DOES THE CLASSROOM PRACTICE OF SCIENCE TEACHERS REFLECT THEIR CONCEPTIONS REGARDING THE NATURE OF SCIENCE?

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An adequate understanding of the epistemological basis of scientific knowledge and its creation has become increasingly important for science teachers in the context of the new curriculum (NCS) which is being implemented in South African schools. This study involved the investigation of the Nature of Science (NOS) views held by 136 practising science teachers in the Eastern Cape Province by analysing their responses to a twelve-item, Likert-type questionnaire and semi-structured follow-up interviews. Analysis of the responses to the questionnaire items and the analysis of the qualitative data from the interviews indicated two broad categories of teachers; those whose beliefs resemble more of a positivist perspective which is more in line with 'traditional' views of teaching and those who hold a more 'contemporary' view (as reflected in the NCS). Four teachers from each category were selected for the purpose of a qualitative study regarding their classroom practices in science with respect to the NOS.

Keywords: Nature of Science, Science teachers, Curriculum, Classroom practice

INTRODUCTION

The epistemological issues concerning scientific knowledge and the scientific enterprise have been debated and researched extensively by philosophers of science, science educators, curriculum developers and researchers over the past few decades (Lederman, 1992). Although nature of science (NOS) remains a difficult construct to define, Lederman, Abd-el-Khallick, Bell, and Schwartz, (2002) suggest that there is consensus among philosophers, historians and sociologists of science regarding certain aspects of the NOS, i.e., scientific knowledge is tentative; theory-laden; creation of human imagination and influenced by social and cultural values. In addition to these aspects, they have identified the relationships and functions of scientific theories and laws, the distinction between observation and inference and the myth of 'Scientific Method'.

One of the critical aims of the curricular reforms in science in the recent past (e.g., American Association for the Advancement of Science, 1993; Department of Education, 1977; National Research Council, 1996) has been the promotion of scientific literacy and the achievement of this aim requires the improvement of teachers' understanding of the NOS. The objective of the new science curriculum in South Africa is a radical shift from the traditional inductivist based and examination oriented curriculum of the past to one of promoting scientific literacy and the development of critical thinkers who are able to make informed decisions about Science-Technology-Society (STS) related issues in a South African cultural context. Hence it has become important to investigate South African teachers' perceptions about science, knowledge development in science, and their readiness to engage in classroom practice in line with the vision of the new curriculum. Investigative studies conducted by Dekkers and Mnisi (2003) in the Limpopo province and by Linneman, Lynch, Kurup, Webb, and Bantwini (2003) in the Eastern Cape Province indicate that science teachers do not possess adequate understanding of NOS that they are required to teach in the new curriculum. In order to redress this issue various higher education institutions in South Africa started introducing course components related to history and philosophy of science in the teacher education programmes, both in-service and pre-service, to develop teachers' understandings of NOS. A case study on two science teachers to explore the effect of a semester-long NOS course focusing on the history, philosophy and sociology of science indicates that the course which employed a discursive approach assisted teachers "*...to present science as a multifaceted, tentative and revisionary human enterprise, arising in a socio-cultural context"*. (Ogunniyi, 2006).

PURPOSE OF THE STUDY

This study examines whether the exposure to explicit instruction in NOS enhanced teachers' conceptions of NOS as compared

with teachers who were not exposed to such an intervention. The participants in this study were 92 practising science teachers (designated as B.Ed. teachers) who received explicit instruction in the NOS through a university accredited B.Ed. in-service programme module and 44 practising science teachers (designated as non-NMMU teachers) who were not part of the B.Ed. programme. In addition to explicit instruction in aspects of NOS, the natural sciences modules in the programme required teachers to develop metacognitive skills to address the issue of alternative conceptions in science held by learners by exploring the origins of the alternative conceptions as well as to design teaching strategies to address learners' misconceptions.

Method

A twelve-item Likert-scale questionnaire (Appendix 1) was developed by considering the key aspects of NOS as espoused by Lederman et al., (2002). Items in the questionnaire were modified and revised after discussion with five lecturers who have been involved in science education for a number of years in an attempt to improve their validity. The questionnaire was administered to all participants in groups in a formal classroom setting.

The answers to the questionnaire items were classified into three categories based on (i) Lederman et al., (2002) 'current shared wisdom' (and so designated as a 'contemporary view'), (ii) views acceptable to positivist/empiricist schools of thought (and so designated as 'traditional' for the purpose of this study), and (iii) 'no opinion' for those who felt that they could not articulate any specific opinion on a particular statement. Based on this classification a contemporary view is reflected by strongly agree or agree for statements 4, 7, 11 and 12 and strongly disagree or disagree options for the rest of the statements. The classification of the participants' responses into the 'contemporary' category is congruent with the aspects of the NOS highlighted in both Benchmarks (American Association for the Advancement of Science, 1993) and Standards (National Research Council, 1996).

Given the problems associated with the use of forced choice, paper and pencil NOS instruments (Aikenhead, Ryan, & Desautels, 1989), teachers were selected for follow-up semi-structured interviews. The analysis of the quantitative data from questionnaires and the analysis of the interview data assisted in developing an initial profile of teachers with regards to their NOS leanings. Four teachers each (i.e. B.Ed. and non-NMMU) with congruent profile from the two sources of data were selected for classroom observations.

Results

Responses to the Likert-scale questionnaire are shown in Table 1. The statements are grouped into seven categories, viz. the nature of scientific theories, the nature of scientific knowledge, the role of observation and inference, the role of imagination and creativity, and the social and cultural embeddedness of scientific knowledge, scientific theories and laws, science-technology-society.

Nature of scientific theories (statements 1 & 7)

Fifty two percent of B.Ed. teachers disagreed with the statement that scientific theories reveal the absolute truth (i.e. there is no uncertainty about the truth) whereas only thirty four percent of non-NMMU teachers disagreed with this statement. The comments of the B.Ed. teachers during interviews indicated that they link their ideas to a more informed understanding of the epistemological and ontological aspects of science that were dealt in the NOS course. On the other hand the majority of the non-NMMU teachers supported the statement that theories reveal the absolute truth based on their faith in experimental evidence in supporting theoretical claims. Paradoxically the majority of the teachers from both groups supported the statement that scientific theories may change with time. A plausible explanation for this anomaly could be that the previous statement in the questionnaire alluded to the view that scientific theories mature as laws after repeated and successful verification.

Nature of scientific knowledge and its generation (statements 2, 6, 9 and 10)

There was exceptionally strong support (97% +) by both groups for the questionnaire statement 2, that the development of scientific knowledge is an orderly, rational and step-by-step process (i.e. scientists first collect data, and then generate theories by looking for patterns in the data). Teachers seem to hold a very strong belief that there is a set process for generating scientific knowledge and this view is augmented by the faith that teachers attach to investigations in science and that the replication of investigations will reveal the same outcome. A B.Ed. teacher (T20) claimed that *"I can say it is, because to convince others about your investigation you have to show them what you have done"*. However, both categories of teachers were much more reserved in their support for statement 9, i.e. that Scientific Method is the only way to study nature and natural phenomena. The majority of teachers subscribe to a more relativistic view of science when it comes to the development of knowledge about natural phenomena as is reflected in the statement of a B.Ed. teacher (T121) when he disagrees with the statement saying *"I disagree, we have to take our backgrounds and our beliefs – not only through scientific method – it only applies in making experiments but not in our cultural knowledge"*. A majority of teachers (75% +) felt that scientists discover theories and laws (statement 6) and the interviews confirmed that they believed that this knowledge was 'something which is out there', i.e. an objective reality independent of scientists. The notion that indigenous

knowledge (i.e. knowledge held by different cultures) cannot be regarded as scientific knowledge was rejected by 70 % of non-NMMU teachers compared to 55% of B.Ed. teachers rejecting this claim.

Group	1	2	3	4	5	6	7	8	9	10	11	12
Non-NMMU (44)												
Contemporary	34	0	23	41	14	16	77	52	43	70	9	59
Positivist	55	99	75	45	80	75	16	25	41	25	89	11
No opinion	11	1	5	9	5	9	7	18	16	2	0	27
B.Ed. (92)												
Contemporary	52	3	28	75	8	17	75	58	48	55	9	66
Positivist	42	97	64	27	89	80	20	29	42	34	91	16
No opinion	5	0	6	0	2	2	4	12	10	11	0	17

Table 1: Responses per category in percentages for the 12 statements

The role of observation and inference (statements 8 & 12)

Fifty eight percent of B.Ed. teachers hold a contemporary view that inferences drawn from observations are theory-laden, i.e. they rejected the notion that *two independent scientists make the same conclusion from observing a natural phenomena* (e.g. draw the same conclusion after observing a forest fire). Most of the B.Ed. teachers espoused the view that prior knowledge held by scientists influence their conclusions by referring to fallibility in observations discussed during the NOS course.

Role of imagination and creativity (statement 3)

Seventy five percent of non-NMMU teachers and sixty five percent of B.Ed. teachers appear to hold a mechanistic view about the role of scientists in developing knowledge in that they support the view that *scientists perform experiments/ investigations when trying to solve problems and they use their imagination and creativity only during the planning and design of these experiments/investigations* (statement 3). The role of imagination and creativity in the development of scientific knowledge seems to be a difficult construct for teachers for most of them scientific enterprise is mostly based on logical reasoning and experimentation without any creative aspect to the process.

Social and cultural embeddedness of scientific knowledge (statement 4)

Seventy five percent of B.Ed. teachers agreed with the statement that theories developed by scientists are influenced by the social, political and cultural contexts (situations) prevailing at that time compared to only forty one percent of non-NMMU teachers agreeing with this statement. The view that scientific knowledge is value free and objective is reflected in a non-NMMU teacher's claim when he asserted that (T90): *"I disagree with that one in the sense that social and political – in my perception – are not part of science per-se. They are falling under humanities in a way, how people are living"*.

Scientific theories and laws (statement 5)

More than 80% of all teachers from both categories in this study appear to adhere to the notion that over time, and after successful experimental verification, scientific theories mature into laws. The prevalence of the perception among teachers that scientific laws are superior to theories was endorsed during the interviews. However, no teacher was able to articulate a coherent answer to the following question posed by the interviewer: "*Do you think that, at some stage all scientific theories will become laws*"?

Science-Technology-Society (statement 11)

The quantitative data suggest that a majority of teachers strongly believe that science should not be thought of as separate from technology. Teachers appear to be confused between the utilitarian role of technology in enhancing the quality and accuracy of observations with science as a way of knowing about natural world. During the interview a B.Ed. teacher (T 21) commented: *"I strongly disagree with that – there are things that you cannot prove without technology. Like you need telescopes to research the movement of stars and the moon"*. Some teachers expressed the view that technology is applied science and a few viewed the relationship between science and technology as being interactive.

Classroom Observations

A classroom observation schedule (Table 2) was developed for this study listing criteria that would indicate the performance of key NOS aspects reflected in the questionnaire. The twelve questionnaire items were reduced to eight key components by conflating items which refer to a broad aspect of NOS. Classroom practice of the eight teachers were analysed using the schedule by observing the recorded classroom action which reflected explicitly or implicitly the criteria listed in the table. For each of the NOS aspect, a teacher was judged to be 'Traditional', 'Transitional' or 'Informed' if she/he displayed behaviours aligned with 50% or more of the criteria listed under each of the respective categories. If a teacher did not display an action related to the NOS aspect which should have formed part of the lesson it was noted as 'Not Discussed' (ND) and if the topic under discussion did not involve a specific NOS aspect it was noted as 'Not Relevant' (NR). Using the criteria stated above, the analysis of the lessons indicated discernible differences between the non-NMMU and B.Ed. categories of teachers.

Non-NMMU teachers

The results indicate that the classroom practice of non-NMMU teachers was largely based on transfer of text book knowledge

from the teacher to the learners with emphasis on scientific principles and laws giving the impression that science is a collection of irrefutable facts to be learnt. The practice of science in the classroom as a clinical activity disconnected from daily life experiences of learners provides further evidence to this view. Although the teachers expressed developed understandings on the social and inferential NOS in their responses to the questionnaire and in interviews there was no evidence of these understandings in their classroom behaviour. The search for the "right answer" and treating scientific concepts in separate silos suggest that the teachers' ideas about science are not consistent with the views expressed at the interviews.

B.Ed. teachers

A pedagogy grounded in constructivist epistemology was observed with the B.Ed. teachers in the way they engaged learners in discussions around open-ended questions to explore learners' views. An emphasis on theoretical explanations to account for causal factors rather than focusing on laws and principles was observed with this group. However, it must be noted that none of the teachers referred to Indigenous Knowledge Systems related issues in their classroom discussions even when the science content area under investigation seemed appropriate for such discussion.

Key NOS aspect	Corresponding questionnaire item(s)
The "scientific method"	2 and 9
Nature of scientific theories	1 and 7
Role of imagination and creativity	3
Observation and inference	8 and 12
Scientific theories and laws	5 and 6
Social character of science	4
Indigenous knowledge	10
Science, Technology and Society	11

Table 2: Classroom observation schedule indicating key NOS aspects and questionnaire items

As opposed to a teacher-directed empiricist tradition reflected in the classrooms of the non-NMMU teachers, the classroom actions of the B.Ed. teachers indicated a developed view of NOS conceptions. The engagement of learners in meaningful discussions and investigative activities grounded in an informed understanding of NOS observed in the classrooms of the B.Ed. teachers suggest that they are more informed about the principles and guidelines of the new curriculum (NCS) than the non-NMMU teachers. Based on the findings from this study it is reasonable to conclude that explicit instruction in NOS contributed positively towards the teaching and learning of science in the observed classrooms of the B.Ed. teachers.

In the science lessons of the B.Ed. teachers there was less emphasis on theoretical terms and chorusing difficult terms. The emphasis was more on developing plausible explanations for why things behave in a particular way. One lesson on electrical circuits in a grade 7 class was particularly noteworthy. The teacher encouraged students to adopt an inquiry approach to learn about why bulbs light up in different circuits differently with the focus being on the energy aspects of the electric current. Conceptual understanding regarding the role of energy in an electric circuit was the emphasis of the lesson rather than learning new terms in science. However, none of the teachers in both categories made any specific reference to aspects of NOS during the lessons explicitly or implicitly.

Conclusion

The analysis of the responses to the questionnaire items indicates that B.Ed. teachers hold a more informed view of NOS compared to the non-NMMU group although both believe in the step-by-step process view of science and that theories mature to form laws after successful verification. The role of theories and laws in science seems to be a problem area for both categories of teachers. Similarly the classroom practice of B.Ed. teachers appears to be more amenable to a contemporary view of science. It is evident that both categories of teachers need additional support in developing their skills in teaching the NOS aspects to meet the requirements of the new curriculum.

However, it should be noted that the observation of one science lesson of each teacher does not provide a full picture of the range of strategies that a teacher may use in developing students' conceptual understanding. A deeper understanding of the teacher's intentions and practice can be gained by observing a series of consecutive lessons in a science topic followed by detailed discussion with the teacher after each lesson.

References

Aikenhead, G., Ryan, A., & Desautels, J. (1989). Monitoring students views on Science-Technology-Society issues: The development of multiple choice items. Paper presented at the annual meeting of the National Association for Research in Science Teaching, 34, 39-55.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University press.

Dekkers, P., & Mnisi, E. (2003). The nature of science–Do teachers have the understandings they are expected to teach? *African Journal of Research in Mathematics, Science and Technology Education*, 7, 21-34.

Department of Education. (1977). *Curriculum 2005–Lifelong learning for the 21st century*. Pretoria: Government Printer.

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., Abd-El-Khalick, F., Bell, R.L., & Schwartz, R. S. (2002). Views of the nature of science questionnaire: Towards valid and meaningful assessment of learners' conceptions of the nature of science. *Journal of Research in Science Teaching*, 39(6), 497–521.

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.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academic press.

Ogunniyi, M. (2006). Effects of a discursive course on two science teachers' perceptions of the nature of science. *African Journal of Research in Mathematics, Science and Technology Education,* 10, 93–102.

Appendix 1

Views of Science Questionnaire

There are no right or wrong answers to the following statements.

Please read each statement carefully and then circle the option *(Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree)* that best describes your view on that statement.

No.	Statements
1	Scientific theories reveal the absolute truth (i.e. there is no uncertainty about the truth).
2	The development of scientific knowledge is an orderly, rational and step-by-step process (i.e. scientists first collect data, and then generate theories by looking for patterns in the data).
3	Scientists perform experiments/investigations when trying to solve problems. They use their imagination and creativity only during the planning and design of these experiments/ investigations.
4	The theories developed by scientists are influenced by the social, political and cultural contexts (situations) prevailing at that time.
5	After repeated and successful experimental verification, a scientific theory becomes a law.
6	Scientists discover theories and laws.
7	Scientific theories may change with time.
8	Two independent scientists make the same conclusion from observing a natural phenomenon (e.g. draw the same conclusion after observing a forest fire).
9	The "Scientific method" is the only way to study nature and natural phenomena.
10	Indigenous knowledge (i.e. knowledge held by different cultures) cannot be regarded as scientific knowledge.
11	Science should be thought of as separate from technology.
12	Observations made by a scientist can be objective, but the conclusion drawn from the observation is subjective.