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# NATURAL SCIENCES JUNIOR HIGH SCHOOL TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE AND ITS IMPACT ON THEIR PLANNING OF LESSONS

**Abstract.** *An adequate understanding and classroom application of the Nature of Science (NOS) has become imperative for science teachers. Current research in senior high school science teachers' understanding of NOS is extensive but junior high school natural sciences teachers' understanding of NOS and planning of lessons requires further exploration. Six junior high school natural sciences teachers' understandings of NOS, and how they translated their NOS understandings into lesson planning in South Africa were explored. The conceptual framework of the NOS used in this research is drawn from the seven NOS aspects of explicit and implicit teaching of NOS. Data were collected from teachers' academic background questionnaires, Views of Nature of Science (VNOS(C)) questionnaires, semi-structured interviews and lesson planning documents of teachers. Data were analysed descriptively and interpretively. The findings revealed that junior high school teachers possessed inadequate understanding of NOS, and that their planning for teaching NOS was hardly influenced by their understanding of NOS aspects. The teachers' work-schedules and lesson plans showed little explicit links of NOS aspects to lesson content. The research findings have implications for the preparation of lessons with NOS aspects linked to the curriculum content.*

**Keywords:** *junior high school teachers, lesson planning, nature of science, natural sciences.*

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## Introduction

The products and applications of science are widely acknowledged by the general public as it is familiar and essential to one's daily living but the way science was developed, is developing and the methods used to acquire knowledge and skills are not fully well known and understood by the general population. Science is still perceived more as 'products' not as 'processes'. In this regard, Lederman (2007) defines science as the "body of knowledge", "method", as well as a "way of knowing" (p. 833). Science consists not only of only laws, theories, and facts but it also involves the processes and the evolution of science referred to as the Nature of Science (NOS). It is expected that a scientific literate person should understand and also know the relationships between science, technology and society.

An adequate understanding of the NOS has become increasingly imperative for science teachers at all levels of teaching. The mounting NOS research and its inclusion is evident in curricular developments over the past two decades (Bell, Abd-El-Khalick, Lederman, McComas, & Matthews, 2001; Lederman, 2007; McComas, 1998; Seung, Bryan, & Butler, 2009; Wang & Zhao, 2016). One of the goals linked to NOS in the Department of Education (DOE) Natural Sciences curriculum in South Africa is that "When teaching Natural Sciences, it is important to emphasize the links learners need to make with related topics to help them achieve a thorough understanding of the nature and the connectedness in Natural Sciences" (DOE, 2011, p. 9). To achieve this goal, teachers need to acquire adequate NOS understanding if we are to achieve the goal of promoting scientific literacy. Such understanding will enable teachers to be able to help learners to develop truthful ideas of what science is, involve them in identifying the kinds of other disciplines (Herman, Clough, & Olson, 2015) and make them appreciate the strengths, limitations and creativity of scientific inquiry (Bell et al., 2001). In the South African context, the term learners is used for students at school.

In South Africa, the experiences of teaching practice at schools suggests that junior high school teachers who teach in the General Education and Training (GET) natural sciences focus mainly on the content and not also on

NOS aspects. The lack of formally acquired NOS knowledge and skills of these teachers implies that their teaching of natural sciences can be severely hampered or limited. Often, they are not aware of the compelling reasons to teach NOS and are not compelled to include NOS in their lesson plans, and, seemingly the chances that they will implement it in the classrooms will be minimal. Even the majority of studies done in South Africa (Dekkers, 2006; Kurup, 2014; Linneman, Lynch, Kurup, Webb, & Bantwini, 2003) and other countries (Herman, Clough, & Olson, 2013a, 2013b; Herman et al., 2015; Lederman, 2007; Ma, 2009; Martin-Diaz, 2006) focused on exploring and describing mostly pre-service, elementary and secondary high school teachers' NOS understandings.

There are limited studies evident from a literature review exploring junior high school Natural Sciences teachers' NOS understandings and their classroom practices such as how curriculum documents and lesson planning are linked to teach NOS (Lederman, 2007). An encounter, prior to this research, with junior high school teachers in the district that the researchers work with and meet at subject meetings is that they seem to have limited NOS background knowledge as they have not been exposed to formal courses in NOS nor have they been supported by departmental advisors in workshops covering NOS in the GET Natural Sciences curriculum. These teachers need assistance to understand the reasons to teach NOS and opportunities must be provided for them to develop accurate notions of NOS and how to effectively implement it in science classrooms.

In relation to NOS lesson planning, Herman, Clough, and Olson (2013a) and Kurup (2014) argue that teachers are unable to decode their NOS understanding into teaching practices due to factors such as extensive curriculum, administrative constraints, the availability of resources and time to implement NOS teaching. Planning explicit lessons to teach NOS involve several steps. To begin with, there must be deliberate and reflective attempts by teachers to plan and include NOS aspects before-hand. This planning entails teachers allocate instructional time to NOS, decide on suitable NOS activities, relate individual lessons with NOS emphasis to the curriculum, compile a series of NOS activities to be presented to learners, set the pace of teaching, select homework with NOS exercises to be given to the learners, and identify techniques to assess their learning of NOS, amongst others.

The *research problem* is that current research in senior high school science teachers' understanding of NOS is extensive but little is known about *junior high school* natural sciences teachers' understanding of NOS and explicit planning of NOS lessons both in Africa and internationally and this requires further exploration. The following research questions are posed i) What are Grade 9 Natural Sciences (GET) teachers' understanding about Nature of Science (NOS) and ii) How do Grade 9 Natural Sciences (GET) teachers' plan to teach NOS and, how do their understanding of NOS influence their lesson planning?

## Methodology of Research

The research scope covered junior school teachers' understanding of NOS and to what extent their lesson planning included content linked to NOS aspects in a mixed racial school-district in Northern KwaZulu-Natal, South Africa. As an interpretive qualitative and case-study research, data were collected from i) questionnaires requesting teachers' academic backgrounds as their type of degrees and teaching experiences can influence their understanding of content knowledge and NOS teaching ii) standardized Views of Nature of Science (VNOS(C)) questionnaires iii) semi-structured individual teachers' interviews where VNOS(C) was used to explore further teachers' NOS understanding and iv) teachers' planning documents (Natural Sciences curriculum, work-schedules and lesson plans).

### *Conceptual Framework*

Nature of Science (NOS) refer the "principles and beliefs inherent to the development of scientific knowledge" (Lederman, 1992, p. 331). It is also about how scientists build up and rationalize "knowledge claims about the natural world" (McComas, Clough, & Almazroa, 1998, p. 4). The conceptual framework of NOS in this study draws from the seven core NOS aspects, research on teachers' naïve and sophisticated understanding of NOS and notions of explicit and implicit instruction. The VNOS(C) questionnaire (Abd-El-Khalick, 1998; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001) contained ten NOS aspects but this research used seven relevant targeted aspects applicable to the GET curriculum. These are: scientific knowledge is (a) tentative (subject to change) (b) empirically-based (based on and/or derived from observations of the natural world) (c) subjective (theory-laden) (d) partially-based on human inference, imagination, and creativity and (e) socially and culturally-embedded. The distinction between f) observation and inference, and g) the functions of, and relationship between scientific theories and laws.

When evaluating NOS understandings, the terms often used in NOS research are 'inadequate' or 'naïve', 'mixed'

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or 'transitional' and 'adequate' or 'sophisticated' (Lederman et al., 2001). The descriptions, 'inadequate' or 'naïve' views correspond with the positivist view and 'adequate' or 'sophisticated' views with constructivists' views (Kang & Wallace, 2005). When evaluating NOS lesson planning documents and teaching, the frequent terms used in NOS research are 'explicit' and 'implicit' (Lederman, 2007). These descriptions of evaluating NOS understanding and lesson planning documents are also used in this research. Implicit teaching refers to poor or lack of connections to NOS aspects while explicit teaching refers to deliberate planning and focus on content linked to NOS aspects. In the explicit approach, teachers should plan for NOS teaching and should deliberately attract learners' interest to NOS aspects through conversations, channelled suggestion, and explicit questioning during class using "activities, investigations and historical examples" (Schwartz, Lederman, & Crawford, 2004). The use of explicit rather than implicit curriculum teaching approaches has been widely recommended for the development of learners' understandings of the NOS (Dekkers, 2006; Vhurumuku, Holtman, Mikalsen, & Kolsto, 2006). The NOS aspects, and descriptions of evaluating teachers' NOS understanding and lesson planning documents guided the researchers in analysing and interpreting the data obtained.

*Time and Selection of Participants*

This qualitative research explored junior high school Grade 9 Natural Sciences (GET) teachers' understanding about Nature of Science (NOS). Ten Grade 9 junior natural science teachers were initially requested to participate in this research from a district in Kwazulu-Natal, South Africa. Only six teachers' volunteered but were sufficient for this research as this was an in-depth qualitative exploration of teachers' understanding of NOS and their lesson planning. Table 1 describes the larger characteristics of the participants in the research.

**Table 1. Characteristics of the participants.**

| Teacher | Gender | Age (years) | Qualification | Years of teaching | Teaching subjects and grades | School background |
|---|---|---|---|---|---|---|
| Brian | male | 30 | Diploma (Education), B.Sc. | 9 | Natural Sciences- Grade 9; Physical Sciences and Mathematics- Grade 10-12. | Girl's only school with a large enrolment of over 1000 learners. The school has adequate resources and is in an upper class suburb. |
| Leoran | female | 28 | B.Ed, B.Ed-(Honours) | 6 | Life Sciences - Grades 10-12; Natural Sciences- Grade 9. | High class suburb school. Larger number of learners. Good resources. |
| Nancy | female | 40 | Diploma (Education)- Biology, FDE (Education), B.Ed (Honours). | 22 | Natural Sciences- Grade 9; Physical Sciences- Grades 11 and 12. | Mixed middle-class school with larger number of learners. Resources and laboratory adequate. |
| Sindile | male | 40 | B.A., Diploma (Education), B.Ed (Honours). | 27 | Natural Sciences- Grade 9; Life Sciences- Grades 11 and 12. | Informal township with poor learners. The school has limited resources. |
| Nkosi | female | 40 | B.Sc. (Physics and Chemistry) | 8 | Natural Sciences- Grades 8-9; Physical Sciences- Grades 10-12 | Large school of over 1000 learners. The school is well-resourced. |
| Sakhile | male | 40 | Diploma (Education), HDE, B.Ed (Honours). | 23 | Natural Sciences- Grades 8 and 9 | Lower-class township with essential resources but a disused laboratory. |

The teachers were followed for a period of a year in 2014. Teachers were accessed for about 2 hours in the afternoons and on six different occasions throughout the year. This included seeking out volunteers, explaining to teachers the purpose of research, obtaining their permission to participate, discussing the questionnaires, collecting questionnaires, reviewing teachers' lesson planning documents, and interviewing teachers at their school. In selecting the teachers, purposive and convenience sampling were done. Some schools due to previous apartheid policies had a dominance of one race over another in staff and learner population, hence purposive sampling was adopted as only junior high school teachers were selected from different cultural and racial school backgrounds. Convenience sampling was done due to geographic accessibility as it was convenient for the primary researcher to travel to the schools in the same district due to full-time teaching commitments.

*Instruments and Validity*

Qualitative data were collected from the teachers as follows i) a questionnaire on teachers' academic background ii) a VNOS(C) questionnaire iii) a semi-structured interview schedule based on the VNOS(C) questionnaire and iv) planning documents (curriculum document, work-schedules and lesson plans). The standardized VNOS(C) was used as it was already developed and modified (Abd-El-Khalick, 1998) and validated by tertiary science educators (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). VNOS(C) was also used in the South African context as the language used is clear and unambiguous, especially for English second-language speaking teachers (Govender & Fikeni, 2016). The questionnaire also permitted the teachers to write more information, explain and qualify their responses.

In this research, the researchers compared interview responses to written responses to the VNOS(C) questionnaire for reliability or consistency. Where there was inconsistency between the questionnaire and interview data the researcher gave priority to the interview data. Interviews were carried out in controlled locations in vacant school classrooms, after hours and about 45 minutes in duration. The aim was to gain in-depth understanding of how these six teachers plan to integrate NOS aspects when preparing lesson plans. The researchers sought to find out the motivations behind the teachers' action by probing their background academic experiences, their content knowledge area and social reality of their daily school lives. This data helped in getting to know the teachers better and created a climate of trust. With the permission of the teachers, the interviews were audio-taped, transcribed and analysed.

For the analysis, the researchers collected copies of the lesson planning documents. Teachers' lesson plans and its analysis regarding NOS provided an understanding of how they integrated activities and assessment strategies of NOS as well as the integration of NOS aspects into the science content. The researchers focused on whether teaching NOS was planned explicitly or implicitly in the documentary analysis process. A schedule (a template of Table 2) for analysing the planning documents was developed using the seven core NOS aspects. Each teacher's lesson plan was judged against the NOS aspects. Each teacher's documents were scrutinized for at least one lesson focus knowledge. Most of the lessons on a specific topic aimed to cover about a week, therefore we analysed all the activities planned for the topic to see if there was anything relating to the nature of science that was presented either implicitly or explicitly. Notes were taken while the analysis was taking place. A narrative description of the information that emerged in the documents served as a source of data.

*Data Analysis*

The researchers employed the inductive process for analysing and interpreting the data within the NOS conceptual framework. In answering the first research question, after the VNOS(C) questionnaires and semi-structured interview data were read and interpreted several times, emergent categories were developed by the primary researcher. Each teacher's understanding of NOS was classified as naïve, inadequate, mixed or transitional and adequate and the process was repeated two weeks later to ensure correct classification. The emergent categories were also independently obtained by second researcher and validated by a colleague familiar with the NOS research. Teachers' NOS understanding were then finally collated and are presented in Table 2.

Data from the teachers' academic background questionnaires, semi-structured interviews based on lesson planning and lesson planning documents were used to analysis and answer the second research question. Teachers' interviews involved how they plan to teach and integrate NOS aspects such as the tentative nature of scientific knowledge and the role of imagination and creativity in their teaching. Their narrative responses were given and the data were summarised in Table 3. The lesson planning documents (DOE curriculum documents, work-schedules and the lesson plans) for each teacher were also used in the analysis. The researchers used the core NOS aspects to develop a checklist to analyse both the work-schedules and lesson plan documents for each teacher. These documents were read and analysed, synthesized and discussion notes were developed by the researchers during this process. Interpretive and descriptive accounts are presented.

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*Ethics*

The teachers were given an information sheet to read about the research and to be familiar with its aims, process and confidentiality. It also assured the respondents that it was voluntary to participate and they could exit from the research at any time. To guarantee confidentiality, anonymity and non-traceability, respondents were assured that their identities were to be concealed by pseudonyms. Pseudonyms are used for both schools and participants in this research. The participants were given adequate telephonic notice of visits to their schools. Permission was sought from all gate-keepers to conduct this research. The interviews with the teachers were conducted after-hours and did not interfere with school activities. There were no monetary rewards offered to teachers.

## Results of Research

The results are presented from the analysis as i) VNOS(C) questionnaire and semi-structured interviews ii) teachers' planning documents: work-schedules, interviews on lesson planning to teach NOS and lessons plans integrating NOS.

*Results of Analysis of VNOS(C) Questionnaires and Interviews*

The results of analysis of VNOS(C) questionnaires and interview data provided information on teachers' understandings of NOS under the seven aspects of NOS and shown in Table 2.

**Table 2. Summary of naïve, inadequate, mixed and adequate understanding of NOS.**

| NOS Aspect | Number of adequate understanding | Number of naïve understanding | Number of mixed understanding | Number of inadequate understanding |
|---|---|---|---|---|
| Empirical nature of science | 2 | 0 | 0 | 4 |
| Tentative nature of scientific theory | 3 | 1 | 0 | 2 |
| Role of imagination and creativity | 2 | 1 | 1 | 2 |
| Observation and inferences | 2 | 2 | 0 | 2 |
| Distinctions between theory and laws | 1 | 1 | 1 | 3 |
| Social and cultural character of science | 2 | 0 | 0 | 4 |
| Subjectivity and objectivity of science | 3 | 0 | 0 | 3 |

The results show that although some teachers possessed adequate understanding of certain aspects of NOS, their understanding of all aspects of NOS at a level for GET junior high school teachers was overall *less adequate.* Their explanations from the semi-structured interviews based on VNOS(C) questionnaire revealed that even though the teachers recognised the importance of experiments in science, they also indicated limited understanding that experiments are the only source of evidence in developing scientific knowledge. For example, Brian responded *"without an experiment you cannot see science, experiments have to be performed... scientific method is a procedural idea. There is a procedure to be followed in everything in science".* Teachers also possessed a dichotomy of understanding based on meaning of the scientific method. Two out of six responses possessed adequate understanding that 'there is no uniform or prescribed way of doing scientific method', whereas the other four possessed inadequate understanding evident in that the 'scientific method is always a prescribed step-by-step way or procedure of conducting investigations to provide proof'. For example, Nancy responded *"the scientific method is always performed as a step-by step way of investigation. I think that scientist use certain methods when they are doing their investigation. So they observe, they collect data, they discuss it, and they end up having their conclusions. I believe that for obtaining true results they have to accurately follow all the steps".*

*Results of the Analysis of Teachers' Planning Documents: Work-schedules*

The results of the analysis of teachers' work-schedules provided evidence of teachers' planning to teach NOS as presented in Table 3. Five teachers (Brian, Sindile, Nkosi, Sakhile and Nancy) used the third-term prescribed work-schedule which was provided by the DOE to plan their teaching in Natural Sciences Grade 9. Leoran's work-schedule was provided to her by her head of department and based on Continuous Task Assessments (CTA).

**Table 3. Teachers' selection of NOS aspects from grade 9 natural sciences work-schedules.**

| | Content | NOS Aspect/s | Activities |
|---|---|---|---|
| Sindile, Nkosi, Sakhile and Nancy | DOE-curriculum: Particle model of matter in chemical reaction, models of molecules of common compounds, chemical reactions of acids with metals, metal oxides and carbonates. | Empirical nature of science. | Learners to build models of molecules. Learners to conduct investigations/experiments. |
| Brian, Leoran | | Observations and inference. Empirical and theory and laws. | Learners to represent reactions of elements and compounds using models, pictures, words and balancing chemical reactions. |
| | CTA content | None | None |

Analysing Table 3, the four teachers Sindile, Nkosi, Sakhile and Nancy chose the same NOS aspects, hence the data were collated together in one column, and Brian extended the aspects of the curricuum deeper and chose more NOS aspects. The different teachers' work-schedules did not explicitly state all the NOS aspects that needed to be integrated during teaching.

*Results of Teacher Planning Documents: Lesson Planning and Interviews to Teach NOS Aspects*

In teachers' planning to teach NOS aspects, they were asked during the interviews "How do they plan for teaching the tentativeness of science to the learners in their classroom?" as well as "How do they integrate imagination and creativity during Natural Sciences teaching?" for topics like 'Particle Nature of Matter'. Only two aspects of NOS are focussed due to space constraints. Three teachers' NOS lesson planning intentions and teaching approaches are given in Table 4. All three teachers came from well-resourced schools and had opportunities to use sufficient resources to plan for explicit teaching of NOS embedded in content like the 'particle nature of matter'.

**Table 4. Teachers' intention to include NOS aspects and approaches in lesson plans.**

| | Brian | Nancy | Leoran |
|---|---|---|---|
| Tentative NOS | Plan but depends on the nature of the topic like 'particle nature of science' lends itself to NOS discussion. | Does not plan explicitly but incidentally integrate during the lessons. | Incidental as the focus is on text-book content teaching. |
| Imagination and creativity | Provides opportunities for modelling in the 'particle nature of matter'. | None | Incidental |
| Plans to teach NOS | Explicit emphasis on NOS aspects. | If a need arises. | Incidental |
| Teaching approach | Didactic teaching and class discussions in groups. | Didactic teaching. | Didactic teaching and occasional discussion with learners. |

Table 4 reveals that only Brian plans to integrate the targeted NOS aspect in his teaching. On the other hand, Nancy and Leoran did not plan to teach these aspects, it only happens incidentally. Brian's responses reveal that when teaching about the aspects of NOS, he uses two approaches, namely, didactic teaching (teacher-centred) and discussion approach (learner-centred). Nancy's approach seems to be didactic teaching as she mentioned

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that she "*explains everything until learners' understood the content*". Leoran's focus is on the content covered in the textbook and she occasionally uses the discussion approach.

In probing, deeper how the three teachers plan to teach the *tentative nature of science* and *imaginative and creativity* aspect of NOS, they were asked during their interviews how would they teach learners that theories change as part of tentative nature of scientific knowledge in a topic. From their responses, none of them were certain that she/he would plan NOS aspects explicitly in their teaching. They all claimed that if learners asked questions pertaining to theories and laws, they would only then tell them. The following is what they had to say:

Brian: "*Not most of the times, it depends on the topic that is related to the content. If the topic like particle nature of matter requires you to teach about theories and laws, sometimes then you have to tell them that theories and laws change depending on the theory or the law you are teaching about because some do not change, so it depends.*"

Nancy: "*I have never prepared this as a lesson for NOS. Sometimes it happens we discuss it in class because maybe there was a question like "Can you see atoms?" or when I see the need, maybe like when I see learners in class confused then I explain.*"

Leoran: *"Honestly in most cases we teach what is on the book. If the book does not state it, you do not tackle that aspect. Only on rare occasions where you find learners asking questions than I will lead to a discussion of theories being changed because of new evidence."*

On planning to teach NOS aspect of imagination and creativity during their Natural Sciences lessons, the teachers responded.

Leoran: "*It depends on the focus knowledge we are dealing with. Honestly, we do a little of that, because of time we have the content to cover. In most cases, we follow what is in the books when we do demonstration experiments with the aim of showing the learners that what is said in books is true."*

Nancy: "W*hat I do in class is to teach the content knowledge and I try to explain everything to learners so that they understand. There is no time to waste because we have a lot of content to cover and our Grade 9 learners have to be prepared for the CTAs at the end of the year. That does not mean that our learners are restricted, they use their imagination and creativity when given projects and investigations to do. You will be surprised to see how creative they are if they do their investigation and designs for the science expos."*

Brian: "*Yes. I give provide opportunities for learners to use their creativity and imagination and their opinions are shared with other learners. Some ask questions about things, some come out with ideas which we discuss to see if it is tangible because all I will say is most of the things that are to be discovered now have been discovered. All the things we do, are to make things smarter.*" To explain more what he meant he gave the following example, *"Cars were invented so many years ago but many cars have been produced after that, which if you look you'll see that it's a same procedure. The one thing that has been done maybe the engine has a higher horse-power and so forth. They created higher functions, higher than you think, so it is about the ability to think and go an extra mile. That is how laws have been amended and you must extend what you know*."

*Results of Analysis of Lesson Planning: Lesson Plans*

Results of analysis of data from lesson plans revealed the six teacher's aspects of NOS integration with content and are captured in Table 5. Teachers' weekly lesson plans were scrutinized, highlighting if NOS aspects were focussed and if NOS activities took place. The categories "Explicitly Discussed (ED)" if the teacher clearly stated the NOS aspect he/she intended to address when planning to teach NOS in the lesson plans, "Implicitly Discussed" (ID) if the teachers' lesson plans reflected some topics/or activities that addressed NOS aspects but not clearly stated and "Not Discussed" (ND) if the teacher did not display any NOS aspect in the lesson plans. The lessons are discussed as follows:

*Brian:* His lesson plans focused on: Elements, mixtures and compounds; formulae; equations and reactions. He planned learning activities and stated that in five lessons the topics outlined will be covered in two weeks. The lesson objectives were stated, together with their assessment outcomes. His teaching approach was based on the activities his learners will engage in. Analysing planned activities of Brian, it was noted that learners were to make models of molecules however there was no evidence to indicate whether he planned to explain to his learners why models are used in science. He also planned for learners to investigate some reactions. It was evident that Brian planned to expose learners to the scientific research process and to make them aware of models used in science. However, there was no evidence of whether he planned to engage them in fruitful arguments and using investigations that will lead to an understanding of how science is done. Only the NOS aspect 'observation and inferences' were implicitly discussed (in Table 5).

*Leoran:* Her planned lesson topic was Atomic Structure and the Periodic Table. She stipulated the core knowledge she wanted for her learners to grasp as: the basic structure of the atom, how the atoms of one element are different from those of the other and that elements are arranged in the periodic table. One of the learning activities that Leoran planned for was based on the scientist ideas about the structure of atoms, the models used to present the structure and why did scientists use models. Although the lesson plan did not clarify her teaching approach, she did show intention to integrate some NOS aspects in her teaching. The evidence for this is based on the use of the word "ideas" and "models". Her lesson plans showed she possessed adequate understanding of the use of models in science and that in science there is no single idea or truth and the discoveries done by scientists changed or were added on as new discoveries came up. It was also evident that she wanted her learners to understand the reasons why scientist used models to picture the structure of the atom. Her planning also showed that some NOS aspects such as observation and inferences were to be addressed. In her lesson plan she stated the assessment task she planned for her learners. Three of the planned assessment tasks carried the aspects of NOS. Task 1 was stated as follows: "Use the table about the history of the discovery of atoms to trace the way the theory about the structure of atom has changed over the period of time". In this task learners had to identify the changes in the theory of the structure of the atom. In performing this task, learners will be able to understand the tentative nature of science. In Task 2, learners had to use pins to make models of atoms. In this activity learners had to use their creativity and imagination and also inferring were required of them. Another assessment tasks she planned for the learners was a group discussion whereby learners discuss in groups why there are gaps in the periodic table. This was not explicitly stated, however through this discussion the researcher assumed that the teacher wanted her learners to understand that science is tentative, therefore they should expect that in their following grades they might be able to uncover some gaps filled in the periodic table because of new discoveries made. Only the NOS aspect 'empirical nature of science and tentative nature of scientific theory' were implicitly discussed, whereas the 'role of imagination and creativity and observation and inference' were explicitly discussed (in Table 5).

*Nancy:* She planned to teach about reactions that go faster with heating. The core knowledge she planned to focus on was reactions of metals and non-metals with oxygen, rusting and decomposition of compounds. While she planned to cover all three learning objectives, the lesson did not clarify what aspects of NOS are to be covered. However, the 'inferences' aspect of NOS was planned to be integrated as learners were going to draw models of molecules. The one activity planned for assessment was to link modern science with the culture of indigenous people and their knowledge. In this activity, they were to answer questions about how people obtained iron in the olden days. Only the 'empirical nature of science' aspect was implicitly discussed (in Table 5).

*Sindile:* He planned to teach reaction of oxygen with metals and non-metals. To achieve this she planned to lead a discussion about elements using a Periodic table, demonstrate a simple test to show how metals/non-metals react with oxygen and how to write the equation. The planned learners' activities involved grouping elements into metals and non-metals, recording observations, conduct simple investigation, write word equations, use symbols and balance equations and understand ways of preventing rusting and corrosion and its impact on the economy. Her lesson plan did not reflect any integration of the NOS aspects.

*Nkosi*: The focus knowledge planned by Nkosi was atoms and molecules. To develop learners' understanding of the concepts he planned for the learners to investigate the dots that make up a photo, and to teach them about molecules, elements and compounds. He also planned to teach and make them understand why models are used in science. Lastly, he planned to use models to teach learners about chemical reactions. In his lesson plan, what also transpired were the assessment activities. Among these assessment activities were activities for learners to make models. Learners were to make models of elements and compounds, role play models to demonstrate their understanding of chemical reactions and to make a 'bean' model of the magnesium and oxygen reaction. In analysing Nkosi's lessons, the lesson plan showed that he planned to teach learners so that they understand why scientists use models and he showed he would use models to make them understand chemical reactions. He anticipated that learners would demonstrate their understanding through making their own models and through role playing. In such teaching situations, the learners will be able to understand that scientists use their creativity and imaginations in science and they will also infer what they have observed. Through this teaching plan, learners will be able to understand two aspects of NOS although the teacher did not state explicitly that he will be tackling these aspects. Only the NOS aspect 'empirical nature of science and the tentative nature of scientific theory' were implicitly discussed in his lesson plans (in Table 5).

*Sakhile*: His lessons focussed on the atomic structure, the nucleus of the atom, the periodic table and reactions of metals and non-metals with oxygen (in Table 3). In his detailed lesson plan (see Appendix I) he clearly stated

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the learners' role, their activities and the teachers' activities. For his role, he planned to discuss with learners the history of discovery of atoms, explain why scientists used models to present the structure of an atom and why the Bohr model of an atom is used, discuss with learners the nucleus of an atom, discuss with learners the differences between the old and modern periodic table and use a test to demonstrate how metals and non-metals react with oxygen. Learners were to compare the scientists' atomic models, make their own models, apply knowledge about the nucleus of the atom, use the periodic table to classify elements in terms of gases, metals and non-metals; identify elements, mixtures and compounds, record what they have observed from the teacher's demonstration, in groups they are to design their own investigation on metals and non-metals reaction with oxygen, observe, record their findings and report back. An analysis of his lesson plans did not explicitly state the aspects of NOS that he intended for his learners to understand. However, through discussing the history of discovery of atoms and the comparing the old and modern periodic table, learners will be able to understand that science is tentative. They will also be able to understand that scientists communicate with each other, discuss, provide evidence, and are highly critical of their discoveries and decide as a unique group, through peer-reviewed publications, what to accept and what to be rejected. Through understanding of why models are used to present the structure of the atom, learners would be able to understand that scientists sometimes also use inferences to come to a decision. Table 5 shows that the NOS aspects 'tentative nature of science and observation and inferences' were explicitly discussed and the NOS aspects 'role of imagination, social and cultural character of science and subjectivity and objectivity of science' were implicitly planned to be discussed. Table 5 is a summary of NOS aspects focused by all six teachers' lesson plans.

**Table 5. NOS aspects focus of teachers' lesson plans.**

| NOS aspects | Brian | Leoran | Nancy | Sindile | Nkosi | Sakhile |
|---|---|---|---|---|---|---|
| Empirical nature of science | ND | *ID* | *ID* | ND | *ID* | ND |
| Tentativeness of science | ND | *ID* | ND | ND | *ID* | **ED** |
| Imagination and creativity | ND | **ED** | ND | ND | ND | *ID* |
| Observation and inference | *ID* | **ED** | ND | ND | *ID* | **ED** |
| Distinction between scientific theories and laws | ND | ND | ND | ND | ND | ND |
| Social and cultural character of science | ND | ND | ND | ND | ND | *ID* |
| Subjectivity and objectivity of science | ND | ND | ND | ND | ND | *ID* |

**ED**= Explicitly Discussed; *ID*= Implicitly Discussed; ND= Not Discussed

The results of the research are limited in terms of generalizability as this is a local case-study of six teachers in one district and province in South Africa but the issues pertaining to aspects of NOS teaching and lesson planning is of value to the broader national and international science education fraternity.

## Discussion

From the information of teachers' background (Table 1), we know how they acquired their experiences of science content and NOS knowledge and how their contexts of teaching might influence their planning and teaching of science-NOS focused lessons. The six teachers all have tertiary teaching qualification in their disciplines, four have honours in science education and all have qualifications in teacher education. The schools in the urban suburbs are well resourced while township schools (largely in low-class residential areas) have poor resources, lack of science equipment and laboratories. Also, the schools have large number of learners, large number per class and limited resources, all of which, make planning for teaching, including the NOS very difficult. There science teachers are males and females and their ages range from 20 to 40 years with an average teaching experience range of 10-27 years. This implies that the six teachers do have a rich repertoire of content knowledge and pedagogic content knowledge and skills in teaching natural sciences as many have majors in Physical Sciences and/or Biology. It is only Leoran who had some formal exposure to NOS teaching as she is recently qualified. The university science education BEd program that she enrolled for includes NOS content. It is expected then that most of the other teachers will have limited understanding of NOS aspects and knowledge of integration of NOS aspects into their lessons. This inference is confirmed in Table 2 as the analysis shows that teachers possessed inadequate understanding of NOS. Only the categories of tentative nature of science, subjectivity and objectivity showed adequate understanding than the others. These aspects would have developed as they studied their content majors as well during teaching while using the traditional science focused school textbooks. Most research from a literature review (Lederman, 2007) shows that teachers do not acquire NOS understanding by themselves through daily experiences of teaching nor through formal content modules unless there is an explicit inclusion of NOS in the curriculum or had been exposed to NOS modules in tertiary and in-service education (Kurup, 2014). For example, in a recent study by Faikhamta (2013), the in-service science teachers who engaged in a NOS focused course developed an adequate understanding of NOS, as well as an reflective and explicit content- and non-content NOS teaching skills.

Teachers' work-schedules (in Table 4) show examples of science content related to empirical, observations and theory and laws. Their focus was mainly on textbook content, namely, on the particle model of matter where they included atomic models, symbolic notations, formulae and chemical reactions. It seems that teachers' teaching strategies in this topic were limited to the learners' planned activities as stipulated by the Department of Education (DOE, 2011). The DOE curriculum, for instance, prescribes the building of models of different molecules, conducting investigations and experiments, observing and identifying acids and bases using household products and litmus paper, classifying elements and compounds, recording and identifying products of reactions using models or other representations of the reactions. While the use of models and the conduction of investigations and experiments are in line with the aspects of NOS, not all aspects of NOS were explicitly stated in their lesson plans. For example, Brian's work-schedule only emphasised models and symbolic representations of chemical change and chemical reactions. Of the seven aspects of NOS, the empirical aspect of NOS was easily identified and focussed by all teachers. The use of models requires creativity and imagination, an aspect of NOS but was not recognised by most of the teachers (Table 5). Even a familiar aspect of NOS, like the distinction between scientific theories and laws, was not explicitly identified nor recognised by the teachers as valuable aspects of NOS to be integrated into chemistry lessons. The law of constant composition as well as the collision theory to explain chemical reactions were not covered by the teachers. These examples could have been used to show the distinction between laws and theories as learners often believe that a theory eventually becomes a law (Lederman, 2007).

Since 70% work should be covered as outlined in the Natural Sciences DOE document, teachers still had opportunities to enhance the curriculum with NOS teaching through the 30% work that is not stipulated in the work-schedule. Also, only content aspects of the DOE curriculum were highlighted suggesting teachers teach mostly to the prescribed curriculum. For example, Leoran in a semi-private school chose to follow only the CTA content as her work-schedule showed only the concepts that were usually assessed during the common task administration and showed no link to NOS either implicitly or explicitly, yet she was exposed to NOS content in her honours curriculum. Research in the history of the topic 'matter' with learners showed that it can be developed historically with scientists contestations of theories and evidence as time elapsed which was not considered by teachers in this research (Adbo & Taber, 2009).

Based on the semi-structured interviews of teachers' intention to plan for NOS teaching and on the samples and analysis of teachers' lesson plans, the researchers in this research argue that even though some of these teachers included few activities either for their learners or for themselves as an intention to address NOS aspect, they do not explicitly focus nor assess about NOS. They planned to conduct lessons where there was no clear indication of integrating NOS aspects in the introduction, aim and conclusion of the lessons, and hence adopted an implicit NOS approach. Of all the teachers, only Leoran and Sakhile's lesson plans (in Table 5) show some explicit and implicit NOS aspects to teach using the content. Both had some formal NOS knowledge acquired through tertiary education. All six teachers' translation of NOS conceptions into practice was largely dominated within their school science content and hardly any transfer of their NOS understandings in new and out of school content and context was evident. The difficulty in attempting to address NOS explicitly is also highlighted in Wahbeh and Abd-El-Khalick's (2014) study where in-service teachers where exposed to 6-week NOS course and while holding high to moderate levels of NOS understanding, the teachers met with challenges and successes at translating NOS aspects into teaching. Studies generally support the view that the pre-service (Abd-El-Khalick, 2005; Scharmann, Smith, James, & Jensen, 2005) and in-service teachers who received explicit instruction in NOS display better understandings in some or most aspects of NOS compared with those who are not exposed to NOS instruction (Faikhamta, 2013; Herman et al., 2013b; Kurup, 2014). Furthermore, it is evident from Table 5 that teachers in this research experience difficulties in mediating certain NOS aspects as the majority of them excluded the socio-cultural, the role of imagination and creativity and distinction between theories and laws in their lesson plans. Other studies with pre-service and in-service teachers showed similar exclusion of NOS aspects (Akerson, Abd-El-Khalick, & Lederman, 2000; Akerson, Morrison, & McDuffie, 2006; Kurup, 2014). A surprising result of the research was that while four teachers hold an

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honours degree in science education, Leoran, a recent graduate where NOS was covered in her degree, did not explicitly show NOS aspects in her lesson plans. While some studies have shown that teachers' knowledge of subject matter was a mediating factor in the successful teaching of NOS (Abd-El-Khalick, 2013; Schwartz & Lederman, 2002) it seems that there must be explicit NOS curriculum focus, exemplars and materials offered by the education department and in tertiary education institutions via their prescribed curricula to ensure adequate and explicit teaching of NOS (Clough & Olson, 2008).

**Conclusions**

This interpretive qualitative case-study research revealed that teachers hold a blend of naïve, adequate, transitional, but more inadequate understanding about the aspects of Nature of Science (NOS). Teachers revealed that they are mostly dependent on the textbooks and departmental curriculum documents to teach the content in Natural Sciences. Analysis of documents revealed that the teachers were unable to make explicit NOS connections with content knowledge in planning their work-schedules. Even though the teachers possessed some understanding of NOS aspects, most of the teachers did not plan to teach NOS explicitly and some of their teaching approaches can be described as implicit. Only two out of six teachers were able to plan for teaching explicitly and only on two aspects of NOS implying that the teachers failed to translate all seven aspects of NOS understandings into their classroom lesson plans.

The results of the first question of this research revealed that the six natural sciences *junior high school* teachers have inadequate understanding of most NOS aspects, and that for the second question, their limited NOS understanding impacted minimally on their lesson planning as they barely transferred NOS aspects explicitly into their lesson planning for Natural Sciences teaching.

**Implications and Recommendations**

This research showed that the teachers are not aware of the compelling reasons to teach NOS and seemingly the chances that they will implement it in the classroom will diminish. Teachers will therefore need support to develop accurate and deep notions of NOS and how to effectively plan and implement NOS teaching. If teachers do not integrate all NOS aspects successfully in their lesson planning in their curriculum, then learners bear the consequence of possibly being not fully scientifically literate citizens. The evidence also suggests that formal NOS exposure is not sufficient for teachers' intention to teach, there must be explicit NOS aspects stipulated and made compulsory in the departmental curriculum documents.

It is also suggested that subject advisors should provide more support for teachers in terms of NOS classroom practice as part of curriculum reform development and training. It is recommended that when subject advisors/HODs work through subject committees in designing activities such as lesson plans, sequencing, reflective practice of their lessons, and work-schedules for teachers, NOS aspects must be explicitly focused in the content. Where in-service teachers have little formal exposure to NOS construct and its aspects, it is recommended that these teachers enrol with tertiary institutions where such programmes involving NOS aspects are offered. Furthermore, schools should prioritize on buying textbooks and resources including ICT resources that explicitly include NOS activities as this will assist in making science learning more meaningful by offering exemplary content examples of NOS.

The limitations in the research is that it was a localized study of a small number of teachers in a mixed district and hence not generalizable to a wider population. The findings, however, support and corroborate other international researches regarding teachers' translation of NOS in classrooms. The research, in particular, contributes to more awareness of *junior high school* teachers' pedagogy of NOS as there has been limited studies in this area both in Africa and internationally.

**Appendix I**

*A sample of Sakhile's Lesson Plan*

| LESSON PLAN LEARNING AREA: Natural Sciences GRADE: Nine DURATION: 3 Weeks | |
|---|---|
| *Learning Aims*: Scientific Investigation, Constructing scientific knowledge, Science, society and the environment | *Assessment:* Plans investigation; conduct investigations and collect data; evaluate data and communicate findings; recalls meaningful information; categorizes information; interprets information; applies knowledge; Understand science as a human endeavour |
| *Linking with previous lesson*: Different phases of matter (solid, liquids, gases) | *Linking with next lesson*: Models of chemical reactions |
| *Core knowledge*: 1. The atomic structure 2. The nucleus of the atom 3. The periodic table 4. Reactions of metals and non-metals with oxygen. | |
| *Learning Activities and assessment*<br>1. Compare scientist's atomic models<br>2. Make their own models<br>3. Apply knowledge about the nucleus of the atom<br>4. Using the periodic table to classify elements in terms of gases, metals or non-metals<br>5. Identify elements, mixtures and compounds<br>6. Record what they observed from demonstration<br>7. Work in groups of five [5] to design their investigations about the reactions of metals and non-metal with oxygen using things they from home.<br>8. Record their findings and report back. | *Teacher Activity*<br>1. Discuss with learners the history of discovery of atoms<br>2. Explain why scientists used models to present the structure of the atom<br>3. Discuss with learners the nucleus of the atom<br>4. Discuss with learners the modern periodic table<br>5. Use a test to demonstrate how metals and non-metals reacts with oxygen |
| *Forms of assessment*: Informal assessment activities (Groups activities); Formal assessment task-Assignment. | *Resources:* Library and internet; Periodic table; Different metals and non-metals; Grade 9 Learners' and Teacher's guide. |
| *Expanded opportunities*: Investigate corrosion and rusting as the reactions that occur in our everyday life. | *Teacher reflections* |

**References**

Abd-El-Khalick, F. (1998). *The influence of history of science courses on students' conceptions of nature of science.* Unpublished doctoral dissertation, Corvallis.
Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: the impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education, 27* (1), 15-42.
Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education, 22* (9), 2087-2107.
Adbo, K., & Taber, K. S. (2009). Learners' mental models of the particle nature of matter: A study of 16- year- old Swedish science students. *International Journal of Science Education, 31* (6), 757-786.
Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37* (4), 295-317.
Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of research in Science Teaching, 43*(2), 194-213.
Bell, R. L., Abd-El-Khalick, F., Lederman, N. G., McComas, W. F., & Matthews, M. R. (2001). The Nature of Science and Science Education: A Bibliography. *Science and Education, 10*, 187-204.
Clough, M. P., & Olson, J. K. (2008). Teaching and assessing the nature of science: An introduction. *Science and Education, 17*, 143-145.
Dekkers, P. (2006). Reconstructing the creature - developing understandings of NOS through inquiry and reflection. *African Journal of Research in Mathematics, Science and Technology Education, 10* (1), 81-92.

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

DOE. (2011). *Curriculum and Assessment Policy Statement GRADES 7-9 NATURAL SCIENCES*. Pretoria: Government Printing Works.

Faikhamta, C. (2013). The development of in-service science teachers' understandings of and orientations to teaching the nature of science within a PCK-based NOS course. *Research in Science Education, 43* (2), 847-869.

Govender, N., & Fikeni, T. (2016). Life science teachers' understanding the nature of science in the context of biological evolution and religion for teaching. *Ponte*, *72*(6), 183-208.

Herman, B. C., Clough, M. P., & Olson, J. K. (2013a). Association between experienced teachers' NOS implementation and reform-based practices. *Journal of Science Teacher Education, 24* (7), 1077-1102.

Herman, B. C., Clough, M. P., & Olson, J. K. (2013b). Teachers' nature of science implementation practices 2–5 years after having completed an intensive science education program. *Science Education, 97* (2), 271-309.

Herman, B. C., Clough, M. P., & Olson, J. K. (2015). Pedagogical reflections by secondary science teachers at different nos implementation levels. *Research in Science Education*, *10*, 1-24.

Kang, N. H., & Wallace, C. S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education, 89* (1), 140-165.

Kurup, R. (2014). The relationship between science teachers' understandings of the nature of science and their classroom practices. *African Journal of Research in Mathematics, Science and Technology Education, 18* (1), 52-62.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. *Journal of Research in Science Teaching, 29* (4), 331-359.

Lederman, N. G. (2007). Nature of science: Past, present and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-879). Mahwah, NJ: Lawrence Erlbaum.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, S. (2002). Views of nature of science questionnaire: toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-521.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Preservice teachers' understandings and teaching of nature of science: an intervention study. *Canadian Journal of Science Mathematics and Technology Education, 2*, 135-160.

Linneman, S. R., Lynch, P., Kurup, R., Webb, P., & Bantwini, B. (2003). South African Science teachers' perceptions of the nature of science. *African Journal of Research in Mathematics, Science and Technology Education, 7*, 35-50.

Ma, H. (2009). Chinese secondary school science teachers' understanding of the nature of science - emerging from their views of nature. *Research in Science Education, 39*, 701-724.

Martin-Diaz, M. J. (2006). Educational background, teaching experience and teachers' views on the inclusion of Nature of Science in the Science Curriculum. *International Journal of Science Education, 28* (10), 1161-1180.

McComas, W. F. (Ed.). (1998). *The Nature of Science in Science Education: Rationales and Strategies*. The Netherlands: Kluwer Academic Publishers.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the Nature of Science in Science Education. In W. F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (pp. 3-39). Boston: Kluwer Academic Publishers.

Scharmann, L. C., Smith, M. U., James, M. C., & Jensen, M. (2005). Explicit reflective nature of science instruction: Evolution, Intelligent Design, and Umbrellaology. *Journal of Science Teacher Education, 16*, 27-41.

Schwartz, R. S., & Lederman, N. G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of research in Science Teaching, 39* (3), 205-236.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science education, 88* (4), 610-645.

Seung, E., Bryan, L. A., & Butler, M. B. (2009). Improving preservice middle grades science teachers' understanding of the Nature of Science using three instructional approaches. *Journal of Science Teacher Education, 20*, 157-177.

Vhurumuku, E., Holtman, L., Mikalsen, O., & Kolsto, S. D. (2006). An investigation of Zimbabwe high school chemistry students' laboratory work–based images of the nature of science. *Journal of research in science teaching, 43* (2), 127-149.

Wahbeh, N., & Abd-El-Khalick, F. (2014). Revisiting the Translation of Nature of Science Understandings into Instructional Practice: Teachers' nature of science pedagogical content knowledge. *International Journal of Science Education, 36*(3), 425-466. doi: 10.1080/09500693.2013.786852

Wang, J., & Zhao, Y. (2016). Comparative research on the understandings of nature of science and scientific inquiry between science teachers from Shanghai and Chicago. *Journal of Baltic Science Education, 15* (1), 97-108.

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