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Pre-service Teachers' Beliefs about Scientific Inquiry and Classroom Practices

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ABSTRACT This study investigates the pre-service teachers' beliefs about the nature of scientific inquiry and how these beliefs interact with their classroom practices during teaching practice. It also determines some of the conceptual ecological factors that facilitate or impede the translation of these beliefs into classroom practices. The participants are two student teachers who were studied during a three-week teaching practicum session. Data sources include interviews, lesson observations, and analysis of lesson plans and student files. The results suggest that while the pre-service teachers' beliefs about nature of scientific inquiry permeate classroom behavior and action, their behavior and actions are much more influenced by the 'school context factors' and their desires to get a credit from assessment. The school context factors found to influence behavior and actions include, availability of teaching and learning materials, nature of guidance and support from mentoring teachers, and the "quality" of learners. Recommendations for science teacher training, teaching practice supervision and research are raised.

INTRODUCTION

It is generally accepted that beliefs are a critical factor in shaping a teacher's classroom practices (Borg 2015; van Uden et al. 2014). This is true for experienced, beginning and pre-service teachers. Teacher beliefs comprise a complex, interrelated system of personal knowledge, assumptions, implicit theories, attitudes, and cognitive maps that are said to guide teacher instructional decision-making and action (Pajares 1992). Classroom teaching practices are about observable pedagogical behavior and actions. Although it is generally accepted that pre-service teachers' classroom practices, behavior and actions are influenced by a variety of beliefs including beliefs about what knowledge is and how it comes to be (Brickhouse 1989; Mellado 1998; Hashweh 1996; Richardson 2003), there is still little known about how exactly teacher beliefs permeate classroom practices. According to Borg (2015), so important are beliefs that contemporary teacher preparation programs should cease to focus entirely on developing subject knowledge and pedagogical skills, but also endeavor to cognitively understand how beliefs permeate instructional practice. Sound teacher preparation programs and curricula might be drawn and implemented. However, all such efforts might stumble, if the various beliefs (for example, about teaching, learners, the nature of the subject, and learning) pre-service teachers bring to the classroom are not clearly understood.

An important premise is that what happens in the teacher's cognitive ecology has a great influence on how the teacher acts and behaves in the classroom (Borg 2015; Kim et al. 2013). By cognitive ecology it is meant the whole conceptual system of epistemological beliefs, personal theories, motivational attributes, meta-cognitive and epistemic factors, and knowledge of competing conceptions and analogies embedded in the individual (Strike and Posner 1992; Southerland et al. 2003) that guide teacher behavior and action. The existence of these elements has long been established (for example, Pajares 1992; Nespor 1987; Lotter et al. 2007; Strike and Posner 1992). While beliefs have long been associated with teacher classroom practices, a recent study by Shi et al. (2014) shows that the classroom practices of novice teachers are not always consistent with their espoused beliefs. Thus, the exact nature of the interaction of beliefs within the teacher's conceptual ecological system is still not thoroughly understood. However, there is a strong argument to suggest that, as far as the beliefs and classroom practices interface is concerned, it is possible to use a combination of interviews and classroom observations as the empirical to unravel the nature of interactions going on within a pre-service teacher's conceptual ecological system. Wickman (2004) argues that the reasons for a teacher's classroom behavior can be explained through careful interpretation of what the teacher says and his actions. To achieve this, Wickman (2004) asserts that one does not need an axe to open the individual's head. All one has to do is observe the actions and listen to what the individual says.

Objectives of the Study

Accordingly, the major objective of this study is to determine two pre-service teachers' beliefs about the nature of scientific knowledge and scientific inquiry (Bartos and Lederman 2014) and how these beliefs interact with their classroom practices during teaching practice. Furthermore, the study seeks to determine some of the conceptual ecological factors that can facilitate or impede the translation of beliefs into classroom practices. For this study, beliefs about the nature of scientific knowledge and scientific inquiry are collectively called "beliefs about scientific inquiry". The rationale for the study is that understanding these issues can be of critical importance in designing teacher preparation programs that can foster good pre-service teacher practices and teaching behavior (van Uden et al. 2014). Within the parameters of these research objectives, the study posits an explanation of the interactions among the pre-service teachers' beliefs about the nature of scientific knowledge (NOS), the nature of scientific inquiry (NOSI) and classroom practices. Furthermore, it is noteworthy that while research on teacher beliefs and classroom practices is globally abound, no research on this subject has been done in South Africa.

Research Questions

Three research questions are posed to guide the study:

1. What are the pre-service teachers' beliefs about scientific knowledge and scientific inquiry?
2. To what extent do the pre-service teachers' beliefs about scientific knowledge and scientific inquiry influence classroom practices?
3. What conceptual ecological factors facilitate or impede the translation of pre-service teachers' beliefs into classroom practices?

Conceptual Framework

Teacher Beliefs and Classroom Practices

Beliefs have been defined as those cognitive constructs, with episodic roots based on personal experience, which the individual accepts as true (Verjovsk and Waldegg 2005). Nespor (1987) describes beliefs as existential presumptions or personal truths generally unaffected by persuasion and tilted more heavily towards the affective and evaluative side. Beliefs are inseparable from human existence, personal experience and action. Although teachers' experiences and actions are social and physical, they are actually part of the belief system as a whole (Wallace and Kang 2004). Teaching experiences and actions are part of episodic memories, knowledge and feelings, which feed into, and interact with, the teacher's belief system. Teachers' knowledge and experiences based on actual classroom practice form part of what has been referred to as "practical theories of teaching" or practical knowledge (Lotter et al. 2007). In addition to contextualized knowledge of the classroom, practical knowledge also includes the teachers' constructed knowledge of the subject matter (Blomeke et al. 2014). For human beings, experience, which includes teacher practical knowledge, is intricately related to incoming perceptual data. Audi (1998) is of the view that perceptual data is linked to and feeds directly into the belief system of an individual. This is supported by Brewer and Lambert (2001) who propose that although beliefs could be innate they are to a considerable extent the result of input of perceptual data. On this basis, it is logical to suggest that experience and perceptual data are an integral part of the belief system as a whole and the teacher's conceptual ecology.

The various types of teacher beliefs form a complex system. Pajares (1992) writes of beliefs as being composed of substructures that are interrelated to each other and to more central beliefs systems. Beliefs also have a filtering effect as part of their being interrelated. This filtering can lead teachers to perceive, and act on information in different ways (Lotter et al. 2007), resulting in different classroom decisions, and instructional actions. Tobin et al. (1990) use the terms "constraints" and "beliefs" to refer to the instructional environment factors (time, resources, curriculum demands, and administrative requirements), which influence teacher decision-making and instructional practice. Lumpe et al. (2000) describe teachers' perceptions of how responsive their teaching environment (for example, resources and people) is to their effective functioning as 'context beliefs'. Context beliefs are about how the entire environment in which instruction occurs and influences teaching behavior and action. This environment includes learners, other teachers, administrators, "institutions, organizations and the physical environment" (Lumpe et al. 2000: 278). Essentially, through perception, context beliefs are part of and belong to the conceptual ecological system. The various types of teacher beliefs are said to compete with or against each other in mediating instructional practice, behavior and action (Kang and Wallace 2005). There is also the possibility that different beliefs could interrelate in such ways as to reinforce or favour certain classroom behaviors and actions by the teacher. These processes are part of belief filtration (Pajares 1992).

While it is accepted that beliefs are generally difficult to change (Pajares 1992), many education experts contend that understanding pre-service teachers' beliefs is essential for development and implementation of new teacher education curricula, effective pre-service training, and the crafting of constructivist pedagogies that might shift their belief structures (Borg 2015; Mansour 2009; Richardson 2003; Thompson 1992; Bryan and Atwater 2002; van Uden et al. 2014). For practicing teachers this implies an ecologically embedded belief driven decision-making process that is, a socio-cognitive process that includes problem identification, reflection and action (Simon and Newell 1970). According to Simon and Newell (1970), decision-making is a problem-solving process during which the teacher selects certain components of the problem task environment and integrates them with his conception of the problem space. The problem task environment comprises of the sundry factors comprising teaching, such as, information about learners, learner behavior problems, use of available resources, and the nature of the curriculum. The problem space is the teacher's own conception of what makes effective teaching.

Beliefs about the NOS and NOSI

In school science education, "teaching and learning science through inquiry" has become an international buzz phrase, a catchphrase and slogan. Teachers of science, including pre-service teachers are expected to develop the learners' subject matter knowledge, science process skills and their understandings of both NOS and NOSI (Lederman et al. 2014; Brown and Melear 2006; Abell and Lederman 2007; Wong and Hodson 2010). Naturally, pre-service teachers go into classrooms with their own beliefs, images, pre-conceptions, dispositions, views, perceptions and a conviction concerning what scientific knowledge is and how it has evolved. Science subject matter knowledge is about the concepts, ideas, models, and theories making the body of knowledge called science. Learners of science develop science process skills when they are engaged in such activities as investigating, problem solving, hypothesizing, observing, questioning, experimenting, and manipulation of apparatus and materials. Teaching about NOS involves developing the learners' ideas about the nature of scientific knowledge (for example, that it is empirically based, is revisionary and tentative). Teaching about NOSI is about developing the learners' understandings of how scientific knowledge is developed and validated (Vhurumuku et al. 2015). This includes developing their appreciation and understanding of the social, cultural, economic, and political contexts embedding the scientific process and nurturing the idea that science is just another human enterprise practiced by ordinary beings called scientists (Bartos and Lederman 2014).

Pomeroy (1993) categorizes beliefs about the NOSI as either *traditional* or *non-traditional*. The *traditional* view of science, which is largely positivistic and empiricist, subscribes to such notions as: scientific knowledge is objective and a true reflection of reality, scientific observations are free from the observer's pre-conceptions, knowledge exists independent of the knower, and observation and experiments are the only infallible sources of scientific knowledge. On the other hand, is the *non-traditional* view, which is largely constructivist and whose notions include, scientific knowledge is partly subjective and reality is a construction of the knower, scientific observations are not free from human pre-conceptions, and that in addition to experiments and observations, serendipity, human creativity and imagination play roles in the production of scientific knowledge. According to this paradigm, the teachers' beliefs about NOS and NOSI can be categorized as either *tradition*al or *non-traditional* depending on what they say in response to questions. Tsai (2002) categorizes the teachers' beliefs about NOS and NOSI into empiricist and constructivists. The empiricists see scientific knowledge as, discovered, objective, empirical, sacrosanct and infallible. Constructivists view scientific knowledge as problematic, invented, subjective, and tentative and revisionary. Vhurumuku (2004) however, argues that these beliefs could actually belong along a continuum ranging from *traditional* to *non-traditional* rather than to dichotomies. Furthermore, it could be argued that there is nothing really traditional about being a positivist. Nevertheless, it suffices to acknowledge that historically, science is associated with positivism and positivistic elements in modern science are difficult to deny.

METHODOLOGY

Sampling and Participants

The two participants, both African males, were pre-service teachers enrolled for a Bachelor of Education degree in the School of Education at a University in Johannesburg, South Africa. For ethical reasons, the teachers are presented here under the pseudonyms, *Kusile* (age 22) and *Bongani* (age 23). They were both fourth-year students training to be specialized Physical Science (Chemistry and Physics) teachers for the South African Senior Secondary school level. Both teachers were studying Physical Science as their subject major with Mathematics as a sub-major. During the period of the investigation, the two participants were on a teaching practicum and were part of a group of eleven Physical Science pre-service teachers assigned to the researcher for teaching experience supervision and assessment. The two participants were conveniently sampled for the study. The major factor determining their selection was that they were the ones who were performing relatively well in terms of subject knowledge mastery in both Physics and Chemistry as adjudged by their marks in the semester prior to the study. Pre-service teacher subject matter knowledge has been shown to be the major factor affecting both the confidence to teach and the quality of science taught to learners (Blomeke et al 2014; Schoeneberger and Russell 1986; Wallace and Louden 1992). The selected pre-service teachers were therefore expected to be the most confident of the eleven in the teaching practicum. However, neither of the two pre-service teachers had been exposed to either NOS or NOSI prior to the teaching practicum.

The two pre-service teachers were teaching at different schools in a township outside Johannesburg. Both schools are so-called formerly disadvantaged schools. The schools are reasonably similar in terms of availability of teaching materials and resources for science teaching. Each of the schools has a science laboratory, equipped with basic apparatus and materials essential for teaching Natural and Physical Sciences. However, *Kusile's* school did not have computer and Internet facilities, whereas *Bongani's* did. Many educators believe that the availability of computers and the Internet greatly influence and change teacher classroom practices (Mama and Hennessey 2013; Dexter et al. 1999). It was interesting to see how this difference related to the pre-service teachers' perceptions of their teaching environment and their beliefs about NOS, NOSI and their classroom practices. As mentioned earlier, such factors are part of so-called "context beliefs" and are located within a teacher's conceptual ecological system.

Data Collection

Beliefs about Nature of Scientific Inquiry

The pre-service teachers' beliefs about scientific knowledge and scientific inquiry were elicited through a semi-structured interview. Each pre-service teacher was asked a set of core questions around which probing for clarification and deeper understanding was done. The semi-structured interview questions were drawn and synthesized from the literature (Ryder et al. 1999; Vhurumuku et al. 2006). All interviews were audiotaped and transcribed verbatim.

The interview sought to gather information about the interviewees' beliefs about the following tenets of the NOS and NOSI, what is science, the tentative nature of scientific knowledge, the purpose of experiments in science the nature of scientific observations, the source of scientific knowledge, the validation of scientific knowledge, and the cultural 'contextuality' of scientific knowledge, that is, scientific knowledge development is influenced by culture. Vhurumuku (2010) describes the NOS and NOSI tenets as the ideas, principles, opinions or doctrines about scientific knowledge and the scientific process that are generally believed or held to be true by members of the science education community. While acknowledging that there is debate around which tenets should belong to NOS or NOSI, Dudu and Vhurumuku (2011) suggest that the first two tenets (what is science and the tentative nature of scientific knowledge) focus on NOS while the rest of the tenets are about NOSI. These tenets were chosen because they are recommended for understanding by secondary school learners in international curriculum reform documents (Achieve, Inc 2013). Moreover, the South African secondary school science curriculum, the National Curriculum Statement (Department of Basic Education (DoBE) 2011) also advocates for the development of learners' understanding of nature of science. On their teaching practicum, the pre-service teachers are expected to develop learners' understandings of NOS and NOSI, as part of their Physical Science teaching.

As alluded to, the focus of this study is to find out what the pre-service teachers' beliefs on the selected NOS and NOSI tenets were and to determine if any of the pre-service teachers' beliefs influenced the way they planned and executed their science lessons. Thus, in addition to eliciting the pre-service teachers' ideas about the selected NOS and NOSI tenets, the interviewees were also asked questions relating to their teaching philosophies.

Interviews seeking to elicit the pre-service teachers' beliefs about NOS and NOSI were done prior to their being observed as part of teaching experience supervision and assessment. It was important to assure the interviewees that the interview was for research purposes only and would in no way influence the researcher's objectivity in the assessment and supervision. In this case, the interviewer was both a researcher and assessor. Enosh and Buchbinder (2005:588) warn of the dangers to validity and trustworthy of data posed by "power relations and conflicts between interviewer and interviewee" in qualitative research. Getting the confidence and openness of the interviewees was, therefore, critical.

Nature of Scientific Inquiry Beliefs and Classroom Practices

Teacher classroom practices were investigated through non-participant, semi-structured observations (Cohen et al. 2000) and in-depth reflective interviews. The pre-service teachers' teaching practice portfolios were also analyzed.

Lesson Observations

Each pre-service teacher was observed for two consecutive 40-minute lessons, teaching the same grade and on the same content topic. *Kusile's* two observed lessons were with a Grade 10 class focusing on *Representing Chemical Change*, specifically, *Balancing Chemical Equations*. *Bongani* was observed teaching a Grade 11 class. The focus of the two lessons was on the relationship between voltage (V), current (I) and resistance (R), essentially, on Ohm's Law, V = IR. For each of the observed lessons, the observer sat at the back of the classroom and took notes, recording proceedings as guided by an observation guide. The aim was to capture as much as possible of the class events. The observation notes were transcribed for analysis.

In-depth Interviews

Pre- and post-lesson interviews were conducted. Before each lesson observation, the pre-service teacher was asked to avail a copy of the lesson plan. He was also asked to brief the observer on the teaching and learning strategies he was going to use and to explain and justify his approach. At the end of each lesson, the teacher was interviewed based on his lesson delivery. The purpose of questioning was to get clarifications and further understand the pre-service teacher's actions and reasons and justifications for those actions. Probing was done with the aim of making the student reflect on both his beliefs about NOS, NOSI and his teaching actions. A similar strategy has been successfully employed by Irez (2007), who used a reflective-oriented qualitative approach to investigate the teachers' beliefs about the NOS. Additionally, each pre-service teacher was probed around the following questions:

1. What is your way of teaching science?
2. Do you think your way of teaching science can help learners to understand what science is all about? Explain.

All interviews were audiotaped and transcribed verbatim.

Documents Analysis

Regarding teaching experience, the pre-service teachers are required to have a teaching experience file or portfolio. The portfolio was analyzed focusing on teaching materials, such as laboratory worksheets, exercises and assessments tasks. The aim was to capture as much as possible of the pre-service teacher's planning and lesson presentations.

Data Analysis

Data was qualitatively analyzed through a combination of analytic induction (Murcia and Schibecci 1999; Lincoln and Guba 1985) and interpretive analysis (Thorne et al.1997; Gall et al. 1996). In analyzing the pre-service teachers' NOS and NOSI beliefs, each interviewee's responses to all the questions were repeatedly read and emerging themes of meaning were coded and re-coded. Data from the pre- and post- lesson interviews were similarly read and re-read and units of meaning were coded and re-coded. The objective here was to gain insights into the pre-service teacher's decision-making process and classroom action and behavior at the conceptual ecological level. For each pre-service teacher, all the data was also read and re-read with the objective of getting a holistic picture of the teacher's NOS and NOSI beliefs and classroom practices, as well as look for patterns that might suggest links or associations between beliefs, decision-making and teaching action.

At the bottom of the data interpretation was an effort to answer the questions: What could have driven the pre-service teacher to teach in the way he did? What could have been going on in the mind of the pre-service teacher? What factors could have influenced the teacher's decision-making and action? How can the data be given meaning from the point of view of the teacher's beliefs and a conceptual ecology model? What could have been happening in the conceptual ecological system of the pre-service teacher? In what ways were the pre-service teacher's NOS and NOSI beliefs influencing his behavior and actions?

There was a deliberate effort to isolate the pre-service teacher's belief in question and make inferences concerning it being reflected in his teaching actions. Borrowing from chemical thermodynamics, where the part of the universe one is interested in is the system and all other things form the surroundings, there was an effort to determine whether the belief in question was influenced or linked to other aspects in the pre-service teacher's conceptual ecology. In this effort, the following questions were addressed: What factors, beliefs, and experiences, within the ecological system are influencing the pre-service teacher's beliefs about NOSI? To what extent are the pre-service teacher's ideas about NOSI represented in the instructional actions? This meant going back to listen to the audio-taped interviews and reading and re-reading the transcribed texts. As Thorne et al. (1997) advise the major focus of this kind of analysis and interpretation should not be simply sorting and coding but synthesizing, reconceptualizing and theorizing. In line with this, there was a deliberate effort to search for patterns and strands of linkage between or among the various pieces of information. The researcher and an experienced science educator in the same University with the researcher carried out coding and re-coding of the responses independently. All the final interpretations were a result of consensual agreement.

RESULTS

In this section, first the results on pre-service teachers' beliefs about the nature of scientific knowledge and scientific inquiry are presented and analyzed (*Research Question 1*). This is followed by the presentation, analysis and interpretation of the findings relating to pre-service teachers' beliefs about the nature of scientific knowledge and scientific inquiry and their relationship to classroom practices (*Research Question 2*). In that effort, the conceptual ecological factors facilitating or impeding the translation of the pre-service teachers' beliefs into practice are teased out (*Research Question 3*).

Pre-service Teachers' Beliefs about Nature of Scientific Inquiry

The two pre-service teachers' beliefs on each of the investigated tenets are summarized in Table 1. For each tenet, exemplary statements are written to capture the major idea(s) expressed by the teacher during the interviews.

Table 1: A summary of the pre-service teachers' beliefs about NOS and NOSI

Nos/Nosi Tenet		*Pre-service teacher*	
		Kusile	*Bongani*
Nos Tenets	what is science	A way of knowing about nature through performing experiments so that what things look like is known	Studying nature in the different subjects Chemistry, Biology, Physics, etc
	Tentative nature of scientific knowledge	Scientific knowledge cannot be changed once it is proved to be true	Scientific knowledge can change in the light of new evidence
Nosi Tenets	Purpose of experiments in science	To verify theory and show that things are real To show that their theories are correct	To investigate the nature of substances with the aim of identifying properties and structure so that they can be used To improve materials and also discover new materials and compounds that can be used
	Nature of scientific observations	Scientific observations are objective because what is observed and what actually happens is one and the same thing	Scientific observations are objective because when we do experiments we always get similar results
	Source of scientific knowledge	From observing and experiments Through following the method, which are used to acquire scientific knowledge the scientific method and experiments	Through experiments and observing, but scientists also think and imagine and create things
	Validation of scientific knowledge	Disputes settled by repeating experiments	Scientists perform experiments to show that things are realThey repeat experiments to settle disputes
	The cultural 'contextuality' of scientific knowledge	Depends on culture and is influenced by culture	Does not depend on culture and is universal

Kusile

As the summarized results show, Kusile's NOS and NOSI beliefs can generally be described as falling within the *traditional* category (Pomeroy 1993). Only on one of the investigated tenets, "the cultural contextuality of scientific knowledge", does he express ideas and positions, which might be described as belonging to the *non-traditional* category. This is illustrated from some of his statements from the interview. For example, he harbored the belief that the role of experiments in science is to prove theory. When asked the question: Why do scientists do experiments? His answer was:

To show or prove that their theories are correct. They start with a hypothesis which they say is it true...let me do an experiment to show or see is it true? So they test...like we do in the lab we can actually show Oh! Light can be refracted by passing it though a prism.

He also held the notion that all scientists need to do in order to discover new knowledge is to perform experiments and make careful observations. He suggested:

When scientists do experiments and observe they come to know about what things really are, they investigate and produce new ideas...something not known before.

These are traditional ways of looking at science, since it is now generally accepted by philosophers of science, that experiments do not prove theory, rather they are artifacts or creations of scientists themselves, which can at best only falsify hypotheses (Popper 1972). It is also accepted that science can also happen without experiments. From the history of science, it is also known that in addition to experimentation and observation, the development of scientific knowledge occurs through the creativity and imagination of scientists (Lederman 1998).

Kusile (K) viewed scientific observations as objective and different scientists as seeing things in the same way and obtaining similar sets of experimental data from the same experiment. If this does not happen then one of them could be making an error or fails to be objective. When quizzed he replied:

K: In science when you make observations you have to be objective, otherwise you are not a scientist…you must see what is really there...and another scientist must also see that this is really.

Interviewer: *But, can't different scientists see things differently or get different results?*

K: They should see the same things if they all observe carefully...Maybe one will not be careful...as for results if they are different, it means one made an error or is inaccurate in measuring or reading, even in our pracs at University this happens...especially when you don't follow the instructions or method properly...take results and make deductions.

He appeared to hold the notion that science is about uncovering infallible ontological truths, through simply making careful observations, following a method or taking accurate measurements. This is not an uncommon finding, as research done around the world (Lederman 2007) shows that such misconceptions among pre-service teachers are widespread. What is interesting here is the fact that Kusile appeared to link his understandings to his laboratory work experiences at University. It could be that some personal experiences embedded within his conceptual ecological system were influencing his notions about the nature of scientific observations and how scientific knowledge is obtained using a method. This is in line with the findings of Vhurumuku et al. (2006), which suggest that the learners' laboratory work experiences have some effect on the way they look at NOS and NOSI. Surprisingly, Kusile had some informed ideas about whether or not scientific knowledge depends on culture. He said:

K: Knowledge depends on culture…we know certain things which white people or science don't know.

Interviewer*: Can you give examples of such things?*

K: Like you know lightning can be made and send to kill you...Emm...or a sangoma can fly to another part of the country during the night riding a basket…!

Interviewer: *But is that science? Earlier on you said science follows a method. Is there a method there?*

K: I don't know really, maybe there is a method we don't know of. You know these things you never know whether true or not people just say...but I think it's different science. I don't know.

He seemed to hold the notion that there are different ways of knowing but failed to explain whether or not the different ways of knowing can be called a science.

Bongani

Bongani (B) harbored traditional beliefs on some tenets and non-traditional beliefs on others. He believed that scientific observations are objective, science is independent of culture and universal, and that all that scientists need to do to validate knowledge is to perform experiments. At the same time he also believed that scientific knowledge changes, was constructivist about the purpose of experiments in science, and acknowledged the role of imagination and creativity in the development of scientific knowledge. During the interviews he revealed some interesting ideas. On the issue of the "the cultural contextuality of scientific knowledge", he said:

B: You see...science is the same everywhere. An electron is an electron and it will jump from one energy level to another whether you go to China or you are in Mpumalanga...so it is not about culture...for example, scientists all over will do an experiment and show that $V = IR$ or show Faraday's law is true...it does not matter where you are, maybe just the conditions.

Interviewer: *But what can you say about the fact that most of the science we know today was discovered in Europe and America? Is that not about different cultures?*

B: But even if it was discovered in Africa, the electron will still be an electron, whether a Blackman or a Whiteman is looking at it doesn't matter...they will still see the electron.

Interviewer: *What I wanted to say was that, is it not that the problems scientists investigate depend on where they are, their culture and what they will be experiencing at the time?*

B: But will that change electron to something else? No, even if it was discovered in Africa it will still be an electron. Why it was not I don't know? Maybe it's God.

As can be seen, Bongani harbored strong positivistic and traditional beliefs about the universality of scientific knowledge and its cultural independence. This belief appears to be linked to a realist epistemological and ontological conviction that the electron is a tangible entity and not a construct created by scientists to explain observables (Dawson 1991). At the same time his defense in the above exchange could be illustrative of the fact that beliefs are resistant to change (Pajeras 1992). On the purpose of experiments in science, he said:

B: Scientists investigate the nature of materials and substances so as to know their properties and structures so that they can be used, or improve materials and also discover or make new materials and compounds that can be used by people.

Interviewer: *How do they come to know that this and that can be used in this way?*

B: They perform experiments and observe! This can do and this can't.

Interviewer: *What happens if the scientists fail to agree?*

B: They do more experiments and get results they think and become creative until they can say surely it's this one which works.

Beliefs about Scientific Inquiry and Classroom Practices

Kusile: Lessons Observations

Kusile introduced the first lesson on *Balancing Chemical Equations*, by asking learners to explain what the word "*balance"* means. After getting several responses all of which pointed towards "to balance is to make equal", he said:

Indeed that is so, when we balance equations we make sure things are equal on both sides. Like in Math, we have the right side and left side of the equation and we say left is equal to right. Then we check whether they equal.

He went on to write the equation:

$Mg + O_2 \longrightarrow 2MgO$

Learners were asked to give reasons as to why the equation as given was balanced. Learners talked and discussed among themselves and some raised hands. There was a subsequent teacher-learner discussion during which the teacher responded to learners' answers and ended with saying, for chemical equations, balancing is about making sure that the number of atoms of each element on either side of the equation is the same. Clearly, some learners showed that they did not understand the meanings of the stoichiometric coefficients such as the 2 in front of MgO and the 2 for O_2. The teacher made no attempt to follow this up, pointing out instead that, "You must have done symbols with your class teacher" who in this case was his school based mentor, who was the Natural Science teacher for that class.

The teacher went on to give the learners rules for balancing equations, which he wrote on the chalkboard. Essentially, the rules he gave were about counting atoms and putting appropriate stoichiometric coefficients in front of or after symbols and making a table to check if atoms on either side of the equation were balanced. He went on to say, "Let's see if you can follow the rules. Can you balance these equations for me?" He wrote on the chalkboard:

(a) $Fe_2O_3 + CO \;\; Fe + CO_2$
(b) $Zn + HCl \;\; ZnCl_2 + H_2$
(c) $KCl + Pb(NO_3)_2 \;\; KNO_3 + PbCl_2$

He went on to tell the learners that they should work in groups of 3. Learners worked, talked and appeared to be sharing ideas and the noise level in the classroom rose. Meanwhile, the teacher was moving around the class from group to group chatting to some learners in the process. After about 15 minutes the teacher called the class to attention and said:

"Now let's see if you could follow the rules. Who is going to show us how to balance equation (a)?" A boy from one of the groups was called up to the chalkboard and asked to work through the balancing. His answer was wrong. The teacher, looking at his notes, which had answers to the questions, told learners that the answer was wrong. He asked for another volunteer. This time the new volunteer, a girl, got it right. And the teacher said it was right because she could follow the rules. However, from the look of things, most learners appeared to have been struggling with the balancing. The same strategy of calling learners to the board was used or questions (b) and (c). To conclude the lesson, the teacher gave the learners five chemical equations to balance as homework. He then said in the next lesson, they were going to do an experiment.

The focus of the second lesson was to demonstrate the *Law of Conservation of Mass*, which is that when a chemical reaction occurs, the mass of reactants is always equal to the mass of products. Commonly, school experiments done on this topic include demonstrating the *Law of Conservation of Mass*. The teacher used the reaction between iron and sulphur to form iron (II) sulphide to demonstrate the concept. Before the demonstration, the teacher discussed the reaction and outlined the experiment giving the anticipated results. He emphasized that the demonstration was to show that the mass of reactants is always equal to the mass of products. The demonstration was performed in the laboratory and outside the laboratory.

First sulphur (8 g) and iron (14 g) were weighed in the laboratory. The class was then taken outside (for safety reasons, the laboratory had no working fume cupboard) and the mixture of iron and sulphur was heated in a metal dish using a portable gas burner. The formed iron (II) sulphide was weighed. The results were that the mass of the iron (II) sulphide was not the same (less than 22 g, it was 21 g) as the mass of separate iron and sulphur heated together. Several learners wanted to know why this was not so, contrary to their anticipations from what the teacher had explained before the demonstration. The teacher's answer was that they could have made errors in measurements and might need to repeat the experiment to get an accurate result. He could not explain that there could also have been a loss in mass as a result of some sulphur combining with oxygen during the heating and escaping as sulphur dioxide. This was evident during the heating. The lesson ended with the teacher explaining the link of the experiment to balancing equations.

Bongani: Lessons Observations

In the first lesson on *Ohm's Law*, Bongani started by writing the equation V = IR. He then worked through the idea of changing the subject of the formula showing that: I = V/R and R = V/I. Thereafter, he went on to work through examples for calculating each of V, I and R. One of the examples he gave was: *Calculate the current passing through a circuit, given that, the Voltage is = 3V and the resistance is equal to 1.5 A.* The approach was purely mathematical. There was no attempt to give a conceptual understanding of the meanings of *voltage, current and resistance*. Nor did the teacher show the learners the relationships among the units for the variables voltage, current and resistance. He also did not talk about the relationship between V and I being a direct one. While the learners actively participated in the lesson, the teacher made little effort to check learner understandings of his explanations, through appropriate questioning.

After demonstrating the calculations, the teacher went on to give the learners a class exercise and asked them to work out the answers in their exercise books. Three problems requiring calculation of voltage, current and resistance were given. No instructions were given to the learners to work either individually or in groups. Some learners worked collaboratively, while others worked individually. The learners worked on the problems and talked among themselves exchanging ideas. The lesson came to an end just after the teacher had completed getting feedback from learners on their calculations for the first problem.

The focus of the second lesson was to experimentally demonstrate that the voltage is directly proportional to the current. Learners were divided into groups of 5, given worksheets with a list of apparatus, diagrams showing how the apparatus should be assembled.

Learners were then instructed to get into their groups and complete the given task. The worksheet had instructions for learners to adjust the power supplied, thus varying the potential difference (p.d) across a piece of high resistance wire. Learners were required to record a series of values (a set of ten readings) for the p.d. and the current and then use their results to plot a graph of p.d. versus current. The plotting of the graph was to be done as homework.

The teacher handed out worksheets to each learner and then read through the instructions, emphasizing and explaining. He called the class to the demonstration desk and showed them exactly what they had to do. He commented:

Doing an investigation like this one means follow instructions and observe and take accurate readings. Be careful. Are we together? Is it clear?

The learners manipulated and chatted. The teacher moved from group to group talking to learners here and there and answering questions. All groups were able to complete the readings before the bell rang. The teacher concluded the lesson by reminding learners that they had to hand in their individually plotted graphs when they came for the next lesson.

Pre and Post Lesson Interviews

Table 2 summarizes the findings from the analysis of pre-service teachers' interview transcripts.

Kusile

Kusile believed that when teaching it is always important to start by looking at what the learner already knows and developing an understanding from there. He frequently used group work and encouraged cooperative learning. When asked to say something about his teaching he replied:

K: I start by letting learners say the things they know about what I want to teach, then, I try to explain to them the new things. Then I give them some work to complete in groups.

Interviewer: *How often do you use group work?*

K: I do it almost every lesson for them to learn from each other and help one another.

The way Kusile organized and executed the second lesson observed seems to be consistent with his beliefs about the purpose of experiments in professional science and in school science. According to Kusile, the purpose of experiments in school science is to "prove theory" and to show learners that "things are real". This belief about the purpose of experiments in school science appeared to be linked to what he thought was the purpose of experiments in real science

Table 2: A summary of the major findings from pre-service teachers' interview transcripts

Teaching and NOS/NOSI aspects	*Pre-service teacher*	
	Kusile	*Bongani*
Teaching philosophy	Tease learner prior knowledge Encourage cooperative learning Develop procedural understanding	Focus on the individual performance Develop procedural understanding
Science teaching approaches and strategies	From theory to practical Frequent use of group work Teacher demonstrations Verificationism Classwork	From theory to practical Teacher demonstrations Seldom use of group work Guided discovery Verificationism Frequent homework
Purpose of experiments in *science*	To prove theory Show things are real	To investigate the nature of substances
Purpose of experiments in *school science*	To prove theory Show that things are real Help learners understand	Demonstrate scientific ideas Develop science process skills Show that things are real Prepare learners for Matric exams
On observations and experiments in *science*	Observations objective Scientists make accurate observations Experiments repeated to settle disputes Experiments prove theory	Observations objective Scientists make accurate observations Experiments repeated to settle disputes Experiments prove theory
On observation and experiments in *school science*	To prove theory Show learners phenomena is real	To prove theory Show learners phenomena is real
NOS and NOSI tenets raised in relation to teaching	One method in science Scientists strictly follow procedures Role of experiments Nature of observations	Scientists strictly follow procedures Scientific knowledge is discovered from experiments Role of experiments Nature of observations
Teaching environment factors impacting on teaching	Fear of the assessor Teacher mentor Examination/test preparation Teaching/Learning Resources Curriculum constraints	Fear of the assessor Teacher mentor Examination/test preparation Teaching/Learning Resources Curriculum constraints
Conceptual ecological factors raised	Beliefs about learners	Knowledge of teaching strategies

as practiced by professional scientists. When asked to reflect on the second observed lesson and to explain why he used the experiment to demonstrate the Law of Conservation of Mass, Kusile said:

K: In science we want to show learners that these things we talk about are real. You see experiments prove that what the scientists are talking about is correct. So I wanted them to see that when we say mass of products is equal of mass of reactants, we are actually talking about real things, which happen not just in theory from a book. Also, they will know better and actually remember and say, we did this so it's correct.

Interviewer: *But in your lesson did you show that since you got different masses?*

K: I think we made an error in weighing somehow or did not read correctly the first time. I will see if my mentor wants us to repeat, so we can get a more accurate result.

Interviewer: *Why did you not use a different reaction? For example, reacting KI and Pb $(NO)_3$?*

K: I can't do that. I do the experiment the class teacher [teacher mentor] *says I must do. Sir, you see the problems we have here, we can't really do what we want because the class teacher will say...hey you will soon be going and I don't want to re-teach, you teach what is in my plan. I will show you how it's done that's why you are here to learn. So, sir, we don't always do what we believe...not on teaching experience, maybe when we graduate?*

This could be symptomatic of the fact that, while the pre-service teacher might want to practice what he believes, he is constrained by the demands and expectations of the mentor teacher. However, even in this situation, there appeared to be some ecological link between what the teacher believed to be the purpose of experiments in 'real science' and what school science experiments should aim to achieve. Kusile also mentioned the need to strictly follow the curriculum and prepare learners for tests and eventually the Matric examination as things he always considered in his planning for teaching. He also mentioned that he wanted to teach best when the University assessor was there, because to him it was important to pass teaching experience and get a credit. According to him, this greatly influenced the way he planned and executed his lessons.

Another belief, which seemed to mediate his instructional decision-making and teaching action, is about the learners' attitudes and preparedness to learn. Reflecting on his planning and execution of the first lesson, he said:

K: I had to use group work here, because even when you say work one, one, they always share and it helps because some of them are lazy, they don't want to work on their own, so others will say work with me here...and they can be difficult to control.

It looked like Kusile's use of group work was not only influenced by his belief about the benefits of cooperative learning, but also his intentions to have control of the class and his beliefs about the nature of the learners.

Bongani

Like Kusile, Bongani's teaching approach also appears to be greatly influenced by the desire to get a credit for the teaching practicum and the need to satisfy the expectations of the mentoring teacher. However, Bongani also believes that his teaching should be tuned towards preparing learners for Matric examinations. For this reason, it is important for learners to do individual work. When asked to justify his approach to the second observed lesson, he replied:

B: It's important for them to individually be able to plot graphs, because in Grade 12 exam you always have plotting graphs, so...they must actually plot individually to acquire the skill.

Interviewer: *What science do you think your learners learnt from the lesson?*

B: Here we wanted also to show that it's true that V = IR. In science we use experiments like this one to really prove and show that this is like this...when they plot the graph they will see and say, for our results, we see whenever we multiply R and I, we get V.

Interviewer*: Did you plan this experiment yourself or was it your mentor teacher?*

B: The teacher gave me the topic to teach and said introduce Ohms' Law. We looked at the textbooks and we said we can do this investigation...they are required to do investigations... that is what the syllabus says.

Interviewer: *What is it about science that learners learn from doing investigations?*

B: For example in the lesson...they had to know that it's important to follow instructions, *that's what scientists do they use the method and follow it to get accurate observations and readings...so I made sure they understood instructions before they collect data.*

While Bongani's approach and strategies were influenced by the teacher mentor, the examination, and curriculum demands, his responses were also suggestive of some linkage between his beliefs that: experiments in science are for proving theory or showing "that it's true that V = IR and that there is a scientific method followed by scientists and his emphasis on learners following instructions. This could be linked to his belief in verificationism: "*We use experiments like this one to really prove and show that this is like this and get accurate observations and readings"*. This is also demonstrated in the way he enacted his second observed lesson and emphasized routine procedures in the first lesson, such as, mathematical verification of *Ohm's Law*.

DISCUSSION

The exploration and analysis of lesson observations and interview data suggests that for the two pre-service teachers, some of the investigated beliefs about scientific inquiry permeate teaching practices. This is in line with Borg (2015), who says beliefs are a critical factor in shaping teacher classroom practices. For both pre-service teachers, there is some linkage between the pre-service teacher's beliefs about the purpose of experiments in professional science, the purpose of experiments in school science and his use of exposition and verificationism as teaching strategies. The two pre-service teachers appear to find justifications for their use of verificationism in the 'nature of scientific inquiry', suggesting that verificationism is right because experiments in science are designed to 'prove theory'. As alluded to this supports both Borg (2015) and earlier studies by Tsai (2002, 2007), which suggest that teachers who harbor empiricist/traditional beliefs tend to use traditional, teacher centered strategies as opposed to those harboring constructivist beliefs.

Bongani's beliefs that there is a method followed by scientists and that it is important for scientists to follow instructions also appears to manifest in the way he emphasizes following instructions in the second observed lesson. In line with what Borg (2015) suggests, this is corroborated by the data from the pre-service teachers' interviews. However, as far as beliefs about scientific inquiry are concerned, it is interesting to note that some of the investigated tenets, especially, *the cultural 'contextuality' of scientific knowledge* and *the validation of scientific knowledge* did not show obvious linkages to the teacher practices as found from the analysis of both the observed lessons and teacher interviews. This supports the findings of Shi et al. (2014), which suggest that novice teacher espoused beliefs do not always manifest in their teaching practices. It could be said that perhaps this is so because the content of the subject matter for the observed lessons did not easily make it possible for a linkage to manifest. For the current study, it could also be that the participating teachers had not been exposed to the pedagogics of teaching about NOSI in science lessons. The analysis of the teaching portfolios for both pre-service teachers revealed that they never deliberately planned to develop the learners' NOSI understandings. According to Vhurumuku et al. (2015), many teachers fail to teach learners about the NOSI because they themselves do not understand NOSI or do not have the pedagogical skills to teach about it. Abd-El-Khalick and Lederman (2000) have recommended that in order for teachers to teach effectively about the NOSI they must be explicitly taught to do so. This implies the introduction of courses on NOSI in pre-service teacher training.

What appears to be the case with the pre-service teachers studied here is that while some beliefs filtrate onto practices, the extent to which they do so is reduced or constrained by some factors in the instructional environment (Mama and Hennessey 2013). This can explain both what was found in the current study and be consistent with the findings of Shi et al. (2014). Both Kusile and Bongani indicate that the extent to which they can practice what they believe is limited because they have to meet the requirements of the teacher mentor. They end up doing "*the experiment the class teacher* [teacher mentor] *says"* or looking at *"the textbooks"* and doing what is agreed upon with the mentor. Additionally, they also appear to be constrained by curriculum and examination demands. This supports Tobin et al. (1990) and Lumpe et al. (2000) who view these "constraints" or "context beliefs" or "external belief" as having an influence on teacher decision-making and instructional practice. The effect of the "external belief" or constraint appears to be to make teachers not to teach science "the way you want" or not always to teach, "What you believe". They develop "practical theories of teaching" (Lotter et al. 2007), which are in line with the realities of the environment in which they operate.

It appears that there was constant conflict between the pre-service teachers' NOSI beliefs and the realities of their teaching environments. As the results here suggest, the teachers' practices seem to be a balance between their NOSI beliefs and their perceptions of the reality of the environmental in which they operate, that is, the contextual factors or barriers or constraints. The researcher refers to these environmental factors as *in vitro* factors. At the same time, other beliefs located in the pre-service teacher's conceptual ecological system also appear to interact with their beliefs about NOSI and the way they enact their practice. For example, in the case of Kusile, it is apparent that his beliefs about the purpose of experiment in school science (belief about teaching) and the nature of the learners have an influence on how and why he teaches the way he does. The researchers calls these beliefs located in the ecological system, *in vivo* factors, since unlike the *in vitro*, they are not directly linked to the physical environment as such. While this is said, it is important to note that both *in vitro* and in vivo factors are a property of the conceptual ecological system. The location of contextual or *in vitro* factors into the teacher's conceptual ecosystem is a feature occurring through perception. Perception here is both mental and epistemic (Brewer and Lambert 2001). It is an interaction of sensory data with the cognitive system. The pre-service teachers reflected on the nature of their instructional practice. They thought about and continuously located features of the instructional environment context into their conceptual ecosystem, an ecological system that is replete with interacting factors.

One can make sense of what is described here in the diagram in Figure 1 (the researcher's own presentation), which is a suggested model illustrating how *beliefs in the ecological system* interact with the actual practice (called the *enacted practice)* by the teacher. What Figure 1 illustrates is that within the conceptual ecological system, *in vitro* and *in vivo* factors interact with teacher beliefs about the NOS and NOSI. It is posited that this interaction could govern the extent to which the pre-service teachers' beliefs about NOS and NOSI influence the enacted prac-

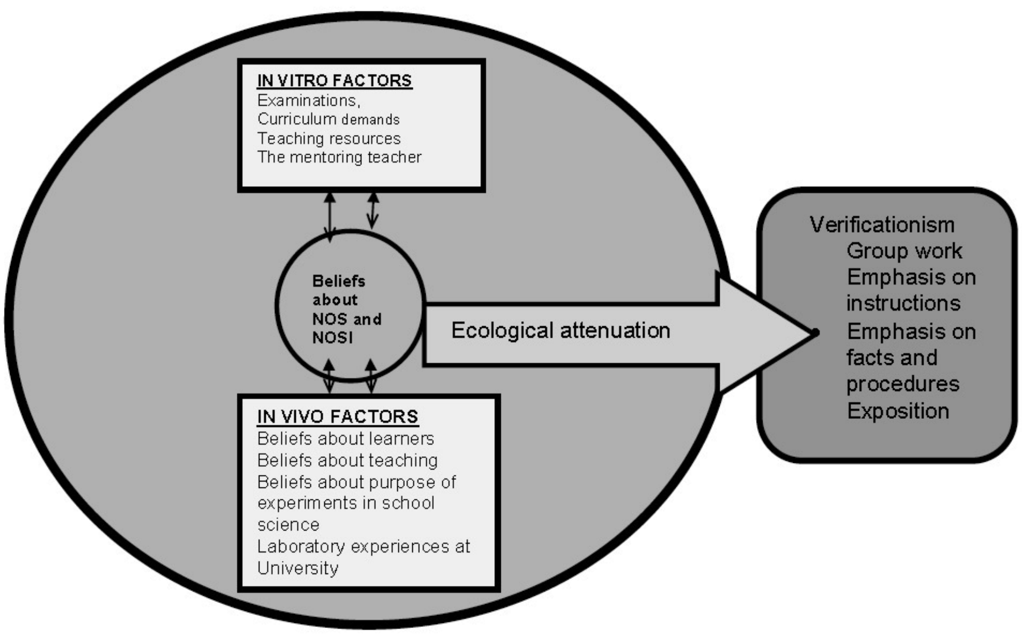

Fig. 1. Diagrammatic representation of ecological attenuation of NOS and NOSI beliefs into teaching practices

tices. The translation of teachers NOS beliefs into practice appears to suffer from attenuation, the researchers coins it *ecological attenuation*. *Attenuation* is a concept used in a variety of fields (Geochemistry, Biology, Oceanography, Ecology, Telecommunications and Medicine) to generally refer to the lessening of amount or magnitude or strength of something. To attenuate is to reduce in force, make thin, reduce signal, to slender or to taper gradually (Sykes 1988). In this context, attenuation is about reducing or decreasing of the interaction between variables; in essence reducing the extent to which the NOS and NOSI beliefs permeate teaching practices. While this is said, it is important to realize that *attenuation* of a pre-service teacher's beliefs into practice is complex because all factors (including the enacted practices) are interrelated. They might all interact and influence on each other (Pajares 1992). For example, teacher practices have been reported to have some influence on the teachers' philosophical orientations and beliefs about teaching (Borg 2015).

Pre-service teachers' perceptions of their instructional environment provide reflective and evaluative mirrors through which they can make judgments about the merits and demerits of instructional decisions (Simon and Newell 1970) viz-a-viz their beliefs about the NOS and NOSI. Because the pre-service continuously reflected on their instructional practices and environment, the realization of *ecological attenuation can be said* not to be a subconscious activity but a conscious purposeful activity feeding into daily decision-making and instructional practice.

CONCLUSION

The interview results suggest that as far as the investigated NOS and NOSI tenets are concerned, the two pre-service teachers harbored beliefs, which can be described as mainly naive. They both believed that scientific observations are objective and free from human preconceptions, scientific theories could be proven as correct by conducting experiments and making accurate observations, scientific disputes could be settled by repeating experiments, there is a method followed by scientists in discovering new knowledge, and that school science experiments are mainly for demonstrating scientific knowledge as a sacrosanct ontological truth. However, the two teachers showed some variations in their thinking. For example, Kusile had the informed view that scientific knowledge was culturally dependent, whereas Bongani believed that it was culture free. Bongani believed scientific knowledge could change and that the purpose of experiments in science was to solve human life problems.

The fact that the investigated pre-service teachers showed some naive ideas about the NOS and NOSI is a worrying but not a surprising finding as it is consistent with the results of many studies from around the world. These studies have repeatedly shown that secondary school teachers and learners harbor naive ideas about what scientific knowledge is and how it is developed and validated. Given that the development of learners understandings of NOS and NOSI is a major contemporary science education curriculum goal, it is important to advocate for the inclusion of modules or courses on Nature of Science in all pre-service teacher education programs. Teachers can only teach about the NOS and NOSI if they have adequate pedagogical content knowledge.

The interview and lesson observation data suggests that some of the pre-service teachers' beliefs about NOSI are associated with their teaching practices. However, the extent to which the teachers' beliefs about science and scientific inquiry permeate, filtrate or influence teaching practices appears to be limited by in vitro factors and in vivo factors. It looks like pre-service teachers can only put their beliefs into practice to a *small, attenuated extend*.

This study has revealed that at the conceptual ecological level, for the pre-service teachers, the translation of NOS and NOSI beliefs into practice appears to be under the governance of in vitro factors and in vivo factors. The following in vitro factors appeared to be associated with the translation: the influence of the teacher mentor, curriculum demands, examination demands, and the very fact that the pre-service teachers were on a teaching practicum and wanted to get a credit. The in vivo factors are teacher beliefs about learners, teacher beliefs about the purpose of experiments in school science, and their own laboratory work experiences at University. It was difficult to determine with certainty, whether any of these isolated factors positively reinforced translation or actually impeded translation. It can only be posited with care that perhaps the in vitro factors appear to impede translation. While the model, the researcher posits here might shed some light on this complex phenomenon, further research is required in order to fully understand what actually happens in a pre-service teacher's ecological system when making decisions about instructional choices and actions.

RECOMMENDATIONS

The teaching practicum can provide opportunities for novice teachers to develop and craft idiosyncratic practices according to their training backgrounds and beliefs. The recommendation from this study is that science teacher preparation programs should also provide pre-service teachers with opportunities to explicitly confront and reflect on their beliefs, and refine and transform them into practices. This has a direct bearing on both science teacher education curricula and teaching practicum models. An interesting study would be to investigate how the beliefs of the pre-service teachers studied here would relate to practices if they were operating in an environment in which there is less "interference" from the mentoring teachers. Would their practices be different? Perhaps a similar exploration under a different teaching practicum model would yield different findings. Could it be that teaching practice models in which the novice teacher is given significant latitude to practice according to his or her own beliefs are better for nurturing, teacher independence and confidence?

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REFERENCES

Abd-El-Khalick F, Lederman NG 2000. Improving science teachers' conceptions of nature of Science: A critical review of literature. *International Journal of Science Education,* 22: 665-701.

Abell S K, Lederman NG 2007. *Handbook of Research on Science Education.* Mahwah, NJ: Lawrence Erlbaum Associates.

Achieve, Inc 2013. On Behalf of the Twenty-six States and Partners that Collaborated on the NGSS (2013). Next Generation Science Standards. From <http://www.nextgenscience.org/nextgeneration-science-standards> (Retrieved on 25 June 2013).

Audi R 1998. *Epistemology: A Contemporary Introduction to the Theory of Knowledge.* London: Routledge.

Bartos S, Lederman NG 2014. Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice. *Journal of Research in Science Teaching,* 51(9): 1150–1184.

Blömeke S, Hsieh FJ, Kaiser G, Schmidt WH (Eds.) 2014. *International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn.* Hamburg: Springer Germany

Borg S 2015. Researching teacher beliefs. In: B Paltridge, A Phakiti (Eds.): *Research Methods in Applied Linguistics: A Practical Resource.* London: Bloomsbury, pp. 487-504.

Brickhouse NW 1989. The teaching of science in secondary classrooms: Case studies of teachers' personal theories. *International Journal of Science Education,* 11: 437-499.

Brown S L, Melear C T 2006. Investigation of secondary science teachers' beliefs and practices after authentic inquiry-based experiences. *Journal of Research in Science Teaching,* 43(9): 938–962.

Brewer FW, Lambert BL 2001. The theory ladenness of observation and the theory ladenness of the scientific process. *Philosophy of Science,* 68: 176-185.

Bryan LA, Atwater MM 2002. Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Education,* 86(6): 821-839.

Cohen L, Manion L, Morrison K 2000. *Research Methods in Education.* 5th Edition. London: Routledge Falmer.

Department of Basic Education 2011. *Curriculum Assessment and Policy Statement (CAPS) Document Physical Sciences Grades 10-12.* Department of Education (Ed.). Pretoria: Government Printers.

Dexter S L, Anderson RE, Becker HJ 1999. Teachers' views of computers as catalysts for changes in their teaching practice. *Journal of Research on Computing in Education,* 31: 221-238.

Dudu WT, Vhurumuku E 2011. Exploring learners' understandings of the nature of scientific inquiry: Validation of a research instrument. *The International Journal of Learning,* 18(2): 67-84.

Enosh G, Buchbinder E 2005. The interactive construction of narrative styles in sensitive interviews: The case of domestic violence research. *Qualitative Inquiry,* 11(4): 588–617.

Gall DG, Borg WR, Gall JP 1996. *Educational Research: An Introduction.* New York: Longman Publishers.

Hashweh MZ 1986. Toward an explanation of conceptual change. *European Journal of Science Education,* 8: 229-249.

Irez S 2007. Reflection-oriented qualitative approach in beliefs research. *Eurasia Journal of Mathematics, Science and Technology Education,* 3: 17-27.

Kang N, Wallace CS 2005. Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education,* 89: 140-165.

Kim CM, Kim MK, Lee C, Spector MJ, DeMeester K 2013. Teacher beliefs and technology integration. *Teaching and Teacher Education,* 29: 76-85.

Lederman NG 1999. Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36: 916-929.

Lederman NG, Antink A, Bartos S 2014. Nature of science, scientific inquiry, and socio-scientific issues arising from genetics: A pathway to developing a scientifically literate citizenry. *Science and Education*, 23(2): 285-302.

Lincoln YS, Guba EG 1985. *Naturalistic Inquiry.* Beverly Hills, CA: Sage.

Lotter C, Hardwood SH, Bonner JJ 2007. The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*, 44: 1318-1347.

Lumpe AT, Haney JJ, Czerniak CM 2000. Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, 37: 275-292.

Mama M, Hennessy S 2013. Developing a typology of teacher beliefs and practices concerning classroom use of ICT. *Computers and Education*, 68: 380–387.

Mansour N 2009. Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental and Science Education*, 4(1): 25-48.

Mellado V 1998. The classroom practice of pre-service teachers and their conceptions of teaching and learning science. *Science Education,* 82(2): 197-214.

Murcia K, Schibecci R 1999. Primary student teachers conceptions of the nature of science. *International Journal of Science Education*, 21: 1112-1140.

Nespor J 1987. The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19: 317-328.

Pajares MF 1992. Teachers beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, 62: 307-332.

Pomeroy D 1993. Implication of teachers' beliefs about the nature of science a comparison of the beliefs of scientists, secondary science teachers and elementary teachers. *Science Education*, 77: 261-278.

Popper KR 1972. *Objective Knowledge*. Oxford: Clarendon Press.

Richardson V 2003. Pre-service teachers' beliefs. In: James Raths, Amy C McAninch (Eds.): *Teacher Beliefs and Classroom Performance: The Impact of Teacher 'Education.* Greenwich CT: Information Age Publishing, pp. 1-22.

Ryder J, Leach J, Driver R1999. Undergraduate science students' images of Science. *Journal of Research in Science Teaching*, 36(2): 201-219.

Schoeneberger M, Russell T 1896. Primary science as a little added frill: A report of two case studies. *Science Education*, 70(5): 519-538.

Simon H, Newell A 1970. Human problem solving: The state of theory in 1970. *American Psychologist*, 26: 145-159.

Shi Q, Zhang S, Lin E 2014. The relationships of new teachers' beliefs and instructional practices: Comparisons across four countries. *Action in Teacher Education*, 36(3): 322-341.

Sykes JB 1988. *The Concise Oxford Dictionary of Current English*. Oxford: The Claredon Press.

Strike KA, Posner GJ 1992. A revisionist theory of conceptual change. In: R Duschl, R Hamilton (Eds.): *Philosophy of Science, Cognitive Science and Educational Theory and Practice.* Albany, NY: SUNY Press.

Southerland SA, Gess-Newsome J, Johnston A 2003. Defining science in the classroom: The manifestation of scientists' beliefs in classroom practice. *Journal for Research in Science Teaching*, 40: 669–691.

Thompson AG 1992. Teachers' beliefs and conceptions: A synthesis of the research. In: DA Grouws (Ed.): *Handbook of Research on Mathematics Teaching and Learning.* New York: Macmillan, pp. 127-146.

Thorne S, Kirkham SR, MacDonald-Emes J. 1997. Interpretive description: A non-categorical qualitative alternative for developing nursing knowledge. *Research in Nursing and Health*, 20: 169-177.

Tobin K, Briscoe C, Holman JR 1990. Overcoming constraints to effective elementary science teaching. *Science Education*, 74(4): 409-420.

Tsai C 2002. Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education*, 24: 771-783.

Tsai C 2007. Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education*, 91(2): 222-243.

van Uden JM, Ritzen, H, Pieters JM 2014. Engaging students: The role of teacher beliefs and interpersonal teacher behavior in fostering student engagement in vocationaleducation. *Teaching and Teacher Education*, 37: 21-32

Verjovsky J, Waldegg G 2005. Analyzing beliefs and practices of a Mexican high school biology teacher. *Journal of Research in Science Teaching*, 42: 465-491.

Vhurumuku E 2004. *An Investigation of Zimbabwe A-level Chemistry Teachers' Epistemological Beliefs, Laboratory Instructional Practices and Students' Images of the Nature of Science.* PhD (Education) Thesis. Belleville, South Africa: University of Western Cape.

Vhurumuku E 2010. The impact of explicit instruction on undergraduate students' understandings of the nature of science. *African Journal of Research in MST Education*, 14(1): 99–111.

Vhurumuku E, Dudu WT, Singh S 2015. Pedagogical Content Knowledge for Nature of Science: In Search for a Meaning for the Construct. *Proceedings of the Twentieth Third Annual Meeting of the Southern African Association of Research in Mathematics and Science Technology Education (SAARMSTE) Conference* hosted by Eduardo Mondlane University, Maputo, Mozambique, 13th-18th January, 2015 (Short Paper).

Vhurumuku E, Holtman L, Mikalsen O, Kolsto SD 2006. Zimbabwean High School Chemistry students' laboratory work based images of the nature of science. *Journal of Research in Science Teaching*, 47(2): 127- 149

Wallace J, Louden W 1992. Science teaching and teachers' knowledge: Prospects for reform of primary classrooms. *Science Education*, 76(5): 507-521.

Wickman PO 2004. The practical epistemologies of the classroom: A study of laboratory work. *Science Education*, 88: 327-344.

Wong S, Hodson D 2008. From the horse's mouth: What scientists say about scientific investigations and scientific knowledge. *Science Education*, 93: 109-130.