The inclusion of nature of science in grade 12 high-stakes physics assessments in South Africa

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Abstract. This research explores the representation of Nature of Science (NOS) is three national high-stakes grades 12 physics examinations. This study has particular significance due to curriculum reform that deliberately attempted to transform the previous curriculum that depicted to the learner and teacher a view of science which was not compatible with the nature of science. Science curricula worldwide have given more emphasis to NOS and this goal was also set by curriculum developers in post-Apartheid South Africa. It is therefore of interest to know whether this curriculum intent translates into the assessment of learners in high stakes physics examinations. A recent characterization of NOS is called the Family Resemblance Approach (FRA). This study adopted FRA as conceptual framework in guiding the analysis of grade 12 physics items for the representation of NOS. FRA offers 11 categories that consolidate the epistemic, cognitive and social aspects of science in a holistic, flexible and descriptive way. The findings of this study suggest that greater attention needs to be given to the representation of NOS in both the cognitive-epistemic and social-institutional systems. A particular concern is the weak representation of NOS in the socio-institutional dimension where it was found that physics items only to a small extent address the categories of professional activities, scientific ethos, social certification and dissemination, social values of science, social organizations and interactions, political power struggles, and financial systems. An implication of this is that learners are not tested on higher-order skills such as critical thinking that would inform their decision-making on socio-scientific issues related to physics. This is therefore a call for deliberation amongst stakeholders on the tasks that are set in physics examinations.

1. Introduction

The construct 'nature of science' (NOS) has been advocated as an important goal for studying science for more than 100 years (Lederman & Lederman, 2014). NOS forms the foundation of science curriculum documents worldwide (Lederman et al., 2013). In the South African Curriculum and Assessment Policy Statement (CAPS) Physical Sciences, NOS is addressed through Specific Aim number 3 where it is stated that "an understanding of the nature of science and its relationships to technology, society and environment" (Department of Basic Education, 2011, p.8).

NOS is an encompassing and multifaceted concept and cannot be defined by a single term or a statement. Nature of science does not describe how the natural world works, but is rather a description of how the scientific enterprise works (McComas & Clough, 2020). McComas, Clough and Almazroa (1998) describe a 'consensus view' of the nature of science extracted from eight international science standards documents. According to this view, scientific knowledge is tentative and subject to change; scientific knowledge is subjective; people from all cultures contribute to science; and scientific ideas are affected by their social and cultural milieu.

Knowledge of the nature of the science assists learners in their understanding of science. McComas and Clough (2020) put it that "NOS is fundamental to any conception of a science education" (p. 11). Incorporating the nature of science in teaching also conveys to learners a view of science as a human activity steered by our sense of curiosity in trying to understand the physical world. This view of science can enhance interest in the subject (Mathews, 1994). An understanding of the nature of science has also been presented as essential for informed decision-making, especially in evaluating the effect of technological innovations on society (Driver et al., 1996).

This research explored the representation of Nature of Science (NOS) is three national high-stakes grades 12 physics examinations. This study has particular significance due to curriculum reform that deliberately attempted to transform the previous curriculum that depicted to the learner and teacher a view of science which was not compatible with the nature of science. Science curricula worldwide have given more emphasis to NOS and this goal was also set by curriculum developers in post-Apartheid South Africa. It is therefore of interest to know whether this curriculum intent translates into the assessment of learners in high stakes physics examinations.

The 'consensus' view of the nature of science has been criticised, with one of the criticisms being that "the consensus view simplifies the NOS but does not illustrate the detailed process and actions in science (Jho, 2019, p. 600). A recent characterisation of NOS is called the Family Resemblance Approach (FRA) (Figure 1). FRA is a holistic perspective that promotes the understanding of science as the conception of dynamic cognitive, epistemic, and social-institutional systems (Akgun & Kaya, 2020). The FRA wheel consists of 11 categories, with the inner-most level representing the cognitive and epistemic aspects of science and the outer levels indicating social-institutional elements. The cognitive-epistemic system comprises the following categories: aims and values, scientific practices, methods and methodological rules, and scientific knowledge. Within the social-institutional system the following categories are identified: professional activities, scientific ethos, social certification and dissemination, social values of science, social organizations and interactions, political power struggles, and financial systems.

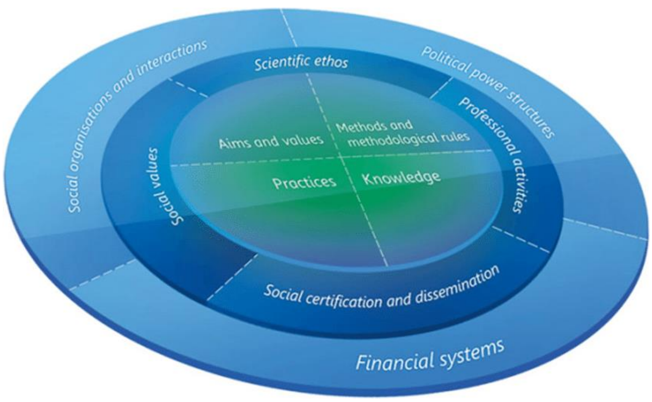

Figure 1: The FRA Wheel: Science as cognitive, epistemic and social institutional system (Erduran & Dagher, 2014, p.28)

The following research question was investigated:

To what extent are the FRA NOS categories represented in three Physics papers in high-stakes matric examinations?

2. Method

The units of analysis included all questions except MCQ that appear in three national high-stakes grades 12 physics examinations. examination paper. Each of the statements relating to NOS were coded according to the FRA NOS categories as reflected in the FRA wheel. For some items, it was realised that multiple codes could apply and so this was allowed. The coding was conducted independently by the author and a researcher in science education. To measure the interrater reliability, Cohen's kappa coefficient (Cohen, 1960) was computed. The inter-rater agreement was K = .85 for the statements, and this was considered good (Miles & Huberman, 1994). Eventually, after discussion on the discrepancy in coding, full agreement was reached between the coders.

3. Results

The frequency distribution of the NOS categories depicted in all three physics examination papers is show in Table 1 below.

Table 1: Frequency distribution of the NOS categories in FRA framework

Aims and values	Scientific practices	Methods and methodological rules	Scientific knowledge	Professional activities	Scientific ethos	Social certification and dissemination	Social values of science	Social organizations and interactions	Political power structure
0	14	11	62	0	0	0	0	0	0

In total there were 87 NOS coded items with all codes (100%) related to the cognitive-epistemic system. Within the cognitive-epistemic system, scientific knowledge (62 out of 87), scientific practices (14 out of 87), and methods and methodological rules (11 out of 87) had the highest proportion of codes. The trend was consistent for all three question papers. The strongest interconnectedness amongst codes was revealed for the categories of scientific practices, and methods and methodological rules, where 10 statements were coded to both categories.

4. Discussion and conclusion

The results of this study have particular significance due to curriculum reform that deliberately attempted to transform the previous curriculum that depicted to the learner and teacher a view of science which was not compatible with the nature of science. A critical finding of this study is that NOS representation in the social-institutional system was absent. Giving enough attention to categories such as social values of science and political power structures that if represented more strongly could give impetus to classroom instruction that engages learners in socio-scientific issues. Various studies have alluded to how focusing on socio-scientific issues (SSI) can enable understanding of nature of science.

5. Recommendations

Greater attention needs to be given to the formulation of assessments tasks that address the social-institutional system. This could have implication for classroom practices because assessments tend to influence learning experiences afforded to learners ('teach to the test'). Teacher professional development needs to focus on assessing for NOS understanding in all dimensions of NOS.

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