophisticated beliefs about science were likely to believe that:

- a good science curriculum should focus on only a few scientific concepts a year, in great detail.
- scientific knowledge is discovered using the scientific method, and the science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.
- the science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.

A statistically significant correlation was also found between subscale 1 of BARSTL and subscale 2 of NSAAQ. BARSTL subscale 1 measures beliefs about how people learn science, and NSAAQ subscale 2 measures epistemological beliefs about how scientific knowledge is generated. This correlation demonstrates that the fourth-year students who held reformed beliefs about how people learn science were likely to hold sophisticated beliefs about how scientific knowledge was generated. This finding suggests that fourth-year students who hold beliefs that students learn the most when they are able to test, discuss and debate many possible answers during activities that involve social interaction are likely to believe that experiments are important in science because they can be used to generate reliable evidence. The same can also be said about those students who believe that students learn in a disorderly

fashion, and create their own knowledge by modifying existing ideas in an effort to make sense of new and past experiences. These students are also likely to believe that science is a process of explanation and argument.

A statistically significant correlation ($r=0.203$, $p<0.05$) was found between the science teaching and learning beliefs (BARSTL) scale and the epistemological beliefs about science (NSAAQ) subscale 2. This relationship shows that fourth-year pre-service science teachers who hold reformed beliefs about science teaching and learning are likely to hold sophisticated beliefs about how scientific knowledge is generated. This finding suggests that fourth-year students who hold reformed beliefs about science teaching and learning are likely to believe that

- experiments are used to test an idea.
- experiments are important in science because they can be used to generate reliable evidence.
- science is a process of explanation and argument.

Similar results have appeared in similar studies. Epler (2011) found that teachers with more advanced epistemological beliefs have a tendency to use student-centred teaching strategies, while those who hold naïve epistemological beliefs tend to use teacher-centred teaching strategies. In a similar vein, Ozdemir (2007) posits that teachers who hold naïve beliefs have been found to transmit knowledge to students, while those who hold sophisticated beliefs understand the relationship between events and are able to apply their science knowledge to novel situations with enjoyment. Knowledge transmitters have also been found to stress the objectivity and reproducibility of knowledge, while knowledge constructors have been found to emphasize meaningful learning. Similar findings were also made by Moos and Miller (2014), who found that pre-

service teachers with more sophisticated epistemology viewed a constructivist approach to teaching as more effective. Otting, et al. (2010) also established the relationship between epistemological beliefs and conceptions of teaching and learning, and found that students who believed that teachers were the main source of expertise tended to have a constructivist conception of teaching and learning, whereas those who believed in the certainty of knowledge tended to have a traditional conception of knowledge. On the other hand Epler (2011) found that pre-service teachers with advanced epistemological beliefs used multiple student teaching methods including class discussions, peer teaching, collaborative groups and higher order questioning techniques, while pre-service teachers with naïve epistemological beliefs were found to use teacher-centred methods such as lectures, demonstrations, and teacher-led discussions. However, Cheng, et al. (2009) found inconsistencies in the relationship between epistemological beliefs and conceptions of teaching among pre-service teachers. While they found that some students with sophisticated beliefs about science were constructivist in their conceptions of teaching and learning, and those who held naïve beliefs about science were traditional in their conceptions of teaching and learning, they also found that some student teachers who possessed sophisticated epistemological beliefs held a combination of both constructivist and traditional conceptions of teaching.

As for the above studies, this study also sought to establish if epistemological beliefs about science held by the third- and fourth-year pre-service science education students were in agreement with the nature of science views espoused by the NCS. The study has found that third-year respondents held naïve beliefs (a) on the nature of scientific knowledge (subscale 1), (b) how scientific knowledge is generated (subscale 2), (c) what counts as reliable and valid scientific knowledge (subscale 3), and (d) the role scientists play in the generation of scientific knowledge (subscale 4). On their part, fourth-year

respondents were found to be naïve on (a) the nature of scientific knowledge (subscale 1), (b) how scientific knowledge is generated (subscale 2), and (c) what counted as reliable and valid scientific knowledge (subscale 3). Fourth-year respondents were found to hold sophisticated beliefs on the role scientists play in the generation of scientific knowledge (subscale 4). These findings render third-year students' beliefs to be in disagreement with the beliefs espoused by the NCS policy. Third-year students could therefore be linked to a positivist theoretical perspective (Rice, 2012). Positivists tend to describe science knowledge as true, real and existing independently of personal experience. These student teachers "see the purpose of activities as being to follow the directions given in the textbook to reach predetermined right answers" (Ozdemir, 2007:359). Third year student teachers believe that scientific knowledge is certain and absolute (Allen, 2008).

However, the fourth-year pre-service science education students were found to hold epistemological beliefs about science that were in agreement with the nature of science views espoused by the NCS on **the role played by scientists in the generation of knowledge** (subscale 4). This suggests that fourth-year students understand what scientists do and what they are like. However, fourth-year students were found to hold epistemological beliefs about science that were not in agreement with the nature of science views espoused by the NCS on **the nature of scientific knowledge** (subscale 1), and on **how scientific knowledge is generated** (subscale 2). They were also found to be naïve on all the questions of subscale 3 of the NSAAQ scale. This demonstrated that the fourth-year students held epistemological beliefs about science that were not in agreement with the nature of science views espoused by the NCS on **what counts as reliable and valid scientific knowledge** (subscale 3).

This suggests that the fourth-year students could not describe the body of knowledge generated by the work of scientists, the process of generating

scientific knowledge, or what counted as reliable and valid science knowledge. The study findings also suggest that at the point of completing their teacher education programme, fourth-year students did not understand (a) the scientific enterprise, and in particular how science knowledge develops, (b) that science knowledge is contested, and depends on social, religious and political factors, and (c) that the explanatory power and the limitations of scientific models and theories need to be evaluated (NCS, 2003: 11). A possible explanation for why students exit the teacher education programme with naïve epistemological beliefs about science can be found from Bromme, et al., who argue that “when individuals study a certain discipline, their growing knowledge base may lead to the assumption that knowledge in the discipline is stable, secure and absolute” (Bromme, et al., 2008:11). Such student teachers may take a less sophisticated stand than the stand they held before studying the discipline (Bromme, et al., 2008). They further argue that “with the growing knowledge about the history of research, concurring theories or research methods within a specific discipline suggest that knowledge in the discipline is dynamic and changing” (Bromme, et al., 2008:11).

This study also found that both the third- and fourth-year pre-service science education students held pedagogical content beliefs about science teaching and learning that were not in agreement with the views espoused by the NCS on **how people learn about science** (subscale 1), **lesson design and implementation** (subscale 2), and the **nature of science curriculum** (subscale 4). Both groups of participants were, however, found to hold pedagogical content beliefs about science teaching and learning that were in agreement with the views espoused by the NCS on the **characteristics of teachers and the learning environment** (subscale 3).

When Chai, et al. (2008) investigated changes in Singaporean pre-service teachers' epistemological beliefs, and beliefs about teaching and learning, during the course of a teacher preparation programme, they found that the pre-service teachers' epistemological beliefs on the programme had become relativistic in nature by the time they exited the programme. They attributed this to the teaching experiences during the student teaching practicum period, and they contended that the changes could have been caused by the teaching challenges they had to face during that period, and the uncertainties in their roles, which did not have clear right or wrong answers (Chai, et al., 2008). The findings of this study indicate that the students' teaching and learning beliefs about science are more or less the same at third- and fourth-year levels of study. Using Chai, et al.'s (2008) findings to try to explain the weaknesses demonstrated by the students in this study, it is possible that the teaching practicum programme is not helping students to develop reformed beliefs about science teaching and learning. This may be attributed to the predominant lack of laboratory facilities at the schools where the students do their teaching practicum. More importantly, though, this lack of a clear transition between the third and fourth year could also be explained by a weakness in the education programme itself, which should have activities which challenge the students' traditional beliefs and notions about science. The persistent weakness in student teachers' beliefs about science teaching and learning could also be a result of the weakness in their epistemological beliefs about science. An improvement in student teachers' epistemological beliefs about science is likely to have a reciprocal impact on their science teaching and learning beliefs, as demonstrated in numerous studies (Otting, et al., 2010; Ozdemir, 2007; Yilmaz & Sahin, 2011; Chan, 2004) which have shown the correlation between the two.

5.3 IMPLICATIONS FOR THE BACHELOR OF EDUCATION PROGRAMME

Given the impact beliefs have on education as a result of teachers' heavy reliance on their core belief systems rather than academic knowledge when determining classroom actions (Nespor, 1987), this study sought to find the epistemological and science teaching and learning beliefs that pre-service science education students held at third- and fourth-year levels of the four-year B.Ed programme. The study also looked at the correlation of epistemological beliefs that the pre-service science education students held at third- and fourth-year levels with their science teaching and learning beliefs. Finally, the study sought to find out if the epistemological beliefs about science and science teaching and learning at third- and fourth-year level were in agreement with the epistemological beliefs and teaching and learning beliefs espoused by the NCS. Investigating beliefs held by pre-service teachers as they go through the programme, and just before they exit the programme, is important to establish the extent to which the programme is succeeding in developing these beliefs.

The findings of the study showed that epistemological beliefs held by fourth-year students were superior to those held by third-year students. This finding is important as it shows that students' beliefs are developing as they go through the B.Ed programme. Indeed, the analysis of subscales showed that the third-year students held naïve beliefs on subscales of the epistemological beliefs questionnaire. The study also revealed that fourth-year students held sophisticated epistemological beliefs on only one subscale of the questionnaire. This finding demonstrated that fourth-year students' demonstrated growth was only in the methods that are used to generate scientific knowledge in science. In other aspects of the epistemological beliefs about science the fourth-year students have shown no development. The findings also revealed that fourth-year students held beliefs about science teaching and learning that were

superior to those of third-year students. Further analysis of subscales also revealed that third- and fourth-year students held sophisticated beliefs on only one subscale of the science teaching and learning questionnaire. These findings taken together led to the conclusion that the students at third- and fourth-year levels of study held epistemological beliefs about science and beliefs about science teaching and learning which are not espoused by the NCS.

These findings did not come as a huge surprise considering that teacher education students start their teacher education programmes with entrenched traditional beliefs about teaching (Karaman & Karaman, 2013). Thus these findings, taken together, show that although the B.Ed programme is succeeding in developing both epistemological beliefs about science and teaching and learning beliefs about science, the level at which it is succeeding is very low. Again, this is not surprising as pre-service science teachers have to deal with the conflict between their deeply embedded traditional beliefs and the ideas that advocate reform-based practices presented in the programme (Karaman & Karaman, 2013). This notwithstanding, the findings of this study have serious and far-reaching implications for the B.Ed programme. One of these is that the B.Ed science programme should focus on explicitly developing pre-service science teachers' epistemological beliefs by presenting students with opportunities to identify and evaluate their epistemological beliefs about science (Jackson, 2010). Jackson argues that because students are not afforded these opportunities, they are not aware of the tremendous impact these beliefs have on the instructional techniques they use, and they also have difficulty developing positive beliefs in implementing student-centred teaching methods (Yilmaz-Tuzun & Topcu, 2013). Yilmaz-Tuzun & Topcu see the development of the pre-service teachers' epistemological beliefs during the course of study as being critical for them to be able to apply appropriate teaching strategies for their learners. The programme should also model a teaching and learning

environment that is consistent with the constructivist approach (Cheng, et al., 2009). The programme should model reflective thinking and judgement instead of encouraging passive reception of knowledge from authority figures (Cheng, et al., 2009). Cheng, et al, caution that the success of the programme in implementing a constructivist approach in teaching practice depends a great deal on conditions at the placement schools. They argue that schools which have not bought into this constructivist philosophy of teaching and learning are not likely to provide the necessary support to the student teachers placed in their schools, as mentors in schools would be lacking the necessary skills to support the students.

Taking Cheng, et al.'s view into account, it seems that the improvement of the programme will also require that the constructivists practices that are being forged in the programme, be linked with the pedagogic practices at the placement schools. This should result in mentors' skills in constructivist pedagogy at the placement schools being developed to enable them to support the emerging constructivist perspectives of students while they are under their care.

5.4 LIMITATIONS OF THE STUDY

The study had three main shortcomings. The first one was that the study was largely based on the exiting students as the principal source of data. When the data analysis took place, the students had already exited the programme, and it was not possible to go back to them to clarify issues that arose during data analysis. Linked to the first shortcoming is the second one, which has to do with the quantitative nature of the study. As the respondents were no longer available as students, it was not possible to go back to them to try and give the study a qualitative flair which would have added value to it by giving the

respondents a voice to support the quantitative data. Lastly, as has already been reported, the fourth-year students showed superior epistemological beliefs to those of third-year students. It would have been very interesting to see if this improvement in students' epistemological beliefs was translated into classroom practice. If the respondents had still been available, data on how they planned and delivered their lessons would have been collected to determine if there was a link between their improved epistemological beliefs and the lesson planning and delivery on aspects where the epistemological beliefs showed improvement.

5.5 RECOMMENDATIONS FOR FURTHER STUDY

This study looked at the relationship between the epistemological beliefs about science and science teaching and learning beliefs of third- and fourth-year students. In the process, the need to investigate the link between the students' epistemological beliefs about science, their teaching and learning beliefs, and their classroom practice became obvious. Further studies are needed to determine if student teachers are better teachers at year four as a result of their improved beliefs. Furthermore, there is a need to determine the role played by content knowledge on the improvement of students' epistemological beliefs about science, and their beliefs about science teaching and learning beliefs. Such an investigation would reveal if students who have superior content knowledge also have superior epistemological beliefs about science and science teaching and learning beliefs. Again, the link between science content knowledge, epistemological beliefs about science, science teaching and learning beliefs and classroom practice would have to be investigated to determine whether the three types of beliefs result in improved classroom practice. These are just a few of the issues that could be investigated as a result of this study. There may also be other possibilities and prospects.

5.6 CONCLUSION

The results have shown that pre-service science education students at fourth-year level held superior epistemological beliefs compared to third-year students' beliefs. The fourth-year students' epistemological beliefs were, however, not sophisticated. This difference in epistemological beliefs between third- and fourth-year students is very encouraging because it shows that the science education programme that the students go through could be having a positive impact on the beliefs that the students hold about science knowledge when they enter the programme. The same impact of the programme was also observed regarding the respondents' beliefs about science teaching and learning. At fourth-year level, students' beliefs about science teaching and learning showed that they had shifted away from portraying the world as a set of absolutes, characterized by right and wrong answers (Osborne, Erduran, Simon & Monk, 2001). However, their beliefs were still not fully reformed. What the study, however, showed was the existence of a significant correlation between the fourth-year students' epistemological beliefs and their science teaching and learning beliefs.

This correlation is important because it shows that the improvement of students' epistemological beliefs could have resulted in the improvement in students' beliefs about science teaching and learning. The weaknesses shown by the students in their epistemological beliefs about science, as well as their weaknesses in their beliefs about science teaching and learning, have demonstrated the shortcomings of the programme that the students went through as far as its ability to develop all aspects of these beliefs was concerned.

The study has shown that the students' epistemological beliefs have improved in some aspects at fourth-year level, but not in others. This lack of overall improvement in the various aspects of the epistemological beliefs has manifested in some aspects of the respondents' science teaching and learning beliefs showing no notable improvements. These programme shortcomings could be addressed in future by, among other things, the explicit teaching of beliefs, and making pre-service science teachers participate in science activities which promote constructivist teaching and learning (Lee, et al., 2013) during their training. It would also be quite useful if such constructivist teaching and learning environments obtained in the schools where the student teachers go for their teaching practicums. These possible remedial actions are, however, not easy to implement, particularly in the schools, as class sizes and resources in most schools tend to militate against constructivist teaching and learning.

Overall, however, the researcher is satisfied that the purposes of this research have been achieved, and that a lot of valuable information and insights have emerged. It is therefore, hoped that some specific improvements will be made in the B.Ed science education programme so that the graduates the Faculty of Education produces will be better prepared for implementing the country's NCS through the instructional approaches directed by CAPS (i.e. the Curriculum and Assessment Policy Statement).

REFERENCES

- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50, 179-211.
- Ali, M. F. A., & Ammar, A. M. I. (2005). An investigation of the relationship between EFL pre-service teachers' epistemological beliefs and their learning strategies, teaching practices and foreign language classroom anxiety. Retrieved from <http://www.tcr.Edu.sa> 15/6/2012
- Allen, M. (2008). Now this is what should have happened...': A clash of Classroom Epistemologies. *Eurasia Journal of Mathematics, Science and Technology Education*, 4, 319-326.
- Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, 41, 53-62.
- Bromme, R. (2005). Thinking and knowing about knowledge: A plea for and critical remarks on psychological research programs on epistemological beliefs. New York: Springer.
- Bromme, R., Kienhues, D., & Stahl, E. (2008). *Knowledge and epistemological beliefs: An intimate but complicated relationship*. New York, Springer.
- Brownlee, J., Purdie, N., & Boulton-Lewis, G. (2001). Changing epistemological beliefs in pre-service education students. *Teaching in Higher Education*, 6(2), 247-268.

- Collins, J.B., Selinger, S.J., & Pratt, D.D. (2003). How do perspectives on teaching vary across disciplinary majors for students enrolled in teacher preparation? *Academic Exchange Quarterly*,
- Cetin, P. S., Erduran, S., & Kaya, E. (2010). Understanding the nature of chemistry and argumentation: The case of pre-service chemistry teachers. *Ahi Evran Univ Kirsehir Egitim Fakultesi Dergisi (KEFAD)*, 11(4), 41-59.
- Chai, C. S., Khine, M. S., & Teo, T. (2006). Epistemological beliefs on teaching and learning: A survey among pre-service teachers in Singapore. *Educational Media International*, 43(4), 285-298.
- Chai, C. S., Teo, T., & Lee, C.B. (2009). The change in epistemological beliefs and beliefs about teaching and learning: A study among pre-service teachers. *Asia-Pacific Journal of Teacher Education*, 37(4), 351-362.
- Chai, C. S., Teo, T., & Lee, C.B. (2009). Modelling the relationship among about learning, knowledge, and teaching of pre service Teachers in Singapore. *Asia-Pacific researcher*, 19(1), 25-42.
- Chan, K. (2002, December). Students' epistemological beliefs and approaches to learning. Paper presented at the AARE2002 Conference, Brisbane, Australia.
- Chan, K. (2004). Pre-service teachers' epistemological beliefs and conceptions about teaching and learning: Cultural implications for research in teacher education. *Australian Journal of Teacher Education*, 29(1), 1-13.
- Chan, C. K. K., & Sachs, J. (2001). Beliefs about learning in children's understanding of science texts. *Contemporary Educational Psychology*, 26, 192-210.

- Chang, T. (1995). An investigation of Taiwanese graduate students' beliefs about scientific knowledge. *Bull. Nat'l Taiwan Nor. Univ.*, 40, 583-618.
- Cheng, M. M. H., Chan, K., Tang, S. Y. F., & Cheng, A. Y. N. (2009). Pre-service teacher education students' epistemological beliefs and their conceptions of teaching. *Teaching and Teacher Education*, 25, 319-327.
- Chi-Kin Lee, J., Zhang, Z., Song, H., & Huang, X. (2013). Effects of epistemological and pedagogical beliefs on instructional practices of teachers: A Chinese perspective. *Australian Journal of Teacher Education*, 38(12), 120-145.
- Collins, J. B., Selinger, S. J., & Pratt, D. D. (2003). How do perspectives on teaching vary across disciplinary majors for students enrolled in teacher preparation? *Academic Exchange Quarterly*.
- Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, 29, 186-204
- Deng, F., Chai, C. S., Tsai, C. C., & Lee, M. H. (2014). The relationship among Chinese practising teachers' epistemic beliefs, pedagogical beliefs and their beliefs about the use of ICT. *The Educational Technology and Society*, 17(2), 245-256.
- De Vaus, D. (2007). *Research design in social research*. New Delhi: Sage.
- Dinal-Taganahan, T. (2008). Epistemological beliefs and conceptual understanding of physics concepts: Challenge of physics teaching and research. Proceedings of the SPVM National Physics Conference and Workshop. Central Mindanao University, Musuan Bukidnon.

- Elliott, B., & Chan, K. W. (1998). Epistemological beliefs in learning to teach: Resolving conceptual and empirical issues. Paper presented at the European Conference on Educational Research, Ljubljana, Slovenia.
- Enderle, P., Walker, J. P., Dorgan, C., & Sampson, V. (2010, March). Assessment of scientific argumentation in the classroom: An observation. Paper presented at the 2010 Annual International Conference for the National Association for Research in Science Teaching. Philadelphia, PA.
- Epler, M. C. (2011). *The relationship between implicit theories of intelligence, epistemological belief, and the teaching practices of in-service teachers: A mixed method study*. Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA.
- Feiman-Nemser, S. (1996). *Teacher preparation: Structural and conceptual alternatives. Handbook for research on teacher education*. New York: Macmillan.
- Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. USA, Addison-Wiley.
- Halloun, I. (2001). *Students' views on science: A comparative survey*. Beirut: Educational Research Center, Lebanese University.
- Hammer, D. (1994). Epistemological beliefs in introductory physics. *Cognition and Instruction*, 12(2), 151-183.
- Hashweh, M. Z. (1996). Palestinian science teachers' epistemological beliefs: A preliminary survey. *Research in Science Education*, 26(1), 89-102.

- Hayden, F. G. (1988). Values, beliefs, and attitudes in a sociotechnical setting. *DigitalCommons @ University of Nebraska-Lincoln*, 6(1), 415-426.
- Hodson, D. (2008). *Towards science literacy: A teachers' guide to the history, philosophy, and sociology of science*. Rotterdam: Sense.
- Hofer, B. K. (2001). Personal epistemological research: Implications for learning and teaching. *Journal of Educational Psychology Review*, 13(4), 353-383.
- Hofer, B. K. (2004). Exploring the dimensions of personal epistemology in differing classroom contexts: Student interpretations during the first year of college. *Contemporary Education Psychology*, 29, 129-163.
- Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67, 88-140.
- Hofer, B. K., & Pintrich, P. R. (2002). *Personal epistemology*. Mahwah, NJ: Lea.
- Hogan, K. (1998). Exploring a process view of students' knowledge about the nature of science. *Science Education*, 84, 51-70.
- Howard, K. (2008). Validating Questionnaires. Kestrel Consultants, Inc. http://kestrelconsultants.com/reference_files/Validating_Questionnaires.pdf. Retrieved 21 April, 2025.
- Jackson, D. B. (2010). *The impact of science teachers' epistemological beliefs on authentic inquiry: A multiple-case study*. Unpublished doctoral dissertation, Baylor University, Texas

- Jehng, J. C. J., Johnson, S. D., & Anderson, R. C. (1993). Schooling and students' epistemological beliefs about learning. *Contemporary Educational Psychology*, 18, 23-35.
- Karaman, A., & Karaman, P. (2013). Examining the beliefs of prospective elementary and science teachers regarding reformed science teaching and learning. *Educational Research Association: The international Journal of Research in Teacher Education*, 4(3), 1-9.
- Khan, U. Z. (2012). Investigating elementary principals' science beliefs and knowledge and its relationship to students' science outcomes. Unpublished doctoral dissertation. Syracuse University, Surface.
- Knobloch, N. A., & Hoop, S. E. (2007). Pre-service teachers' epistemological beliefs, attitudes, and behaviors regarding instructional planning. Retrieved 20/7/2012 from <https://www.ydae.purdue.edu/Ict/SoTL>
- Kruss, G. (2009). *Opportunities and challenges for teacher education curriculum in South Africa*. (Teacher education in South Africa series). Cape Town: HSRC Press.
- Kumar, R. (2005). *Research methodology: A step-by-step guide for beginners*. New Delhi: Sage.
- Kwak, Y. (2001). *Profile change in pre-service science teachers' epistemological and ontological beliefs about constructivist learning: Implications for science teaching and learning*. Unpublished doctoral dissertation, Ohio State University, Columbus.

- Lee, J. C., Zhang, Z., Song, H., & Huang, X. (2013). Effects of epistemological and pedagogical beliefs on the instructional practices of teachers: A Chinese perspective. *Australian Journal of Teacher Education*, 38(12), 120-146.
- Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M., & Ebenezer, J. (2008). Assessing pre-service elementary teachers' views on the nature of scientific knowledge: A dual-response instrument. *Asia-Pacific Forum on Science Learning and teaching*, 9(1), 1-20.
- Linn, M. C., & Songer, N. B. (1993). How do students make sense of science? *Merrill Palmer Quarterly*, 39, 47-73.
- Luft, J. A. & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher belief interview. *Electronic Journal of Science Education*, 11(2), 38-56.
- Mahmood, N. (2007). Elementary school science teachers' beliefs about science teaching in constructivist landscape. *Bulletin of Education & Research*, 29(2), 59-72.
- Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental & Science Teaching*, 4(1), 25-28.
- Markic, S., & Eilks, I. (2007). A case study of German first year chemistry student teachers' beliefs about chemistry teaching, and their comparison with student teachers from other science teaching domains. *Chemistry Research and Practice*, 9, 25-34

- Markic, S., Eilks, I., & Valanides, N. (2008). Developing a tool to evaluate differences in beliefs about science teaching and learning among freshman science student teachers from different science teaching domains: A case study. *Eurasia Journal of Mathematics, Science & Technology Education*, 4(2), 109-120.
- McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science and Education*, 7, 511-532
- Mihladiz, G., Dunan, M., & Dogan, A. (2011). Examining primary school students' attitudes towards science in terms of gender, class level and income level. *Procedia – Social and Behavioral Sciences*, 15, 2582-2588.
- Millwood, K. A., & Sandoval, W. A. (2006). *A comparison of students' beliefs about school science and professional science*. University of California Press, Los Angeles
- Moos, D. C., & Miller, A. (2014). The role of personal beliefs in the evaluation of pre-service teachers' lesson plans: A single case study. *British Journal of Education, Society and Behavioural Science*, 4(6), 769-783.
- National Curriculum Statement Grades 10-12 (2003). *Physical Sciences*. Pretoria: Department of Education.
- Nespor, J. K. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19(4), 317-328.
- Osborne, J., Erdura, S., Simon, S., & Monk, M. (2001). Enhancing the quality of argumentation in school science. *School Science Review*, 82(301), 63-69.

- Otting, H., Zwaal, W., Tempelaar, D., & Gilselaers, W. (2010). The structural relationship between students' epistemological beliefs and conceptions of teaching and learning. *Studies in Higher Education, 1*, 1-20.
- Ozdemir, G. (2007). The effects of the nature of science beliefs on science teaching and learning. *Egitim Fakultesi Dergisi, 20*, 355-372.
- Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307-332.
- Perkins, K. K., Adams, W. K. Pollock., S. J., Finkelstein, N. D., & Wieman, C. E. (2004). Correlating student belief with student learning using the Colorado Learning Attitude science survey. Proceedings of Physics Education Research Conference. Sacramento, California
- Prawat, R. S. (1992). Teachers' beliefs about teaching and learning: A constructivist perspective. *American Journal of Education, 100*(3), 354-395.
- Qian, G., & Alvermann, D. (1994). Role of epistemological beliefs and learned helplessness in secondary school students' learning science concepts from text. *Journal of Educational Psychology, 87*(2), 282-292.
- Ravert, D., & Evans, M. A. (2007). College student preferences for absolute knowledge and perspective instruction: Implications for traditional and online learning environments. *The Quarterly Review of Distance Education, 8*(4), 321-328.
- Rice, K. I. (2012). *Building nature of science: Professional development model to enhance teaching practice*. Unpublished doctoral dissertation, University of Otago, Dunedin.

- Rokeach, M. (1969a). Attitudes, values, and beliefs. Practicum of intelligent conversation. <http://www.BrianDavidPhillip.com> Retrieved 26/03/2012
- Sahin, M. (2009). Correlation of students' grades, expectations, epistemological beliefs and demographics in a problem-based introductory physics course. *International Journal of Environmental & Science Education*. 4, 169-184.
- Saka, Y., Southerland, S. A., & Golden, B. (2007, April 12-17). Describing the effects of research experiences for teacher attitudes and beliefs: Examining science teachers' self- efficacy beliefs, beliefs of reformed-science teaching, attitudes and pedagogical discontentment. Paper presented at the annual meeting of the American Educational Research Association, San Diego.
- Sampson, V. D., and Benton, A. (2006). Developing and validation of the beliefs about reformed science teaching and learning (BARSTL) questionnaire. *Proceedings of ASTE Conference*, Portland, OR.
- Sampson, V. D., & Clark, D. B. (2006, April). The development and validation of the nature of science as argument questionnaire (NSAAQ). *Proceedings of the National Association for Research in Science Teaching (NARST)*. San Francisco, US.
- Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, 89(4), 634-656.
- Savasci-Acikalin, F. (2009). Teacher beliefs and practice in science education. *Asia-Pacific Forum on Science Learning and Teaching*, 10(1), 318-338

- Schommer, M. (1989). *Students' beliefs about the nature of knowledge: What are they and how do they affect comprehension?* Center for the Study of Reading. Technical Report No. 484. University of Illinois
- Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, 82(3), 498-513.
- Schwab, J. J. (1964). The teaching of science as enquiry. In W. F. McComas, H. Almazroa, & M. P. Clough. (1998). *The nature of science in science education: An introduction. Science and Education*, 7,511-532
- Sinatra, G. M., & Kardash, C. A. M. (2004). Teacher and candidates' epistemological beliefs, dispositions, and views on teaching as persuasion. *Contemporary Educational Psychology*, 29, 483-498.
- Songer, N., & Linn, M. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching*, 28(9), 761-784.
- Sormunen, K. (2008). From epistemological constraints towards epistemological resources in the science classroom. *NorDiNA*, 4(1), 23-34.
- Southerland, S. A., Sowell, S., Blanchard, E.M., & Granger, E. (2011). Exploring the construct of teacher pedagogical discontentment: A tool to understand teachers' openness to reform. *Res Sci Educ*, 41, 299-317.
- Stathopoulou, C., & Vosniadou, S. (2006). *Conceptual change in physics and physics-related epistemological beliefs: A relationship under scrutiny.*

- Stathopoulou, C., & Vosniadou, S. (2007). Exploring the relationship between physics-related epistemological beliefs and physics understanding. *Contemporary Education Psychology, 32*, 255-281.
- Tanriverdi, B. (2012). Pre-service teachers' epistemological beliefs and approaches to learning. *Procedia – Social and Behavioral Sciences, 46*, 2035-2642.
- Tickle, E. L., Brownlee, J., & Nailon, D. (2005). Personal epistemological beliefs and transformational leadership behaviours. *The Journal of Management Development, 24*, 1-15.
- Tobin, K., Tippins, D.J., Hook, K.S. (2006). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*(4), 634-656.
- Topcu, M. S., & Yilmaz-Tuzun, O. (2009). Elementary students' metacognition and epistemological beliefs considering science achievement, gender and socioeconomic status. *Elementary Education Online, 8*(3), 676-693.
- Trochim, W. M. (2006). The research methods knowledge base. Retrieved from <http://trochim.human.cornell.edu/kb/index.htm> 11/03/2012.
- Tsai, C. (2000). Relationship between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research, 42*(2), 193-205.
- Tutty, J., & White, B. (2005). Epistemological beliefs and learners in a tablet classroom. [On line series] Retrieved from <http://www.ascilite.org.au/conference/brisbaneos> 26/4/2012

- Uzuntiryaki, E., & Boz, Y. (2007). Turkish pre-service teachers' beliefs about the importance of teaching chemistry. *Australian Journal of Teacher Education*, 32(4), 1-16.
- Yilmaz, H., & Sahin, S. (2011). Pre-service teachers' epistemological beliefs and conceptions of teaching. *Australian Journal of Teacher Education*, 36(1), 73-88.
- Yilmaz-Tuzun, O., & Topcu, M. S. (2008). Relationships among pre-service science teachers' epistemological world views, and self-efficacy beliefs. *International Journal of Science Education*, 30(1), 65-85.
- Zeidler, D. L., Sadler, T. R., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research – based framework for socioscientific issues education. *Wiley Periodicals*, 357-377.

APPENDIX A

The Nature of Science as Argument Questionnaire (NSAAQ)

Appendix: The Nature of Science as Argument Questionnaire (NSAAQ)

Directions: Read the following pairs of statements and then circle the number on the continuum that best describes your position on the issue described. The numbers on the continuum mean:

- 1 = I completely agree with viewpoint A and I completely disagree with viewpoint B
- 2 = I agree with both viewpoints, but I agree with viewpoint A more than I agree with viewpoint B
- 3 = I agree with both viewpoints equally
- 4 = I agree with both viewpoints, but I agree with viewpoint B more than I agree with viewpoint A
- 5 = I completely agree with viewpoint B and I completely disagree with viewpoint A

What is the nature of scientific knowledge?

When you think of the body of knowledge that has been generated by the work of scientists, how would you describe it? The statements below describe scientific knowledge from different viewpoints. Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
1	Scientific knowledge describes what reality is really like and how it actually works.	1	2	3	4	5	Scientific knowledge represents only one possible explanation or description of reality.
2	Scientific knowledge should be considered tentative.	1	2	3	4	5	Scientific knowledge should be considered certain.
3	Scientific knowledge is subjective.	1	2	3	4	5	Scientific knowledge is objective.
4	Scientific knowledge does not change over time once it has been discovered.	1	2	3	4	5	Scientific knowledge usually changes over time as the result of new research and perspectives.
5	The concept of 'species' was invented by scientists as a way to describe life on earth.	1	2	3	4	5	The concept of 'species' is an inherent characteristic of life on earth; it is completely independent of how scientists think.
6	Scientific knowledge is best described as being a collection of facts about the world.	1	2	3	4	5	Scientific knowledge is best described as an attempt to describe and explain how the world works.

How is scientific knowledge generated?

When you think of what scientists do in order to produce scientific knowledge, how would you describe this process? The statements below describe different viewpoints for how scientific knowledge is generated. Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
7	Experiments are important in science because they can be used to generate reliable evidence.	1	2	3	4	5	Experiments are important in science because they prove ideas right or wrong.
8	All science is based on a single scientific method	1	2	3	4	5	The methods used by scientists vary based on the purpose of the research and the discipline.

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
9	The methods used to generate scientific knowledge are based on a set of techniques rather than a set of values.	1	2	3	4	5	The methods used to generate scientific knowledge are based on a set of values rather than a set of techniques.
10	Science is best described as a process of exploration and experiment.	1	2	3	4	5	Science is best described as a process of explanation and argument.
11	An experiment is used to test an idea.	1	2	3	4	5	An experiment is used to make a new discovery.
12	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are common.	1	2	3	4	5	Within the scientific community, debates and discussions that focus on the context, processes, and products of inquiry are rare.

What counts as reliable and valid scientific knowledge?

A central claim of science is that it produces reliable and valid knowledge about the natural world. The statements below describe different viewpoints about what counts as reliable and valid scientific knowledge. Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
13	Scientific knowledge can only be considered trustworthy if the methods, data, and interpretations of the study have been shared and critiqued.	1	2	3	4	5	Scientific knowledge can be considered trustworthy if it is well supported by evidence.
14	The scientific method can provide absolute proof.	1	2	3	4	5	It is impossible to gather enough evidence to prove something true.
15	If data was gathered during an experiment it can be considered reliable and trustworthy.	1	2	3	4	5	The reliability and trustworthiness of data should always be questioned.
16	Scientists know that atoms exist because they have made observations that can only be explained by the existence of such particles.	1	2	3	4	5	Scientists know that atoms exist because they have seen them using high-tech instruments.
17	Biases and errors are unavoidable during a scientific investigation.	1	2	3	4	5	When a scientific investigation is done correctly errors and biases are eliminated.
18	A theory should be considered inaccurate if a single fact exists that contradicts that theory.	1	2	3	4	5	A theory can still be useful even if one or more facts contradict that theory.

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
19	Scientists can be sure that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never worked that chemical	1	2	3	4	5	Scientists can only assume that a chemical causes cancer if they discover that people who have worked with that chemical develop cancer more often than people who have never work that chemical.

What role do scientists play in the generation of scientific knowledge?

The statements below describe different viewpoints for what scientists do and what they are like. Indicate which viewpoint you agree with the most using the scale below...

	Viewpoint A	A not B	A > B	A = B	B > A	B not A	Viewpoint B
20	In order to interpret the data they gather scientists rely on their prior knowledge, logic, and creativity.	1	2	3	4	5	In order to interpret the data they have gather scientists rely on logic only and avoid using their creativity or prior knowledge.
21	Scientists are influenced by social factors, their personal beliefs, and past research.	1	2	3	4	5	Scientists are objective, social factors and their personal beliefs do not influence their work.
22	Successful scientists are able to use the scientific method better than unsuccessful scientists.	1	2	3	4	5	Successful scientists are able to persuade other members of the scientific community better than unsuccessful scientists.
23	Two scientists (with the same expertise) reviewing the same data will reach the same conclusions.	1	2	3	4	5	Two scientists (with the same expertise) reviewing the same data will often reach different conclusions.
24	A scientist's personal beliefs and training influences what they believe counts as evidence.	1	2	3	4	5	What counts as evidence is the same for all scientists.
25	The observations made by two different scientists about the same phenomenon will be the same.	1	2	3	4	5	The observations made by two different scientists about the same phenomenon can be different.
26	It is safe to assume that a scientist's conclusions are accurate because they are an expert in their field.	1	2	3	4	5	A scientist's conclusions can be wrong even though scientists are experts in their field.

APPENDIX B

Beliefs about Reformed Science Teaching and Learning (BARSTL)

Questionnaire

Appendix: The BARSTL Questionnaire

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale...

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
1. Students develop many beliefs about how the world works before they ever study about science in school.	1	2	3	4
2. Students learn in a in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	1	2	3	4
3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	1	2	3	4
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	1	2	3	4
5. Frequently, students have difficulty learning scientific concepts in school because their beliefs about how the world works are often resistant to change.	1	2	3	4
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	1	2	3	4
7. Students know very little about science before they learn it in school.	1	2	3	4
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	1	2	3	4

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale...

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	1	2	3	4
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	1	2	3	4
11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	1	2	3	4
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	1	2	3	4
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading or a demonstration.	1	2	3	4
14. During a lesson, students need to be given opportunities to test, debate and challenge ideas with their peers.	1	2	3	4
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	1	2	3	4
16. Assessments in science classes should only be given after instruction is completed; that way the teacher can determine if the students have learned the material covered in class.	1	2	3	4

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale...

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
17. Students should do most of the talking in science classrooms.	1	2	3	4
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	1	2	3	4
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	1	2	3	4
20. Teachers should allow students to help determine the direction and the focus of a lesson.	1	2	3	4
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	1	2	3	4
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	1	2	3	4
23. The teacher should motivate students to finish their work as quickly as possible.	1	2	3	4
24. Science teachers should primarily act as a resource person; working to support and enhance student investigations rather than explaining how things work.	1	2	3	4

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale...

1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree

	SD	D	A	SA
25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	1	2	3	4
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	1	2	3	4
27. Students should know that scientific knowledge is discovered using the scientific method.	1	2	3	4
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	1	2	3	4
29. In order to prepare students for future classes, college, or a career in science the science curriculum should cover as many different topics as possible over the course of a school year.	1	2	3	4
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	1	2	3	4
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with 'define the problem' and ends with 'reporting the results.'	1	2	3	4
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	1	2	3	4