

## Exploring a Grade 11 Teacher's Conceptions of the Nature of Science

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### Abstract

Teachers' conceptions of the Nature of Science (NOS) are central to their instructional decisions and classroom practices. This study aimed at exploring beliefs and understanding of the NOS from a grade 11 Physical Science teacher in relation to her classroom practice. It focused on a single teacher, Ms Seperepere (pseudonym) working in a rural school in the Limpopo Province, South Africa. Data on her conceptions of the NOS were gathered using open-ended questionnaire and lesson observations. The analysis of data indicated that Ms Seperepere held fairly mixed views of the NOS that were also reflected in her classroom practice. The study recommends the NOS to be taught explicitly to student teachers and in-service teachers so as to enable them acquire informed views of NOS. With informed views of the NOS, teachers will be able to design and implement their lessons to promote knowledge and skills in scientific inquiry, understanding of the NOS and the application of the scientific knowledge; as stipulated in the South African Physical Science curriculum.

**Keywords:** nature of science, teachers' conceptions, Physical Science, scientific knowledge

### 1. Introduction

Recently, throughout the world, there has been an emphasis on scientific literacy which extends beyond knowledge and understanding of science concepts. At the core of this emphasis is the understanding of the tenets of the Nature of Science (NOS) (American Association for the Advancement of Research, 1993; National Research Council, 1996; DBE, 2011; DoE, 2007). Consequently, many countries including South Africa are embracing a paradigm shift from teacher-centred to inquiry-based instruction. Current policy initiatives in South Africa are focusing on teaching Physical Science to promote knowledge and skills in scientific inquiry, understanding of the NOS and application of the scientific knowledge (DBE, 2011). However, research has shown that all teachers possess individualized conceptions that influence their thinking, instructional decisions and classroom management. These personal constructs can further serve as a lens for understanding classroom events (Jones & Carter, 2007). Likewise, Nespor (1987) contends that to understand teachers' perspectives we have to understand the beliefs with which they define their work.

The problem is that teachers themselves do not generally have informed conceptions of the NOS (Lederman, 1992). Most teachers in South Africa are products of dismal education practices under the Bantu Education Act of 1953, which rarely considered Science as a necessity for black South Africans (Muwanga-Zake, 2004). Despite many interventions by the government and NGOs, it is still a challenge to help Physical Science teachers retain appropriate conceptions of the NOS (Abd-El-Khalick & Akerson, 2004; Akerson, Abd-El-Khalick & Lederman, 2000). To Greenberg and Baron (2000), a barrier to change is a function of one's habit, and a failure to recognize the need for change. It is easier for a teacher to cling into the old ways of teaching rather than embracing new skills and strategies. Following the argument by Keys and Bryan (2001) that teachers do not teach what they do not know, these teachers are likely to pass their mixed conceptions to their learners; and therefore the quality of science taught remains under threat.

### 2. Literature Review

This section unpacks two major concepts of the paper namely: teachers' conceptions and the nature of science (NOS).

#### 2.1 Teacher's conceptions

The term "conception" is used quite broadly to describe any mental construct of an individual teacher that potentially

provides a rationale for a particular instructional practice (Dancy & Henderson, 2007). According to Marton and Booth (1997), conceptions are seen as a way of experiencing a phenomenon but they are less tangible and, therefore, are difficult to measure. An individual may have different conceptions of a phenomenon in different circumstances and experiences, adds Akerlind, Bowden and Green (2005). This is to say, different people not only have different experiences of the world, they also interpret these experiences in different ways, and this is influenced by the framework(s) of meaning they are using. Hewson and Kerby (1993), and Hollon, Roth and Anderson (1991) further elaborate that all teachers possess conceptions that influence their classroom actions and how they interpret the curriculum. This is because conceptions are subjective. Teachers also possess conceptions about the social class and the academic ability of such a class. In some cases these conceptions may take preference over views and beliefs specific to science teaching. However, Nespor (1987) contends that to understand teachers' perspectives we have to understand the beliefs with which they define their work.

Teachers' conceptions are influenced by factors such as the cultural and educational environment, technical expertise and staff development opportunities. This argument is supported by Mokiwa and Msila's (2013) study which explored English Second Language (ESL) science teachers' conceptions on teaching strategies. They found that conceptions of ESL teachers were highly influenced by the educational institutions they attended and the perceived teachers' role in the learning of science. ESL teachers in their study emulate their respective favourite science teacher in their own teaching. It is these critical experiences that, in Nespor's (1987) words, influence and frame how one uses what has been learned.

In this study the term "conception" is taken as teachers' views and ideas of the processes and products of science and how learners acquire them (Lederman, 2007). Cornett, Yeotis and Terwilliger (1990) argues that regardless of their graduate training or experience, all teachers bring to their practice what might be called *personal theories* of teaching and learning. These theories are partly unconscious, but nevertheless guide the teachers in their decisions about planning and classroom practices. Argyris and Schön (1974) draw a distinction between two types of personal theory, namely; "the espoused theory" and "theory-in-use". According to them, the espoused theory of a person is essentially what a person professes to believe, whereas the theory-in-use is the theory that governs his or her actions. These two personal theories may or may not be compatible. Usually, it is easy for a person to describe his or her espoused theory. Theories-in-use, however, are more difficult to explicate. Argyris and Schön (1974, p.7) argue that "we cannot learn what someone's theory-in-use is simply by asking him". This is to say, theories-in-use are hidden and can only be inferred from teachers' practice. This study focuses on the aspects of the NOS in the context of secondary school science.

## 2.2 What is the NOS?

The concept NOS has a complex nature and often science teachers disagree on specific definitions for the NOS (Abd-El-Khalick, 2002). Researchers and scholars of the NOS have defined it differently. For example, Lederman (1992) defines the NOS as the values and assumptions inherent to scientific knowledge and its development. This definition is one of the contemporary and frequently quoted in the literature of science education. This definition was later unpacked to by Lederman, Wade and Bell (1998) to explain that "these values and assumptions include, but are not limited to, independence of thought, creativity, tentativeness, empirically based, subjectivity, testability and cultural and socially embeddedness" (p. 596). Gess-Newsome (2002), define the NOS as the epistemological underpinnings of science that include characteristics such as tentative, empirically-based, creative, subjective, unified and cultural and socially embedded.

The variation of the NOS definition reflects in part the variation among science philosophers, adds Cobern (2000). To Abd-El-Khalick and Lederman (2000), the existing definitions of the NOS are centered on the description of the characteristics of scientific knowledge, a function of knowledge formation and development. Embedded in the NOS are the seven tenets (or simply known as, *informed views*) of the NOS as outlined by Abd-El-Khalick, Bell and Lederman (2000, p. 564) and Lederman (1999, p. 917). According to these authors, scientific knowledge is:

- Tentative or subject to change (NOS1)
- Empirically based (based on and/or derived from observations of the natural world) (NOS2)
- Subjective or theory laden (NOS3)
- Partially the product of human inference, imagination and creativity (involves the invention of explanation) (NOS4)
- Socially and culturally embedded (NOS5)
- Developed by observations and inferences (NOS6)

- Developed by an understanding of the relationships between scientific theories and laws (NOS7)

To sum up, the NOS refer to key principles and ideas which provide a description of science as a way of knowing, as well as characteristics of scientific knowledge. Many of these intrinsic ideas are lost in the everyday aspects of a science classroom, resulting in students learning skewed notions about how science is conducted. For the purpose of this study, the NOS is understood to be directly related to the epistemology of science i.e. the knowledge of the construction of scientific knowledge and its development. These tenets were captured in the adopted View of Nature of Science- form C (VNOS-C) (Abd-El Khalick & Lederman, 2002) and Views on Science-Technology-Society VOSTS (Aikenhead & Ryan, 1992) used to gather data from Ms. Seperepere.

### **3. Methodology**

This study adopted a qualitative methodology approach using an intrinsic case study design that examines a Physical Science teacher's conceptions of the NOS. An intrinsic case study was deemed appropriate since I wanted to gain a better understanding of this particular case (Yin, 2009) and it used a small number of participants (Creswell, 2013). The study adopted purposive sampling as participant was selected according to pre-selected criteria relevant to the research questions (Ivankova, Creswell & Clark, 2008). A study sample of one Physical Science teacher (Ms Seperepere) was purposively selected after administering 10 open-ended questionnaires to 4 schools in the Province. Ms Seperepere was observed twice while teaching Physical Science in two different grade 11 classes. This strategy offered me an opportunity to look at what the teacher was doing with different learners of different classes.

#### *3.1 The Participant: Ms. Seperepere*

Ms Seperepere is a female, aged 37. She started her teaching career at the current school and has been teaching there for the last 13 years. She holds a Secondary Teacher Diploma (STD) in education with Physical Science and Mathematics as her major subjects. She is currently teaching Physical Science, Life orientation and Mathematics Literacy for grade 11. She is also a Head of Department (HOD) for Mathematics and Sciences. A large number of her learners come from poor social economic backgrounds. Most learners come from either a child-headed family or from a single parent family. The main language in the area is Sepedi, which is one of the 11 official languages in the country.

#### *3.2 Data collection*

The two methods of collecting data used were open-ended questionnaires and lesson observations. This questionnaire was adopted from the View of Nature of Science- form C (VNOS-C) (Lederman & Abd-El Khalick, 2002) and Views on Science-Technology-Society VOSTS (Aikenhead & Ryan, 1992). The choice to use multiple data collection methods has long been emphasized by researchers in science education (Lederman et al., 2002; Schwartz & Lederman, 2008). I have modelled my methods based on a study by Lederman et al. (2002) where they used a questionnaire in conjunction with lesson observation.

The open-ended questionnaire consisted of eleven items aimed at assessing the seven views of NOS; namely: empirical basis, tentativeness, subjectivity, creativity and imagination, social and cultural embeddedness, differences between observation and inference, and functions (and relationships between) of scientific theories and laws. Participant was asked to respond to each question in details. The total time to complete the questionnaire was about 20 minutes. This was followed by observation of two lessons presented by the participant with the aim to assess the level of consistency between their conceptions of scientific knowledge and observed teaching practice. Each lesson was 45 minutes long. The lessons were audio recorded after securing consent from the participant, and later transcribed verbatim.

#### *3.3 Analysis of data*

The analysis of data was done thematically. This is to say that Ms. Seperepere's responses to the open-ended questionnaire were subjected to open, axial and selective coding (De Vos et al., 2011). When analyzing lesson observations, I used a prior coding scheme (Table 1) in order to establish the presence of the NOS.

**Table 1:** Data analysis scheme used to establish the presence of inquiry aspects and NOS in the PSTs' observed lessons (Adapted from NRC, 2000; and Bell, 2002).

Ability or Feature	Characteristics			
1. Involved in scientifically oriented question (EF1, AI1)	Learner poses a question	Learner guided in posing their own question	Learner selects among questions, poses new questions	Learner engages in question provided by teacher, materials, or other source
2. Design and conducts investigation (AI2)	Learner designs and conducts investigation	Learner guided in designing and conducting an investigation	Learner selects from possible investigative designs	Learner given an investigative plan to conduct
3. Priority to evidence in response to a problem: observe, describe, record, graph (EF2)	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
4. Uses evidence to develop an explanation (EF3, AI4)	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
5. Connects explanation to scientific knowledge: does evidence support explanation? Evaluate explanation in light of alternative explanations to account for anomalies (EF4, AI5, AI6)	Learner determines how evidence supports explanation or independently examines other resources or explanations	Learner guided in determining how evidence supports explanation or guided to other resources or alternative explanations	Learner selects from possible evidence supporting explanation or given resources or possible alternative explanations	Learner told how evidence supports explanation or told about alternative explanations
6. Communicates and justifies (EF5, AI7)	Student forms reasonable and logical argument to communicate explanation	Student guided in development of communication	Student selects from possible ways to communicate explanation	Student given steps for how to communicate explanation
7. Use of tools and techniques to gather, analyze and interpret data (AI3)	Student determines tools and techniques needed to conduct the investigation	Student guided in determining the tools and techniques needed	Students select from tools and techniques needed	Student given tools and techniques needed
8. Use of mathematics in all aspects of inquiry (AI8)	Student uses maths skills to answer a scientific question	Student guided in using maths skills to answer a scientific question	Student given maths problems related to a scientific question	Maths was used

In her two observed lesson observations, Ms Seperepere employed code switching strategy i.e. wobbling between English and Sepedi. She had empathy with learners whose first language was not English, so the use of Sepedi in teaching Physical Science was to make sure that learners followed the conceptual understanding of the subject matter. In so doing, she created opportunities for her learners to engage in questions, but most of the time those questions were posed by her; leading to a guided type of inquiry. For example:

*The only thing ye e le go gore e tlo ba le difference ke the weight because of... akere re ya bohole, ge re lebeletse this diagram if normal force e le this one our weight will go that one and if this one is the surface normal force e santse e eya perpendicular to the surface but the weight yona e yako tlase. Why go tswphantse weight e le yona e yago ko tlase, go sa be eeh, go se na bothata go re the surface is inclined? Why should the normal force be the one that is perpendicular to the inclined surface but the weight yona always e ya ko fase? Why weight ya rena yona e le towards the ground?*

*[The only thing that is going to be different is the weight because of... ok, when we look at this diagram, if this is the normal force then our weight will be that one and if this is the surface, normal force still going to be perpendicular to the surface but the weight will be down there. Why is weight always be the one going down, eeh, irrespective of whether the surface is inclined? Why should the normal force be the one that is perpendicular to the inclined surface but the weight always down? Why our weight is towards the ground?]*

The analysis of data indicated that the following aspects of the NOS were explicit in Ms Seperepere's views and classroom practice.

1. *Science is empirically based*
2. *Science knowledge is not tentative*
3. *Science is universal*
4. *Science is developed by observations and experiments*
5. *Science is subjective*
6. *Science is not a product of human inference, creativity and imagination*
7. *Science is a body of factual knowledge*

The analysis of her responses further revealed that Ms Seperepere holds mixed conceptions of VNOS. This is to say although she expressed some views that were consistent with the informed VNOS, she also held naïve VNOS. She expressed naïve VNOS for items 4, 5, 8 and 9; informed views for items 1, 2, 3, 6(a), 6(b), 6(c), 7 and 9 (see Appendix A). These views were also reflected in her classroom practice.

#### 4. Findings and Discussions

The discussion focuses on the two major findings based on the themes that emerged from the data. These are Ms Seperepere's views of the NOS, and her classroom practices.

##### 4.1 Views of the NOS

The study suggests that Ms Seperepere holds mixed conceptions of the NOS that lacked coherence. She expressed some views that were consistent with the seven contemporary views of the NOS. She also expressed naïve views of the NOS in four out of the eleven items used to assess the seven views of NOS. The comparison between her views of the NOS and classroom practices reflected these mixed and inconsistent patterns. For instance, she believes that science is empirically based; but on the other hand classroom observations revealed that in most cases she emphasized the role of memorization of the step-by-step procedure when conducting investigations. She expects her grade 11 learners to recall steps for conducting practical that she taught them in grade 10.

Learners were constantly reminded to remember definitions and science concepts during examinations. I argue that memorization defeats the purpose of effective learning, demonstration and hands-on activities which leads to learners engaging in scientifically oriented questions; and eventually to prediction and justification of results. Echoing Tobin and Tippins (1993), meaningful learning occurs when a learner gets time to engage in the processes required to evaluate the adequacy of specific knowledge, make connections, clarify, elaborate, build alternatives and speculate. This was not the case with her both observed lessons.

##### 4.2 Classroom practices

The instructional strategy of Ms. Seperepere followed a pattern where she would initiate responses from learners by asking them questions that would need a "yes" or "no" answer; or by asking them a value to substitute in the equation from given data. This approach had its merit and demerits. The merit lies in the fact that it afforded her with an opportunity to immediately give a correct answer when learners are wrong. A major demerit of this approach is that it restricts learners' thinking while encouraging responses that are teacher framed (Gallagher, 1991). Although most of her communicative approaches were interactive, they were also highly authoritative (Mortimer & Scott, 2003) as the direction of lessons was determined by the teacher.

In some cases learners were constantly reminded to remember definitions and concepts during examination. This clearly showed Ms. Seperepere's failure to reflect changes in science teaching and learning that have occurred over the years. She teaches Physical science from the perspectives of normal logical positivism with more emphasis on the mastery of abstract concepts and principles, and little connection with day-to-day lived experiences of learners (Kyle, 2006, Onwu & Kyle, 2011). The failure of Ms. Seperepere to develop curricular connection between science and the real life experiences of her learners is likely to diminish the relevance of science in their lives.

Ms Seperepere's approach to teaching was highly informed by the way she views science. Her misconceptions that (1) Science knowledge is not tentative (2) Science is universal (3) Science is not a product of human inference, creativity and imagination; and (4) Science is a body of factual knowledge; determined her classroom practice. This was

the case for her two observed lessons.

Following the argument of Keys and Bryan (2001) that teachers do not teach what they do not know, Ms Seperepere is passing these misconceptions about the NOS to her learners. She was indeed passing her misconceptions to learners though code switching was prevalent in her lessons with the aim of reinforcing conceptual understanding of science concepts.

## 5. Conclusion and Recommendations

Literature on the NOS has shown us that clear understanding of the NOS is a knowledge-base for the teaching and learning of science. This call for all teachers of science to possess informed views of the NOS since their conceptions influences their decisions in processes and products of science knowledge and how learners' acquire them. Until the time that science teachers hold informed views of the NOS, and are able to recognize where the thin line between inquiry-based and traditional teaching exists, reform science teaching and learning remains under threat.

The study recommends the NOS to be taught explicitly to student teachers and in-service teachers so as to enable them acquire informed views of NOS. With informed views of the NOS, science teachers will be able to design and implement their lessons to promote knowledge and skills in scientific inquiry, understanding of the NOS and the application of the scientific knowledge. These goals are reflected in the South African Physical Science curriculum.

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## Appendix A: Views of the NOS

Adapted from VNOS-C (Abd-El Khalic & Lederman, 2002) and VOSTS (Aikenhead & Ryan, 1992)

1. In your view, what is science?
2. How is science different from the other subjects you are teaching?
3. Does the development of scientific knowledge require experiments? Explain your answer.
4. After scientists have developed a scientific theory (e.g. atomic theory, evolution theory), does the theory ever change? Explain your answer.
5. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and it is not affected by social, political and philosophical values, and the intellectual norms of the culture in which it is practiced.
  - If you believe that science reflects the social and cultural values, explain your answer, giving examples.
  - If you believe that science is universal, explain your answer with examples.
6. (a) How do scientists know that atoms really exist?  
(b) How certain are scientists about the way atoms look?

- (c) Scientists agree that about 65 million years ago the dinosaurs became extinct (all died away). However, scientists disagree about what caused this to happen. Why do you think they disagree, even though they all have the same information?
7. Where do you think scientific knowledge comes from?
  8. From what you do with your learners during practical investigations, what can you say about the use of imagination and creativity in science?
  9. Why do scientists do experiments?