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DEVELOPMENT OF A LESSON OBSERVATION SCHEDULE TO DOCUMENT PEDAGOGICAL CONTENT KNOWLEDGE FOR NATURE OF SCIENCE

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Abstract

The study describes the development of a lesson observation schedule, to document Science teacher pedagogical content knowledge for nature of science (PCKNOS) and a subsequent pilot study to test the instrument. The objective of the study was to develop an observation schedule that could document enacted PCKNOS. NOS refers to the epistemology and sociology of science, science as a way of knowing and understanding the natural world, and the role of values and beliefs of the scientific community in the development of scientific knowledge (Lederman, 1998; Lederman and Lederman, 2004). Shulman (1986) has defined pedagogical content knowledge as the intersection of the knowledge a teacher has of the subject material (content) and the translation of that knowledge into an accessible format for the learners (pedagogy). The ability of teachers to transform their understanding of NOS into a context suitable to facilitate student learning of NOS is known as PCK for NOS (Faikhamta, 2013). This PCK refers to a teacher's knowledge of which NOS aspects can be addressed in the teaching of science topics, an appropriate selection of instructional material or media and the correct use of metaphors, analogies or other pedagogical tools (Haunscin, Lee, & Akerson, 2011). According to literature, paper methodologies such as content representation and the pedagogical and professional experience repertoires (Betram and Loughran, 2011) are commonly used to measure science teachers' planned or espoused PCK. This study aimed to measure enacted PCK through lesson observation. The researcher developed a lesson observation schedule based on Aydeniz and Kirbulut's (2014) instrument to measure pre-service science teachers' topic specific PCK and included NOS aspects as presented in curriculum documents for science education. The schedule was piloted on two teachers through analyzing recorded lessons as the study was carried out during COVID-19 lockdown in 2020. Two raters were used to document teacher PCKNOS using the schedule and it was found to be suitable to measure PCKNOS.

Keywords: *Pedagogical content knowledge, nature of science.*

1. Introduction

This paper describes the development of an instrument, a lesson observation schedule, to measure Pedagogical Content Knowledge for Nature of Science (PCKNOS) of in-service Science teachers in South Africa and a subsequent pilot to test the instrument. The instrument measured enacted PCK of Science teachers through observation in the classroom. The observation schedule scored PCKNOS on a scale ranging from 1 to 5, following which the scores were then categorized as representing a naïve, developing or sophisticated PCKNOS. In compiling the observation schedule, the researcher adapted an instrument by Aydeniz and Kirbulut (2014) designed to measure and enhance topic specific PCK of pre-service Science teachers, termed the Secondary Teachers' Scientific Pedagogical Content Knowledge (STSPCK). In adapting STSPCK, the researcher used some of the observation statements that were related to PCKNOS. Further statements were extracted from aims and objectives in the South African curriculum statements for Science that had a focus on NOS. The aims of the study are listed below.

Aims

- To design an instrument to measure enacted PCKNOS
- To pilot the use of the instrument to measure enacted PCKNOS on in-service Science teachers

2. Pedagogical content knowledge for nature of science

Pedagogical Content Knowledge (PCK) has been defined by Shulman (1986) as the intersection of a teacher's knowledge of subject material (content) and how the teacher translates that material into a format understandable by the learners (pedagogy). A review of literature reveals a plethora of definitions for Nature of Science (NOS) all alluding to what the actual character of science is. Erduran and Dagher (2014) have defined NOS using categories that depict science in a holistic system with dynamic interactions as aims and values; methods; scientific practices; scientific knowledge; social certification and dissemination; scientific ethos; social values; professional activities; social organizations and interactions; financial systems; and political power structures. Lederman (1998) referred to NOS as distinct principles characterizing science, known as the tenets of NOS: empirical; inferential; creative; theory-driven; tentative; myth of the scientific method; scientific theories; scientific laws; social dimensions of science; and social and cultural embeddedness of science. Research by Akerson, Abd-El-Khalick, and Lederman (2000) on Science teachers, both in-service and pre-service, has revealed a general naïve understanding of NOS. This holds truth for the South African context where Bantwini, Kurup, Linneman, Lynch, and Webb (2003); Gwebu (2015) found that teachers had naive to transitional understandings of NOS. Understanding of NOS is important for the development of scientific literacy according to Chaiyabang and Thathong (2013). Vhurumuku (2010) describes scientifically literate citizens as having the ability to contribute to decision making processes concerning technology and the environment or issues pertaining to scientific research. Owing to the naive understanding of NOS by South African teachers, this researcher in a PHd study developed a teacher professional development program to improve NOS understanding of in-service teachers. The study aimed to improve existing PCKNOS of participant teachers and track any changes in their PCKNOS post-training.

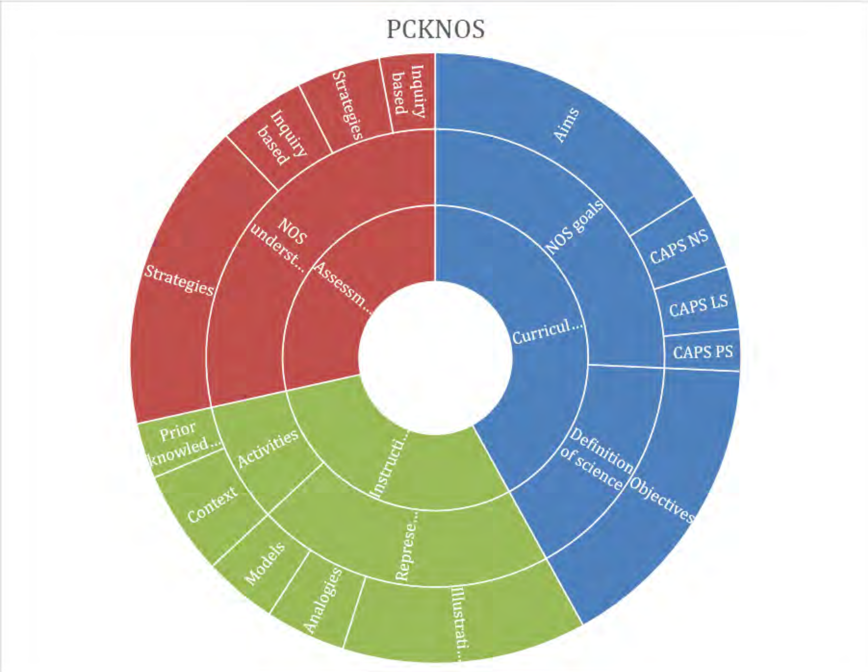
Faikhamta (2013) described PCK for NOS as the ability of educators to transform their understanding of NOS into a context suitable to facilitate student learning of NOS. This includes, but is not limited to, the appropriate selection of instructional material or media and the correct use of metaphors, analogies or other pedagogical tools (Haunscin et al., 2011) by the teacher to address NOS concepts during teaching. This enacted PCK would most appropriately be documented according to the researcher through lesson observations as opposed to documenting planned actions. Planned PCK known as espoused PCK by Aydeniz and Kirbulut (2014) has been documented through tools such as content representation developed by Loughran, Mulhall and Berry (2006) and there exists studies on the use of such tools. At the time of writing this research, there existed limited information on documenting enacted PCK of science teachers.

3. Conceptual framework

In developing the conceptual framework for this study based on PCKNOS, the researcher adapted the Secondary Teachers' Scientific Pedagogical Content Knowledge (STSPCK) tool for documenting PCK of high school Science teachers developed by Aydeniz and Kirbulut (2014). STSPCK was deemed appropriate to measure enacted PCK owing to its statements being posed as actionable teaching strategies that the researcher could observe. Similar to STSPCK, the PCKNOS tool developed for this study would seek to establish PCK domains of curriculum, instructional knowledge and assessment for NOS. Knowledge of curriculum comprises the goals and objectives of NOS for students in the science subject that they are being taught according to Magnusson, Borko, and Krajcik (1999). To document this PCK domain in the observation schedule, the researcher compiled statements extracted from aims, objectives and definitions of Science in the relevant curriculum documents. In South African high schools natural sciences (NS) is taught from grades 7-9 and is a compulsory subject, physical sciences (PS) and life sciences (LS) are optional subjects and taught from grades 10-12. Each subject has its own curriculum statement. For instance, the specific aims of physical sciences in the National Curriculum and Assessment Policy Statement (CAPS) require a teacher to have an understanding of NOS and its relationship to technology, society and the environment. In the PCKNOS observation schedule one of the observation statements for knowledge of curriculum reads: the teacher demonstrates an understanding of NOS and its relationship to technology. To establish instructional knowledge for NOS of the teacher, the observation schedule documented the illustrations, models or analogies used by the teachers to represent NOS knowledge, NOS specific activities and their pedagogical representations. Statements to document knowledge of instruction were adopted directly from the STSPCK tool. An exemplar statement reads: the teacher starts the lesson by helping children to discover what they already know about the concepts of NOS to be taught in the lesson. Finally assessment for NOS is the strategies employed by the teachers to evaluate NOS understanding by the learners and include assessment of inquiry based learning. Aydeniz and Kirbulut (2014) include inquiry based science in the STSPCK tool. Inquiry based science was relevant to PCKNOS, since inquiry based learning involves activities that include learners in discussions and science process skills indicative of NOS. Statements to document knowledge of assessment were adopted directly from the STSPCK tool. An exemplar statement reads: the teacher uses problems that require the students to communicate their understanding of the concept through multiple means.

PCKNOS for this study comprises knowledge of curriculum, instruction and assessment. The diagram below is a visual representation of the PCKNOS framework as formulated by the researcher on which the lesson observation schedule is based.

Figure 1. PCKNOS framework.



3.1. PCKNOS lesson observation schedule

The observation schedule to document PCKNOS termed Nature of Science Pedagogical Content Knowledge tool (NOSPCK) comprised three sections. A) measures curriculum knowledge of NOS by the teacher using statements such as: the teacher emphasizes a curriculum that displays the tentative NOS. B) measures knowledge of instructional strategies using statements such as: the teacher starts the lesson by helping children to discover what they already know about the concepts of NOS to be taught in the lesson. C) measures knowledge of assessment strategies for NOS and includes statements such: as the teacher poses open ended questions on NOS. Each statement that documents teacher actions in these sections is allocated a rating based on a 5 point Likert scale of 1-5. 1 representing never occurs and 5 indicating that the action always occurs.

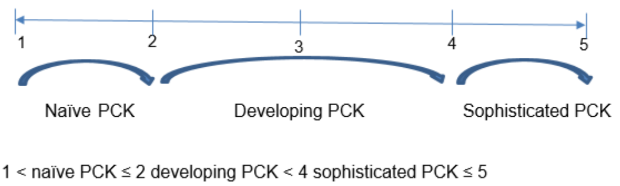
4. Methodology

To test the PCKNOS tool, two Science teachers were observed in their classrooms. Teacher one was teaching the topic of naming compounds to a grade 9 physical sciences class and teacher two taught the topic of genetics in life sciences to a grade 12 class. Both teachers were teaching at the same school, a private school in Johannesburg, South Africa. Due to COVID-19 restrictions at the time of conducting the study and limited access to classrooms by researchers, the teachers recorded online classes that they conducted and sent the recordings to the researcher. The two participant teachers formed part of a larger group of in-service teachers who were participating in a study to improve their understanding of NOS. The teachers were selected based on availability, willingness to participate and access to online services. Prior to the lesson observations, the teachers had completed questionnaires to assess their views of NOS and analysis of those documents had revealed that both teachers had a naïve understanding of NOS.

4.1. Data analysis

On receiving lesson recordings sent by participating teachers the researcher reviewed and transcribed the lessons. Occurrences that fulfill statements on the PCKNOS lesson observation schedule were documented. Each statement is allocated a rating on a 5 point Likert scale of 1-5. 1 representing an occurrence that never occurs and 5 indicating that the action always occurs. From these ratings the PCKNOS of a teacher is then categorized as naïve, developing or sophisticated. A teacher who falls in the naive category would have obtained scores between 1 and 2, and seldom demonstrates aspects of PCKNOS. A developing PCK is characterized by a teacher who sometimes conforms to the aspects of PCK on the observation schedule having scores above 2 but less than 4. A sophisticated PCK is evidenced by a teacher who obtains a score of 4 and 5, defined as often and always conforming to the aspects of PCK on the observation schedule. A visual representation of the categories is shown below:

Figure 2. PCKNOS categories.



4.2. Reliability and validity

To ensure reliability and validity in the data analysis process, two raters were used to analyze the data. Each rater reviewed the data independently assigning points on the Likert scale. Where there were differences in scores, discussions were held until a consensus was reached on the score that was to be allocated.

4.3. Findings

The two participating teachers displayed an overall naïve PCKNOS in their lessons. However, teacher 2 showed a developing PCK for knowledge of instruction of NOS. The table below shows some excerpts from the lesson observation schedule for the participating teachers:

Table 1. Excerpts from PCKNOS tool for teachers 1 and 2.

Statement	**Score 1-5**	**Teacher 2 examples and comment**
The teacher uses a curriculum that emphasizes NOS	3	Focuses only on science knowledge through theory of naming compounds and drawing models of compounds
the teacher uses probing questions to help students retrieve relevant information and experiences on NOS	1	Teacher centered instruction
Statement	**Score 1-5**	**Teacher 1 examples and comment**
the teacher demonstrates the social NOS	2	Teacher refers to arguments and debates amongst examiners about phenotypical orientations
the teacher emphasizes a curriculum that displays the empirical NOS	2	Uses history of science example of the case of haemophilia in a royal family

5. Discussion of findings

The overall under-developed PCKNOS of the two participating teachers is consistent with their naïve understanding of NOS. One of the domains of PCK is knowledge of content, it therefore follows that without knowledge and an understanding of NOS concepts the PCKNOS will be underdeveloped. This consistency in findings has led the researcher to conclude that the PCKNOS tool exhibits some reliability as an instrument to document enacted PCKNOS. The instrument will need to be tested on a larger group of participant teachers to verify these findings and further reliability of the instrument can then be commented on.

6. Conclusion

This paper has reported on the development and subsequent testing of an instrument to document teacher PCKNOS. The tool was tested on two in-service teachers and produced findings that are consistent with the views of nature of science of the teachers that had been documented using a separate instrument. These findings resonate with literature produced by Gwebu (2015), Govender and Zulu (2017), that in South Africa the NOS is a naively understood concept amongst teachers and there is a need for professional development of in-service teachers on NOS.

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