A COMPARISON OF SOUTH AFRICA GRADE 11 LEARNERS' AND PRE-SERVICE TEACHERS' UNDERSTANDINGS OF NATURE OF SCIENCE

Elaosi Vhurumuku[1] and Washington T. Dudu
[1]Marang Centre for Science and Mathematics Education, University of Witwatersrand, School of Education, P.O. Box 488, Wits 2050, Johannesburg,South Africa,
E-mail: elaosi.vhurumuku@wits.ac.za Fax: 086 529 6753

ABSTRACT
This paper reports the results of a study that compared South Africa Grade 11 learners (n=10) and third year B.Ed. Pre-service teachers' (n=10) understandings of Nature of Science (NOS) as part of their Physical Science subject matter knowledge. Data on the learners' and pre-service teachers' NOS understandings was quantitatively and qualitatively collected using a Likert type questionnaire and interviews respectively. Quantitative analysis of the data is done using the Mann-Whitney U test and graphical comparison of median scores of Likert questionnaire items to ascertain differences in NOS understandings between the Grade 11 learners and the B.Ed. Pre-service teachers. A combination of typological and interpretative analysis of interview transcripts is done to determine differences in NOS understandings between learners and Pre-service teachers.The analyses reveal that overall, the Learners and B.Ed. Pre-service teachers' understandings of NOS are not very different from each other. It is recommended that if the goal of science education for scientific literacy is to be achieved, initial teacher education training should do more to explicitly develop pre-service teachers' subject matter knowledge understandings, pedagogical skills and valuing of NOS, that is, their pedagogical content knowledge for nature of science. Explicit testing of learners' NOS understandings is suggested as a way of improving the school Physical Science curriculum.
Keywords: nature of science, learners, pre-service teachers, comparison

INTRODUCTION
Most science education reforms worldwide advocate for the development of teachers and learners' understandings of nature of science (NOS), as an important goal of science education (see for example, NRC, 1996; Achieve Inc., 2013; AAAS, 1993; Lederman, 1992, 2007). Nature of Science is a complex and multi-faceted concept which has been controversial in the science education community for more than half a century now. It has been perceived differently by scientists, philosophers, teachers and researchers resulting in the absence of an agreed universal definition of the concept (Lederman, 1992; Abd-El-Khalick and Lederman, 2000; Schwartz, Lederman and Lederman, 2008). However for this paper we broadly define NOS understandings as comprising the views, perceptions, ideas and beliefs held by an individual about both the nature of scientific knowledge and the processes of its development and validation (Vhurumuku and Mokeleche**,** 2009**)**. Our definition of NOS science therefore encompasses the individual's understanding of both the nature of scientific knowledge (NOSK) and nature of scientific inquiry (NOSI). Scientific knowledge refers to the ideas, facts, principles, laws and theories making the body of knowledge called science (Bartos and Lederman, 2014). By scientific inquiry we mean the processes through which scientific knowledge is developed, validated and accepted (Achieve, Inc., 2013). These processes include problem and hypothesis formulation as well as the gathering of data using the senses and experiments and the communication of empirical findings.

Whichever way one looks at the construct NOS, there appears to be consensus that in order for teachers to teach learners effectively about NOS they themselves must have acceptable cognitive and epistemic understandings of the construct (Vhurumuku, 2015). Our contention is that NOS understandings are part of pedagogical content knowledge (PCK) as has been proposed by several researchers (for example, Irez and Cakir, 2006; Ratcliffe, 2008; Schwartz and Lederman, 2002). We also are of the view that teachers can only teach about NOS if they themselves also understand NOS. In South Africa the new Further Education and Training (FET) phase Grade 12 Physical Science curriculum, requires that learners' understandings of NOS be developed in order for them attain a reasonable degree of scientific literacy (Department of Education, 2011). While this is so, copious research, by the government and academics, indicates worrying numbers of new teachers who are poorly prepared to teach (Mail and Guardian, April 17, 2015) partly because of poor subject content mastery including knowledge about NOS.

In South Africa, the development of learners and student teachers understandings of NOS is an important science education goal. An understanding of NOS is part of citizens' scientific literacy. Scientifically literate citizens can contribute meaningfully to any country's socio-economic development through for example, participating in debates of socio-scientific issues (Kolsto, 2001). From an educational perspective it is important to determine the ways in which would be teachers and learners' understandings of NOS are different from each other so as to inform both initial teacher education and curriculum development and implementation at the secondary school level. The focus of this study therefore was to compare the NOS understandings of student teachers at a South African university enrolled in a B.Ed. Programme, with those of Grade 11 learners studying the new Science CAPS curriculum in South Africa. In South Africa, the recently revised science curriculum documents encourage promotion of learner understanding of NOS (DoE, 2011). There is an underlying assumption that teachers should have more developed understandings of the science subject matter including NOS, compared to the learners they are supposed to teach. Abd-El-Khalick and Lederman (2000) argue that teachers' understandings of NOS should be addressed first if there is any hope of developing adequate understandings of the learners. Coleman, Stears and Dempster (2015) allude to the fact that South African learners are taught by teachers who themselves often do not have an adequate understanding of NOS. They also suggest that teachers who lack basic understanding of NOS knowledge might present science subject matter in manners which leave room for learner misinterpretations and misconceptions. The purpose of this study therefore was to compare the NOS understandings of Grade 11 learners and third year Science Pre-service student teachers enrolled in a B.Ed. Programme.

The critical question the research sought to answer was: How do the NOS understandings of Grade 11 learners' compare with those of third year Physical Science Pre-service student teachers enrolled in a B.Ed. Programme?

METHODOLOGY

This research is located within both the quantitative and qualitative frameworks. To obtain quantitative data on Grade 11 learners and Pre-service teachers understandings of NOS, a Likert type questionnaire consisting of 20 items adopted from the Beliefs About Science and School Science (BASSSQ) instrument developed by Aldridge, Taylor and Chen (1997) was administered to 10 conveniently sampled Grade 11 Physical Science learners at a school outside Johannesburg, South Africa and 10 conveniently sampled third year Physical Science student teachers enrolled for a B.Ed. Programme at a university in central Johannesburg, South Africa. Qualitative data was obtained from interviewing each of the 10 Grade 11 Physical Science learners and each of the 10 third year Physical Science student teachers enrolled for the B.Ed. Programme. Semi-structured interview questions were selected items from the Views of Nature of Science- Form C (VNOS-C) instrument of Abd-El-Khalick (1998) and Views about Scientific Inquiry questionnaire (VASI) by Lederman et.al. (2014). Three aspects of NOSK and two aspects of NOSI were assessed in this interview following the administration of the BASSSQ. All interviews were audiotaped and transcribed verbatim.

Grade 11 learners and Pre-service Teacher Participants

Ten Grade 11 Physical sciences learners were conviniently selected from the School outside Johanneburg based on perfomance in Physical Science and willingness to participate. Of the 10 learners, 4 are males and 6 are females. The learners ages ranged from 16 to 18. Of the 10 learners 1 is white, 2 are Indians and the rest are blacks. English is the first language for 3 participants and the second or third for the other seven 7 participants. All the learners come from good socio-economic backgrounds and have access to many learning resources such as libraries, internet, textbooks and tablets. The ten conviniently sampled Pre-service teachers were third year students studying full time for a Bachelor in Education training to be specialist Physical Science (Physics and Chemistry) teachers. Six are males and 4 are females. Two of the Pre-service teachers are English first language speakers. The Pre-service teachers had done a number of courses in Physical Sciences and Science Teaching Methods courses in the last two years. They had all five three week teaching experiences periods prior to their participation in the study. All of them were over 18 years old and had done very well in all their courses in their first and second years at university.

DATA ANALYSİS

Quantitative analysis

First, the Mann-Whitney U test was employed on the BASSSQ data to ascertain whether there was a difference in the understandings of the two groups. The hypotheses tested were as follows:

H0: There is no difference in the understandings of NOS of Grade 11 learners and Pre-service teachers.
H1: There is a difference in the understandings of NOS of Grade 11 learners and Pre-service teachers

Secondly, responses to the 20 BASSSQ items were assessed. Ten of the items have to with understanding of NOSK and ten understanding of NOSI. The items were scored using a Likert scale. The responses most congruent with acceptable NOS understandings received a score of 5, and the responses least congruent with NOS understandings received a score of 1. Thus, the possible range of total scores was 20 - 100. Thirdly, the group median score on each of the 20 items was computed and recorded using EXCEL Programme 2010

Version. These scores were used to make a graphical comparison.

Qualitative analysis

Qualitatively learner and Pre-service teacher interview data were analysed through a combination of typological analysis (Hatch, 2002) and interpretive analysis Denzin and Lincoln (2002) using predetermined categories of naïve or informed understandings as done by Abd-El-Khalick and Lederman (2000). Responses were read and re-read and categorised as naive or informed. Some illustrative responses then selected for data presentation with meanings attached to the data.

RESULTS

Quantitative Results

To test the null hypothesis, the Mann-Whitney U test was performed for a two tailed test with significance level set at .05. Median latencies in Grade 11 learner and Preservice teachers were 39 and 41 respectively; the distributions in the two groups did not differ significantly (Mann–Whitney $U = 113$, $n1 = n2 = 10$, $P < 0.05$ two-tailed). This led to failure to reject the null hypothesis, that there is no difference in the understandings of NOS of Grade 11 learners and Pre-service teachers. This result is further corroborated when a plot of a comparison of median scores for each item on the BASSSQ is done as shown in Figure 1. Figure 1 shows that there was not much difference in the performances of the two groups on each item. Thus overall, the Mann–Whitney *U test* and the graph show that Grade 11 learners and Pre-service teachers' understandings based on the *BASSSQ* were not very different from each other.

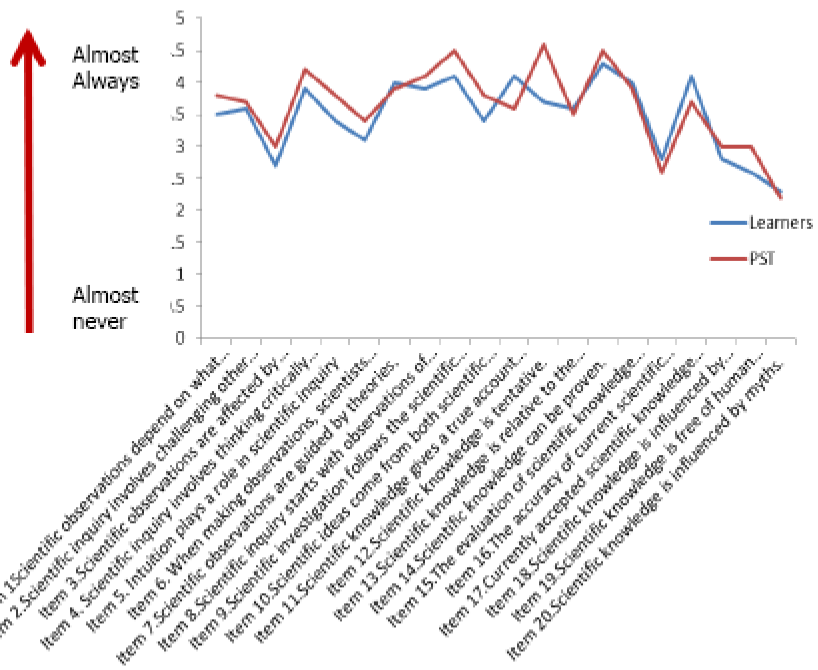

Figure 1: Comparison of median scores for each item on the BASSSQ (n=10)

Qualitative Results

Analysis of interview responses shows that on most of the NOS aspects assessed in the Grade 11 learners and third year Pre-service teachers have more or less similar understandings of NOS. For example, exploring the two groups' understanding of the NOS aspect scientific method resulted in the following respective responses:

PST 7: *If scientists do not follow a set of steps or method that is standard, then we risk not being able to replicate the experiment. This then makes the experiment unreliable. However, I do believe that you do not always need to follow the steps in a set order.*

Learner 3: *All scientists use the scientific method. The scientific method covers all the aspects of an investigation. It helps plan out the procedure and information of the experiment and allows scientists to understand the outcome of their experiments with clear conclusion.*

PST 7 and Learner 3 both held naïve perceptions about the scientific method and there was no difference in their

understanding of that NOS aspect.
Furthermore, when the two groups were assessed on their understanding of another NOS aspect, the social and cultural embeddedness of scientific knowledge their responses were not very different from each other. Clearly, both groups exhibited mixed and naïve responses. The extracts below are illustrative:

PST 5: *I believe science is universal. This is because the same data will be gathered if the same method is used anywhere in the world.*

Learner 4: *Science is universal due to the fact that it is not based around subjective or biased decision making, for example the Big Bang theory. Everything is factual and can be understood in global measures.*

Learner 4 and PST 5 misinterpreted the NOS aspect and asserted that science is universal (mixed view) and then went on with their explanations which were misconceptions. From these
responses, one could clearly see that there was no difference in understanding of this NOS aspect between the two participants from the two groups.
The interview results also showed that both the Grade 11 learners and the Pre-service teachers held informed views on the tentativeness of scientific knowledge. Both groups' interviewees demonstrated their appreciation and acknowledgement that scientific views and ideas have changed overtime by saying the following;

PST 7: *Yes. More information about a specific theory could be found thus changing the original idea or concept of the theory due to recent discoveries.*

Learner 3: *Scientific knowledge is always changing. As a result, new discoveries are constantly made and these discoveries may contribute to a scientific theory being changed.*

Learner 3 clearly asserts that scientific knowledge is dynamic while PST 7 affirms by saying that "Yes" scientific knowledge changes overtime due to new discoveries. It is evident that there was no difference in the understanding of the tentativeness of scientific knowledge between the two groups. Both groups showed a relatively good understanding of this NOS aspect.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The findings from this study indicate that there is little or no difference in understanding the NOS between high school learners and Pre-service teachers. It was expected that Pre-service teachers would show a significantly better understanding compared to the Grade 11 learners. These findings suggest that there is no clear development in NOS understanding as learners' progress from high school to university. This concurs with Palmquist and Finley (1997) who suggest that most pre-service teachers enter the teaching programmes at university and tightly cling to their mixed and naïve views of the NOS. This is despite the fact that at university, they are expected to do science education courses which emphasize the inclusion of the NOS in their science instruction (Mathews, 1998; Ogunniyi, 1983). The findings support McCommas's (1998) assertion that NOS is not very much emphasized in science lessons in schools. The lack of any differences in the understandings of the NOS between the Grade 11 learners and the Pre-service teachers hence becomes completely surprising because of the differences in which NOS instruction is treated and emphasized at their respective different science education levels. These findings suggest that more should be done by the university to explicitly develop pre-service teacher understandings of NOS if the goal of science education for scientific literacy is to be achieved**.** Abd-El-Khalick and Lederman (2000) argue that teachers' pedagogical content for NOS should be addressed first if there is any hope of developing adequate understandings of the learners. Additionally, it might be necessary to include assessment of learners NOS understandings as part of school examinations. Perhaps that way both learners and teachers can begin to value NOS. This study's findings point towards the need to pay attention to ways in which NOS is represented and addressed in both the school curricula and the science education teacher programs in South Africa.

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