

ASSESSING PRESERVICE SCIENCE TEACHERS' NATURE of SCIENCE UNDERSTANDINGS: FROM EXPLICIT TO TACIT

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ABSTRACT

The importance of accurately teaching NOS to individuals is widely recognized and the issue of exposing and assessing the NOS understandings, especially the tacit ones, seem to be crucial. The purpose of this study, therefore, was to explore both the explicit and more deeply-held tacit NOS understandings with an interpretative research design. Thirty preservice science teachers were enrolled in a STS course in the context of demarcation of science from pseudoscience. Open ended questions and activity sheets prepared by participants constituted the data sources which were analyzed qualitatively. The results of the research implied that participants' explicit NOS understandings were naive for various aspects with an absolutist view of scientific knowledge in a belief-free context that can be gained through a universal, unique scientific method involving a set of fixed stages. The tacit understandings were seen to be in accordance with these explicit ones and portray a general view of science based on "discovery" of "facts" without any interpretation. Solely, direct observations or experiences of "facts" without any inferences were seen to be viewed as doing science by participants. Moreover, the participants' tacit understandings seemed to form the basic rationale for their explicit views which should be examined further.

Keywords: *NOS Understandings, Explicit, Tacit*

INTRODUCTION

The importance of accurately and deliberately teaching NOS to individuals is widely recognized as evident in science education reform documents (Clough, Olson, 2008; Meichtry, 1993; Kang, Scharmann & Noh, 2005) and the development of individuals' understandings of the NOS has been considered as an important aim of science instruction (Duschl 1990; Meichtry 1993; Kang, Scharmann & Noh 2005). However, little done to provide some instructional methods to enhance the development of the NOS understanding (Scharmann, Smith, James & Jensen 2005) and as a consequence of diverse definitions developed over several decades, researchers had been seen to not share a common conception of NOS (Abd-el Khalick, Bell & Lederman 1998; Kang, Scharmann, Noh 2005). The philosophers, historians and sociologists of science are quick to disagree on specific issues (Lederman, Abd-El-Khalick, Bell & Schwartz 2002) and have proposed different views about what science is and how it works with different rationales. But, most of these disagreements about the NOS are seen to be irrelevant to science education (Abd-El-Khalick, Lederman 2000) and the shared wisdom at a certain level of generality about the NOS among the philosophers of science (Smith, Lederman, Bell, McComas, & Clough, 1997) constituted a common ground for science education.

Based on this common ground, the nature of science (NOS) is often seen to be used to refer to both the epistemology and sociology of science as a way of knowing including the values, beliefs inherent to scientific knowledge (Lederman, 1992), ontological foundations of science (Clough, Olson, 2008) and understandings about the organization of science as an enterprise (Ryder, Leach, & Driver, 1999). Such a perspective underlines some aspects such as; (i) tentativeness, (ii) empirical nature, (iii) theory-laden nature, (iv) socio-cultural embeddedness; (iv) myth of a universal scientific method; (v) roles of hypothesis, theories and laws; (vi) creativity and imagination and, (vii) persuasive communication, for a basic understanding of the NOS (Smith, Scharmann 1999; McComas, Clough &

Almazroa 2000; Lederman, Abd-El-Khalick, Bell & Schwartz 2002). So, without ignoring the philosophical debates about specific issues and the related complexity, these aspects mentioned in many documents should be claimed to establish an acceptable ground for the NOS (Lederman, Abd-El-Khalick, Bell & Schwartz 2002), which is crucial for clarifying the intention teaching.

The search of related literature indicated two general positions for such an aim of teaching the NOS which Bravo (2004) called as 'curriculum perspective' and 'meta-theoretical perspective'. According to curriculum perspective, the focus is on the intrinsic value of the NOS for the education of citizens, which based on democratic and cultural arguments. An understanding of the NOS is evaluated as necessary for making sense of socioscientific issues, participating in the decision-making process (Driver, Leach, Millar & Scott 1996; Zeidler, Walker, Ackett & Simmons 2002) and seen to be crucial for effective local and global citizenship (Smith & Scharmann 1999). Being an educated citizen of the twenty-first century is not claimed to require just to know science but also to know about science; how it is created, how it evolves through history and how it relates to society and culture (Bravo, Merce & Anna 2001). On the other hand, in the meta-theoretical perspective NOS is assumed to represent a second order reflection on the content and methods of science that positively contributes to teachers' autonomy especially when transforming scientists' science into school science (Bravo 2004).

However the results of previous researches concerned with improving students' understanding of the NOS indicated that students from various age groups and even teachers possess both inaccurate and inappropriate views of NOS regardless of the instruments or methods used in investigations (Lederman, 1992; Duschl, 1990; Abd-El-Khalick, & Lederman, 2000). Such a failure had explained by the help of the view that perceptions about the NOS are well assimilated into mental structures and resistant to change (Meichtry, 1992). Hence, any expected development in the NOS understandings firstly requires the exposing of the current perceptions to challenge or alter and this issue addresses the effective assessment of NOS understandings which still remains equivocal (Lederman, Wade, & Bell, 1998; Craven, Hand & Prain, 2002). An important aspect in this context is related with the nature of assessment and the underlying assumptions of the instruments used that are either standardized or open ended but an additional one should also be considered; the distinction between explicit and tacit understanding forms.

The search on the assessment of the NOS understandings indicate the use of standardized or open ended questionnaires with a general tendency towards assessing the explicit understandings which individuals can immediately access and verbalize while communicating with others. However, the assessment of tacit understandings which are unarticulated but are demonstrable by use and action (Polanyi, 1966) are seemed to be overlooked. Although has been used in various ways, tacit knowledge is seen to be defined as the procedural knowledge (rather than the factual one) about the things that have personal importance for the learner and assumed to be learnt without the help of others or any explicit instruction (Sternberg et al., 2000; Torff, 1999) and hence, should be held seriously in educational practice as intuitive conceptions. The purpose of this study, therefore, was to expose and assess both the explicit and more deeply-held tacit NOS understandings of the pre-service science teachers in which various aspects were considered for a basic understanding of the NOS.

DESIGN ISSUES

The present study made use of an interpretative research design with a qualitative data analysis approach (Strauss, Corbin, 1998) to examine both the explicit and tacit perceptions of pre-service science teachers about the NOS.

Participants and Context

Participants of this research were 30 pre-service science teachers of 13 males and 17 females with ages ranged from 20 to 22 at the undergraduate level in a state university, in Istanbul, Turkey. They were enrolled in the Science-Technology-Society course, taught

by the researcher for three hours a week for a period of 12 weeks. All the participants had completed science courses of the teacher education program such as physics, biology and chemistry but none of them had any prior instruction related with the nature, history and philosophy of science. The research covered the first three weeks of the course, the introduction phase, in which the NOS as the core concept under the heading of scientific literacy and the issue of the demarcation of science from pseudoscience as the context of the course were presented to participants. In this phase, any informative instruction about any aspect of NOS did not performed in the class but a common understanding about the context of demarcation of science from pseudoscience was tried to be constructed conceptually. For this, the case of being pseudoscientific was introduced to participants; it defined as having the claim of being scientific although do not meet various standards mentioned by philosophers of science (Preece & Baxter, 2000), and some samples, especially the ones which placed in the popular media such as astrology were briefly overviewed in the class. Within this process, the participants did not have any instruction about the criteria proposed by various philosophers of science and the arguments about the issue of demarcation but tried to be informed about the term pseudoscience to establish a common ground for the context. At the end of this process, the participants were asked to design an activity which should be performed in the elementary science classes, to provide students a basic understanding about the main properties of scientific enterprise and the criteria for demarcating it from pseudoscience.

Data Sources and Analysis

Two data sources were used in this research to expose and assess the participants' both explicit and tacit understandings about the NOS. The first data source was the "*Views of Nature of Science Questionnaire-C (VNOS-C)*" that developed by Lederman et al. (2002), that based on various aspects of NOS such as the empirical nature of scientific knowledge, the theory-laden nature of observations, the socio-cultural embeddedness of scientific knowledge, scientific method/methods and the scientific theories, laws. The intention of this questionnaire was to examine the explicitly pronounced NOS understandings of the participants and was given to them at the first week of the course. So, these explicit understandings were thought as the experience based beliefs of the participants about the NOS, which were developed within their formal education up to this course. The second data source was the set of activity sheets prepared by the participants to emphasize the criteria for demarcating science from pseudoscience, after the introduction of the concept of pseudoscience in the course. With the analysis of these activity sheets, the determination of the tacit understandings of the participants about the NOS was aimed. These activity sheets were examined to elicit the participants' tacit understandings about science as an enterprise, which did not pronounced explicitly but reflected in the process of demarcating it from pseudoscience, in action.

Both data sources were analyzed comparatively for each participant and the analyses began with the search of patterns in the data to derive a coding system. For this, the responses for the open ended questions and the activity sheets of each participant were read and any bit of information related with the issue stated by a word, a sentence or a whole paragraph was used as a conceptual construct to be coded. The list of codes established was then narrowed and a new list of codes developed to sort the data mechanically (Gay, Mills & Airasian, 2006; Bogden & Biklen, 2007). With the help of this sorting process, various themes were determined and grouped into more abstract constructs; categories (Strauss, Corbin, 1998; Maxwell, 2005; Creswell, 2005). Then, the data sources were again examined to evaluate the success of these themes for representing the existing data. This process also provided the researcher to determine the frequencies of the emergence of these themes across the data sources. When it was satisfied that the themes represented the data adequately, the analyses process ended and the distribution of the participants for these themes were clarified.

RESULTS AND DISCUSSION

The results of the research presented in this section were grouped under two headings according to the understanding forms that examined about the NOS; (i) participants' explicit NOS understandings and (ii) participants' tacit NOS understandings.

Participants' Explicit NOS Understandings

The qualitative analysis of the responses given to VNOS-C questionnaire implied that the majority of the participants held naive views about several NOS aspects. An absolutist view of scientific knowledge in a belief-free context that can be gained through a universal, unique scientific method involving a set of fixed stages was seen to be central in these explicit NOS understandings.

The great portion of the participants (73%) defined science as a fact based discipline demanding certain answers to questions through an exact method which has unique steps to follow with experimentation at the core. With this perspective, the participants presented experiments as a "proving" process and dismissed the possible role of personal and social factors in the generation and validation of scientific knowledge:

"Scientists seek the answers of questions about nature. They use the scientific method and make experiments about the facts. They prove their results and everyone accept the results without any discussion. Religion is personal, you can believe or not and in philosophy everyone can propose opinions" (P 11).

The difference of science from other disciplines was also seen to be based on this argument by the participants and religious, philosophical fields were labeled as disciplines which rely upon ideas and mere opinions contradictory to the definite conclusions of science that arrived by the use of facts. This idea of "proving" by experimentation and having certain answers at the end of the process was also seemed to be reflected in various aspects of the NOS understandings by the participants. The tentativeness of the scientific knowledge and the status of scientific laws, theories were among these.

A majority of the participants (80%) presented scientific knowledge and, especially scientific laws, as certain constructs which have been proved to be true many times by experiments and accepted by everyone without any doubt. In this context the tentativeness of the scientific knowledge was seen to be denied by this group of participants. Its certainty was claimed to be satisfied at the end of the process in which any socio-cultural factor do not have any role:

"Scientists perform experiments about the facts they examine and after they perform many experiments they reach certain scientific laws which are valid for everyone at everywhere. They are then proved to be true" (P2).

It should be noted that nearly all the participants used the concept "tentativeness" in their discussions but it was seemed to be emphasized mainly for scientific theories which are not "proved" yet. They defined scientific theories as immature products of science, an intermediate phase in the generation of certain scientific knowledge, and presented the development of technology as the main reason for a possible rebuilding process.

In accordance with these arguments about the tentativeness of the scientific knowledge, theories and laws, a majority of the participants (87%) asserted a hierarchical relationship between scientific theories and laws. They claimed that the scientific theories, which are unproven yet and hence unaccepted by the scientific community, become scientific laws after they are confirmed by many experiments and researches:

"Scientists have some theories and study on them. These theories should not be accepted by the community since they are not proved yet. But after they are tested with many experiments and are confirmed, they become laws which are certainly true" (P7).

The scientific laws were seen to be placed at the top of this hierarchy by the participants, as the knowledge of the facts which are certainly true in all cases. This approach was also seen to be informative for the participants' conceptions about the structure and the testing process of the theories. The idea of the confirmation of the theories by the experiments indicated that they conceived theories as some type of guesses which can

be directly tested. They seemed to not have informed views about the structure of scientific theories and their roles in research. They thought that they learn theories, even the changed or rejected ones, to see their failures and to have the chance of evaluating the current ones.

These naive views about scientific theories and lack of information about their guidance in research were also indicative for participants' conceptions about scientists as observers. It was seen that a minority of participants (17%) presented informed views about the theory-laden nature of observations, which was not surprising in the whole group, where majority of the participants portrayed science as a process of proving of the facts. The scientists were presented as blind minded researchers who are free from all the personal and cultural values/beliefs by this majority of the participants, as seen in their discussions about the dinosaur extinction controversy:

“Although two different views exposed in this controversy, I think the problem here is the time period they are talking about. It was a long time ago and we cannot be sure what happened at that time. But, when enough data is found one of them will be accepted” (P21).

The participants emphasized mainly the lack of data as a reason for such a controversy and the impossibility of being sure about an issue that happened a long time ago, but did not exhibit any understanding of the role of prior knowledge and scientific theories which influence scientists' interpretation of current evidence.

The majority of participants' (80%) understandings about the models, the structure of atom in this case, were also seen to be naive, which also presented some cues that reflected their views about the creative and imaginative NOS. The participants indicated that scientists are generally sure about the structure of atom, as they performed many experiments and gained data:

“The scientists performed some experiments with alpha particles and collect data. They performed many such experiments, corrected previous failures and after that they become sure about the structure of the atom” (P19).

Although a limited portion of the participants (20%) asserted that the views about the structure of the atom should be altered in the future with the advance of technology, the reason they proposed was seen to be based on having some additional data. The creative and imaginative aspects of NOS (in the construction process of the models and theories) were not explicitly emphasized in any of the participants' responses. The general tendency was to discuss the scientific models as constructs that represent the reality as it is. The use of creative and imaginative NOS by the great portion of the participants (70%) was seen to be limited with designing of the experiments to collect data, as a step in the process of scientific research.

The participants' discussions about the universality of the science, finally, were seen to be informative for their naive understandings about many aspects of the NOS. Nearly all the participants asserted a “universal science” understanding, which is totally free from social and cultural values, at least as an end product. Although some of the participants (23%) gave credit to the role of socio-cultural factors in the scientific enterprise, their comments were mostly related to the motivating aspect of these factors for scientists:

“A research area can be supported in some countries whereas forbidden in the others. Socio-cultural values can direct the interests of the scientists or the distribution of the funds. However, they cannot be determinant in the process of research, for the acceptance or rejection of results” (P18).

The main rationale that frequently observed in the participants' responses for the universality of science was seen to be based on the objective reality it examines. They stated that science is about the facts, which are the same everywhere, and mainly gave the sample of the free fall of a mass. It is noted that all the masses will fall down, when dropped, in the same manner on the earth wherever you are. The common failure of the participants in this context was seen to be about the discrimination between the objectivity of the phenomena that scientists examine and the science itself as a complex

process. As a result, they could not exhibit an informed understanding about science as an enterprise which is embedded in a socio-cultural milieu that impacts the NOS.

Participants' Tacit NOS Understandings

The qualitative analysis of the activity sheets prepared by the participants to demarcate science from pseudoscience implied that the majority of the participants portray a general view of science which based on the discovery of physical phenomena without any interpretation. Solely, direct observations or experimentations of "facts" without any inferences such as buoyancy and expansion of metals were seen to be viewed as doing science by them.

The activities planned by the participants were seen to be grouped into two according to their strategies for developing an understanding of demarcation of science and pseudoscience. The first group (60%) was directly focused on the comparisons between scientific knowledge claims and pseudoscientific ones. The generally used scientific knowledge claims in this group were about directly observable and sensible physical phenomena, such as the expansion of heated metals. The contrary pseudoscientific ones in these comparisons were mostly astrological claims, such as the behavioural properties of individuals related to their astrological signs. The following example should be viewed in this manner:

"Firstly the students in the class will perform an experiment about the expansion of the heated metals. They will take a piece of metal rod and measure its initial length and temperature. Then they will heat it and again measure its current length and temperature. In the last step, they will compare its initial and last length in accordance with the increase in its temperature. They will see that the scientific knowledge about the expansion of heated metals is proved by this experiment. In the second phase, the students will be asked to write their behavioural properties and date of birth on a piece of paper. Then these papers will be collected and grouped according to the dates of birth with the help of students. In the next step they will be examined to determine if the behavioural properties are directly related to the dates of birth. The students will realize that the claim of astrology for such a relation is inaccurate and pseudo" (P28).

The other sample activities planned in this first group were also seen to be very similar in their nature. The scientific units in the comparisons were based on either direct measurements or observations of objective phenomena such as the boiling of water at 100°C. However, the pseudoscientific units were astrological claims including subjective constructs such as behavioural properties which tried to be questioned with the students in the class. These activities had indicated that the participants had perceived the scientific claims as absolutely true and strictly verifiable. Objective, reproducible and directly sensible matters of facts were thought as the only scientific without any emphasis on any conceptual or theoretical entity. Such an approach was seen to strictly bound science to a narrow, naive understanding which should be a source of crucial misperceptions about scientific enterprise.

The second group (40%) was seen to be more flexible for the comparisons they planned and took the units to be examined as disciplines rather than individual knowledge claims. The general tendency was determining some criteria for demarcation of science from pseudoscience and evaluating sample cases, such as alternative medicine and acupuncture, according to these criteria in class with the students. They planned to ask students a search for possible criteria of demarcation which then intended to discuss in the class to develop a common list. With the use of such a list of criteria, either small group discussions or whole class discussions on provided sources, such as texts about various fields of inquiry or videos, were designed.

"I will ask students to search the properties of science and after they develop a list of criteria for being scientific, they will discuss them in small groups in the class. Then, these lists which will be developed in small groups will be discussed in the class as a whole and a final list of criteria will be determined. I will guide the

students in the discussions and will provide them a sample case, alternative medicine, to be examined for being scientific according to the list of criteria developed in the class... Students will realize that alternative medicine is not accepted as scientific by the whole community and does not have powerful experimental support" (P 6).

Although this approach was seemed more powerful to develop a demarcation understanding for elementary science students, the fuzziness in the criteria to be determined and the inadequacy of the portion of this group to whole were evaluated as problematic. The participants either did not label any sample criteria for demarcation or listed objectivity, universality and experimentation as determinants of science or mainly highlighted the products of the disciplines to be examined according to these criteria. Any sign of perspective about the processes which the disciplines occupied while generating knowledge claims and about their ontological and epistemological assumptions were not seen in these activity plans. So, although the activities planned by the participants in this study were grouped into two according to their strategies, the rationale in their approaches for a discipline or individual knowledge claim to be scientific were seen to be similar.

CONCLUSION

The results of the research implied that participants' explicit NOS understandings were naive especially for the aspects; (i)theory-laden nature of observations, (ii)socio-cultural embeddedness of scientific knowledge, (iii)the myth of a universal scientific method and (iv)the roles of hypothesis, theories and laws in scientific enterprise. An absolutist view of scientific knowledge in a belief-free context that can be gained through a universal, unique scientific method involving a set of fixed stages was seen to be central in participants NOS understandings. The tacit understandings emerged with the analysis of activity sheets were seen to be in accordance with these explicit ones and portray a general view of science based on discovery of physical phenomena without any interpretation. Solely, direct observations or experiences of "facts" without any inferences such as buoyancy and expansion of metals were seen to be viewed as scientific activities by a majority of the participants, which is subject to the absolute confirmation. So, the results of the research indicated that participants' tacit understandings seemed to form the basic rationale for their explicit views which should be examined further by the help of activities planned by them to have a chance of developing naive beliefs. Within such a process, the participants should be provided with explicitly discussed NOS aspects that based on the reflections of their tacit understandings. The development of tacit understandings in action would then be transferred into explicit interpretations of NOS.

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