Relationship between grade 10 learners' views about nature of science and contextual factors

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Abstract: This study investigated relationships between learners' views about the nature of science (NOS) and contextual factors. The participants were a group of 100 grade 10 learners who applied to participate in a science enrichment programme offered by a South African university. A modified 'Views on the Nature of Science' (VNOS) questionnaire consisting of eleven open-ended questions was used to examine learners' views on seven aspects of the NOS. We investigated relationships between students' VNOS performance and parents' level of education, learners' gender, performance, home language as well as their school's performance in national final examinations. Findings showed no significant difference in the test scores between genders. The students' scores on the VNOS test were strongly correlated to the educational background of the parents, and learners with English as a home language performed better. However, there was poor correlation between the VNOS scores and learners' performance in Mathematics, Science and English. Also, the matric pass rate of the school did not correlate strongly with the test scores. From the results, it is concluded that the strongest factor influencing learners' performance on the VNOS test are parents' educational background and the use of English as a home language.

1. Introduction

One of the essential goals of science education reforms throughout the world is to prepare scientifically literate individuals [1, 2]. It is argued that an adequate understanding of NOS and scientific inquiry is essential for the development of scientific literacy [3]. Generally, scientific literacy includes an understanding of science content, scientific methods of inquiry and NOS [4]. Many learners in different parts of the world have poor conceptions of NOS [5]. This may be related to teacher-centred instruction methods which teachers have developed from their own experiences as students [6]. Teacher-centred instruction which does not promote the development of a better understanding of different features of NOS [7, 8] is still used in many South African schools. The science education reforms which supported scientific literacy in South Africa started after the introduction of Curriculum 2005 (C2005) policy in 1998. Many curriculum changes occurred after 1998 that eventually gave birth to National Curriculum Assessment Policy Statement (NCAPS) [9]. NCAPS encourages the development of science process skills, application of scientific knowledge in real-life problems and acknowledging the relationship between science, society and technology [9].

The current study was undertaken at a South African university that hosts a science enrichment programme for senior secondary school pupils. The name of the university is not mentioned for the sake of anonymity as required by ethical guidelines. The enrichment programme, presented by the Faculty of Natural and Agricultural Sciences, uses an inquiry approach in preparing learners in a three year programme from grade 10 to 12 in developing better understanding of science. The programme is focussed on physics and chemistry. Learners who successfully participate throughout the programme receive a full bursary if they enrol for a Bachelor of Science degree at this university, after completing grade 12. This paper reports on the first stage of a three year research project which tracks the development of NOS understanding amongst a cohort of participants in the enrichment programme. The focus of this paper is on exploring the views of NOS amongst learners upon entering the programme when in grade 10. The research question addressed in this paper is: *How do grade 10 learners' views about nature of science relate to contextual factors?* In this study the contextual factors include: gender, parents' level of education, home language, learner performance, and school performance.

2. Literature review

NOS is a dynamic scientific construct without a generally accepted definition. There are still disagreements amongst science educators, scientists, philosophers of science, and historians of science, regarding the precise meaning of NOS [1, 10]. This study was informed by Lederman's [11] perception of NOS, which he described as "epistemology of science, science as way of knowing, or the values and beliefs inherent to the development of scientific knowledge". Irrespective of the differences among aforementioned scholars with regard to the definition of NOS [19], there is a level of consensus on aspects of NOS that should be taught to high school learners [12, 13]. These aspects are discussed below.

The seven aspects of NOS include that scientific knowledge is tentative; empirical; theory-laden; subject to imagination and creativity; influenced by social and cultural values; based on observation and inferences; and described by scientific theories and laws and developed in the absence of a universal scientific method. Individual views of nature of science vary between well informed and naïve. The former views include understanding that scientific knowledge is tentative; empirically based; subjective; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Other aspects of NOS include the relationship between observations and inferences, the relationship between scientific theories and laws and use of variety of scientific methods [14]. The latter views include understanding that scientific knowledge is a discovery of an objective reality external to human beings; is generated through use of a single universal scientific method and that evidence collected through scientific processes will produce reliable knowledge [15] which is not affected by social and cultural values [16].

3. Methodology

The study is located in the interpretivist paradigm [17], using a mixed methods approach. Qualitative data were collected using the slightly modified open-ended Views of the Nature of Science (VNOS Form C) questionnaire containing eleven questions adapted from Lederman *et al* [12]. The modifications made to the test were mainly to adapt the test to the South African context. The VNOS questionnaire has been validated [13], and used regularly in research [18]. The changes made were considered minor with no significant effect on the validity of the test. The data were then analysed and quantified by scoring responses on a five point linkert scale ranging from naïve to informed views (1 = naïve, 2 = partially naïve, 3 = moderate, 4 = partially informed, 5 = informed). These scores were then analysed using descriptive statistics. The scores were added to obtain an average score per individual and used in further analysis of the data. Descriptions of NOS aspects by [19] were used as a guide during the scoring process.

Purposeful sampling was used, utilizing the entire group of 100 applicants to the university's science enrichment program. From these, science enrichment programme annually selects a maximum of 50 well performing grade 10 learners to enrol in the programme. For the current paper, the entire group of 100 grade 10 applicants acted as the sample. The ethical procedures were followed when selecting participants in this study. Permission was granted by the Ethics Committee of the University prior to the commencement of this study.

4. Results

The results from this study are represented in the three graphs shown in Figure 1, 2 and 3.

4.1 Average score per question

Figure 1 shows the performance of the students on different VNOS questions, using the 5 point scale. The majority of learners scored well on questions 2, 5 and 9 which were addressing VNOS aspects that science knowledge is empirically based, that scientific theories are tentative and that social and cultural values influence the development of scientific knowledge.

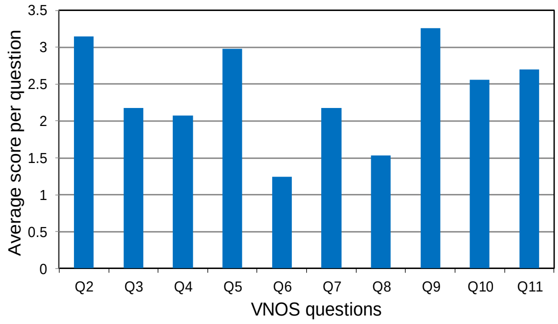

Figure 1. Learners' VNOS score averages on eleven open-ended questions.

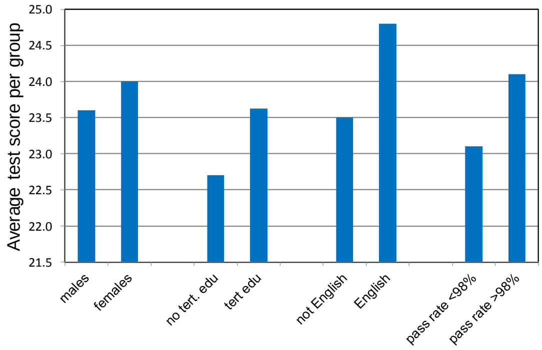

Figure 2. Learners' average test scores against contextual factors.

Learners obtained lower scores on questions 3, 4, 7, 10 and 11. These questions targeted the following VNOS aspects: learners' understanding of that scientific investigations are not always following a recipe-based scientific method, but involve observations and inferences to generate science knowledge (3, 4 and 11) and learners' understanding of scientists' application of imagination and creativity in the development of scientific knowledge (7 and 10). Finally, learners scored lowest on questions 6 and 8 focussing on learners' understanding of the difference between a scientific theory and a scientific law (6) and learners' understanding that science is subjective with opportunity for different interpretations (8).

4.2 Contextual factors

The average test scores for students from different backgrounds are shown in Figure 2. Students whose parents have a tertiary education obtained higher VNOS scores than those of parents without tertiary education (p = 0.054). In addition, students who had English as home language scored higher (p = 0.074) than other students using other languages. Also, the school background showed that VNOS scores were higher for the students from schools which had a matric pass rate over 98% (p = 0.30). There was no significant correlation (r = –0.04) found between VNOS test scores and Grade 10 marks for the group. However, there was a gender effect: Males showed a slight positive correlation between test scores and grade 10 marks (r = 0.33), whereas females showed a slight negative correlation (r = –0.27). After investigating correlation between genders in terms of understanding different aspects of the NOS, as determined by a t-test, there was no statistical difference between them (p = 0.95). Figure 3 shows the average score per gender that students obtained in the VNOS test. It can be seen that in different individual questions, there were only small differences between males and females. Statistically the most significant differences were observed when asked on their knowledge of the difference between a scientific theory and a law, where males scored marginally better (question 6, p = 0.16), and the VNOS aspect demonstrating an understanding that scientists use their imagination and creativity in the generation of scientific knowledge, where females performed marginally better than males (question 7, p = 0.13).

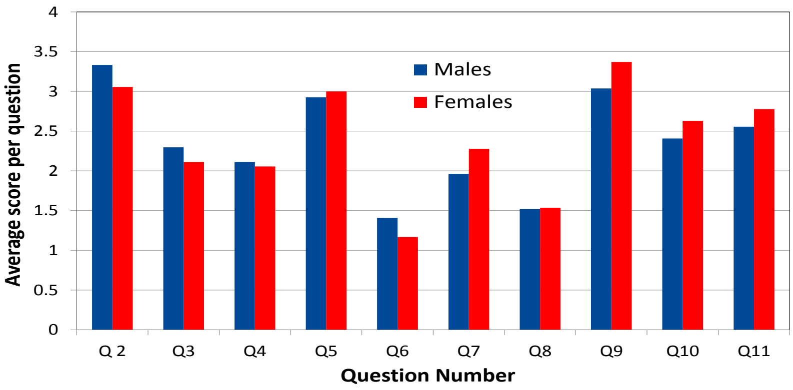

Figure 3. Gender differences in average scores per question

5. Discussion and conclusions

This study has demonstrated a noticeable variability in understanding different aspects of NOS. Students generally scored well on NOS aspects such as the tentative, empirical, and influence of social and cultural values on the generation of scientific knowledge. Previous research shows that many teachers and students perceive scientific knowledge as fixed and unchangeable. Additionally, they believe that scientific knowledge generated through experiments and technological means only is legitimate and reliable [20]. However, learners' performance in questions 2, 5 and 9, demonstrates that learners in this study are reasonably well informed in three VNOS aspects: empirical, tentative, and sociocultural embeddedness. This finding differs from the previous international studies.

Previous research shows that learners believe that scientific knowledge is tentative and modified in the light of new technological discoveries [12]. The history of science indicates the view that science knowledge could be changed through evolution and revolution of scientific ideas [21]. Students in this study struggled with differentiating between a theory and a law and understanding that different conclusions are possible given the same data due to the inherent subjectivity of scientists when interpreting data. Many teachers and students do not understand that observations and inferences are subjective and theory-laden as they are guided by scientists' prior knowledge and experiences of current science knowledge which could lead to multiple valid inferences [12]. Instead they believe that scientists would make objective observations and inferences of the same natural phenomenon [22]. Students also have misconceptions on the use of different scientific methods when generating scientific knowledge. This finding is similar to the results of studies conducted in the North of America and Australian contexts, where high school students experienced the same difficulties as South African learners [5].

Empirical research has shown that many teachers and students believe that laws are certain and proven whereas theories are unproven ideas [21]. Teachers and students also believe that there is a hierarchical relationship between theories and laws [23]. They also believe that theories will later change into laws depending on the accumulation of supporting evidence [12]. Students should know that science involves translation of data into evidence, invention of explanations and theoretical models which demand the use of creativity and imagination by scientists [12]. Furthermore, question 8 assessed learners' beliefs on different subjective factors such as theoretical commitments, and influence of social and cultural values that affect scientists' work. Learners should know that although science knowledge is considered to be general and universal, it is influenced by the societal and cultural values of the context in which it is generated. Many teachers and students consider science as a hunt for the universal truth not influenced by cultural and societal values [20]. Lederman *et al* [12] posited that many learners have a misconception that there is a universal scientific method used by all scientists when they conduct scientific investigations. Kuhn [21] asserted that scientists use a mixture of different scientific approaches depending on their prior experiences, creativity and imagination and current paradigms in their fields of research.

Regarding contextual factors, it was found that the strongest correlation with learner's performance in the VNOS test was their parents' education, followed by home language and the matric pass rate of the school attended. These findings may be attributed to various factors such as the existence of many indigenous languages and use of English as a language of learning in the South African context. Additionally, majority of parents have low level of education due to poor schooling and segregated education system during the apartheid era. Similar findings were reported in a study conducted by Dogan and Abd-El-Khalick [24] in Beirut, Lebanon. They investigated the influence of social backgrounds on grade 10 Turkish students' and science teachers' conceptions of NOS. Results from their study showed that teachers' and students' views were similar and related to teacher graduate degree and geographical region, and student household socioeconomic status (SES), parent education, and SES of their city and geographical region. These relationships demonstrated the influence of western culture in their understanding about NOS. Similarly it can be argued that the effects observed in the current study can be attributed to the influence of western culture on development of scientific literacy in South Africa.

There was no statistical significant difference on average scores between genders. Lederman *et al* [12] posited that understanding of the different features of nature of science is not gender biased. Research studies in psychology have shown that there are differences with regard to the cognitive skills between boys and girls. One group of research has shown that boys outperform girls on tasks relying on spatial orientation and visualisation skills [25]. Many people believe that success in STEM (Science, Technology, Engineering and Mathematics) courses is linked to spatial capabilities, but research has shown that there is no relationship between STEM and spatial skills [26]. In contrast, girls outscore boys on tasks relying on verbal and writing skills, memory and perceptual speed [27]. This could be one reason why female learners outperform boys in question 7 which was addressing the role of human inference and creativity in science, and the notion that scientific models are not copies of reality.

The results of this study should not be generalized to the entire grade 10 population of South Africa. However, results could be generalized within the population of well performing students in the city from which the sample was drawn. The reproduction of results would be possible drawing a similar sample of learners from city schools and administering the questionnaire. The findings of this study especially the students' informed views on the tentative nature of science agree with the international research. These results may be attributed to the changes that occurred in the education system in South Africa after the introduction of C2005 in 1998. However, there are currently still many disadvantaged students with poorly educated parents in South Africa. This is a persisting consequence of the segregated education system during the apartheid era and which cannot be overcome in a short time. The language issue, that is the use of English as a medium of instruction in schools also disadvantages learners who speak indigenous languages at home. This language problem has no simple solution. Clearly, changes which occur at the political level have an influence at what is happening in teaching and learning process in a classroom situation [28]. A follow up study will again be conducted with the same group of students after the three year programme to examine the changes in their views of NOS due to their involvement in the science enrichment programme. In the next study, the relationships between parents' level of education and the use of English as a medium of instruction on students' views of the nature of science will also be investigated.

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