In-service and Preservice Teachers' Conceptions of Nature of Science

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Abstract

Nature of science (NOS) is an important component of scientific literacy. Science teachers can have naïve conceptions and misconceptions of NOS which is detrimental to their students' science learning. The aim of research was to examine in-service and preservice science and mathematics teachers' understanding of NOS conceptions using open-ended VNOS-B instrument online anonymously. 13 in-service teachers from Finland, Norway, and Russia and 21 preservice teachers from Finland participated in the research which was organized in the context of the international *BeTech!* project seminar in Finland in September 2019. Qualitative analysis of data from the questionnaire indicated that the conceptions of NOS were adequate in two aspects of NOS: tentative nature of scientific knowledge and creativity of scientists. Understanding the distinction between scientific theory and law, and theory-laden nature of scientific knowledge was interpreted naïve in both groups. The results of in-service and preservice teachers were very similar showing that the practice of teaching profession does not implicitly improve teacher's understanding of NOS. In-service and preservice training using explicit reflective instruction is necessary to raise the awareness of the importance to teach NOS at schools, and to increase in-service and preservice teachers' pedagogical content knowledge with respect to teaching NOS.

Keywords: Nature of science, qualitative research, VNOS-B, in-service teachers, preservice teachers

1. Introduction

Nature of science [NOS] is considered as an essential component of scientific literacy in science education. Scientific literacy requires a wider understanding of science than what is attainable by focusing only on the products of science (e.g. facts, laws, and theories). John Miller (1983) divides scientific literacy into three aspects of what is needed to have understanding of a) the norms and methods of science (NOS and scientific inquiry [SI]), b) key scientific terms and concepts, and c) the impact of science and technology on society. Today scientific literacy is often connected with global problems of ecological, social, and economic sustainability such as climate change (see e.g. Hodson 2003; Holbrook 2009). This study examines the understanding of NOS aspects of those in-service science and mathematics teachers whose students participated in the international seminar in Oulu, Finland, organized by the Kolarctic Cross-Border Collaboration [CBC] project (KO 2071) *Development of common approaches to involve youth into science and technical sphere – BeTech!*. All the participating preservice science and mathematics teachers were from Finland because many of them were mentoring and assisting students in the activities of the project.

NOS is often defined as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). Lederman, Antink & Bartos (2014) have discussed what is an appropriate level of understanding of NOS in K-12 science classrooms: Scientific knowledge is subject to change (tentative), based on and/or derived from observations of the natural world, subjective, inevitably involves human inference, imagination and creativity (invention of explanation), and it is socially and culturally embedded. Scientific knowledge is obtained through observing natural phenomena that are directly accessible to senses, or extensions of the senses, or through inference about phenomena that are not directly accessible to senses (i.e. atoms, genes, gravity, etc.). Many individuals are known to hold an elementary, hierarchical view of the relationship between theories and laws where laws have a higher status than theories. Theories and laws are different kinds of knowledge which cannot develop into the other: Laws are statements or descriptions of the relationships among observable phenomena and theories are inferred explanations for observable phenomena. Scientific theories direct investigations, produce new research problems, and explain observations (Lederman et al., 2014).

Research has shown that science teachers' understanding of NOS is typically inadequate (e.g. Dogan & Abd-El-Khalick, 2008). According to Glough and Olsen (2012), the NOS misconceptions held by science teachers impact their students' attitudes towards science and understanding of science content. They argued that firstly, understanding of NOS helped students to understand and work from the assumptions that underlie scientific knowledge; secondly, understanding of NOS raised student's interest in science thus improving the motivation to learn science content; thirdly, the construction and reconstruction of ideas became clear helping students to understand that some of their ideas were once held by scientists. (Glough & Olsen, 2012) On the other hand, it is also widely recognized that teacher's informed understanding of NOS does not automatically translate into classroom practices. Teachers often regard NOS less important component of science education than traditional subject matter (Lederman, 2007). According to Vesterinen and Aksela (2012), teacher's commitment to teach NOS has at least three prerequisites: Internalizing the importance of NOS as valued instructional outcome, understanding NOS concepts, and possessing pedagogical content knowledge to transfer NOS ideas into practice. Research has demonstrated that explicit, reflective instruction in teaching NOS is more effective than implicit instruction through experiences with simply "doing" science (Lederman, 2007).

Research questions are:

1. What is in-service and preservice teachers' current understanding of NOS?
2. What are the differences in the NOS views between in-service and preservice teachers?

2. Method

Anonymous online questionnaire was used as a data collecting technique. The instrument was "The views of the Nature of Science questionnaire" (VNOS-B) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The VNOS-B consists of seven open-ended questions that help identify understandings of the tentative, empirical, creative, subjective, theoretical, cultural, and social nature of science. The VNOS-B has been reported as a reliable and valid measure of NOS aspects when combined with some interviews, but interviews were not included in this research due to the anonymity of the respondents.

13 in-service teachers responded the questionnaire in September 2019: three from Finland, four from Norway, and six from Russia. All the preservice teachers were from Finland. Neither in-service nor preservice teachers had got any training in various aspects of NOS; their understanding of NOS has been built implicitly within their science discipline and science education studies. Researchers read each response carefully and gave 1, 2, or 3 (integers) points by interpreting the respondents into three groups of informed (mean 2.35-3.00), intermediate (mean 1.68-2.34), and naïve (mean 1.00-1.67). A rubric with characteristic views for informed, intermediate, and naïve responses (Kartal et al., 2018) together with an original article presenting VNOS-B (Lederman et al., 2002) were used to aid the classification of teachers into three groups. Intermediate describes the participant holding to both informed and naïve beliefs, views, and understandings of a specific aspects of NOS, simultaneously. Inter-rater reliability measure, Cohen's Kappa, is **k =** 0.80 indicating substantial agreement according to Landis and Koch (1977).

3. Results

Table 1. Comparison of in-service and preservice teachers' responses to the VNOS-B. Mean values of the assessed responses in a group are given in parentheses.

Aspects of NOS in VNOS-B Questionnaire	In-service teachers	Preservice teachers
1. Tentative nature of scientific knowledge	Informed N=13 (2.92)	Informed N=21 (2.71)
2. Observation, inference, and theoretical entities in science	Intermediate N=13 (2.00)	Intermediate N=21 (2.00)
3. Distinction between scientific theory and law	Naïve N=13 (1.31)	Naïve N=21 (1.48)
4. Creative and imaginative nature of scientific knowledge; subjectivity	Intermediate N=13 (2.00)	Naïve N=21 (1.48)
5. Creative and imaginative nature of scientific knowledge	Informed N=10 (2.48)	Intermediate N=18 (2.17)

6. Empirical nature of scientific knowledge	Intermediate N=11 (1.82)	Intermediate N=20 (2.15)
7. Theory-laden nature of scientific knowledge; subjectivity vs. objectivity, social and cultural influences	Naïve N=10 (1.50)	Naïve N=20 (1.60)

4. Discussion and conclusions

Preservice and in-service teachers got very similar results. Only in two questions (4. How are science and art similar? How are they different? and 5. Other than the planning and design of experiments/investigations, do scientists use their creativity and imagination during and after data collection?) in-service teachers gave more adequate responses than preservice teachers. Those questions mainly refer to the creative and imaginative aspects of NOS. Both groups agreed that science and art require creative thinking but among preservice teachers there was a stronger belief in the objectivity of science and subjectivity of art: "*Art is about impressions and feelings, science is all about the facts".*

All respondents indicated that theories change (question 1) and "*the accumulation of new evidence"* was the main reason for theory change; "*new technology"*, "*identifying new effects out of existing theories"*, and "*contradictions"* were also mentioned as reasons. Respondents seemed to understand well the tentative nature of scientific knowledge (Table 1). Responses in the context of question 3 (Is there a difference between a scientific theory and scientific law?) revealed, however, that many teachers from both groups thought that laws don't change while theories are subject to change, for example one in-service teacher wrote that "*theory is more a presumption and scientific law is the rule in force"* and according to one preservice teacher, "*law is law and theory is just a thought"*. Only three in-service teachers and two preservice teachers viewed scientific theories and laws as distinct but equally valid forms of scientific knowledge. Two in-service teachers and five preservice teachers believed that scientific theories become laws when proven through repeated testing.

Especially preservice teachers (question 7. How is it possible that scientists can draw different conclusions when they look at the same experiments and data?) expressed the view that researchers can make different interpretations of the same data due to *"different views"* or "*lack of information"*. Some of them implied that these interpretations are researchers' opinions which "*we* *just have to believe"*. Some in-service teachers also thought that "*there is not enough data to create scientific law from universe"* or "*researchers have different incompetency"*. Responses for questions 3 and 7 were assessed naïve for both groups. Teachers did not provide examples or explanations where they would have expressed the theory-laden nature of observations, investigations, and data interpretations as a justification to their response.

When asked what an atom looks like (question 2), three in-service and three preservice teachers responded that either they themselves or scientists knew/had seen the structure of the atom exactly. One in-service teacher responded: "*Before seeing an atom, scientists had to create many theories and equipment – a scanning tunneling microscope. Person can look now beyond the unknown. Erwin Muller saw first an atom. Its shape is close to spherical."* Five in-service teachers and twelve preservice teachers, however, understood the inferential nature of scientific models.

Inservice science teachers had an informed view of NOS regarding tentativeness, creativity of scientists and imaginative nature of scientific knowledge. Views of distinction between scientific law and theory and theory-laden nature of scientific knowledge, on the other hand, had not developed in teaching practices being at the same inadequate level with those of preservice teachers. Training using explicit reflective instruction is needed to achieve changes in both in-service and preservice teachers' conceptions of NOS. It is essential that science education provides pupils with opportunities to build their understanding of the purposes of scientific work, of the nature and status of scientific knowledge, and of science as a social enterprise (Driver, Leach, Millar, & Scott, 1996).

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