THE INFLUENCE OF DISCIPLINES ON THE KNOWLEDGE OF SCIENCE: A STUDY OF THE NATURE OF SCIENCE

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Abstract. At least four factors affect pupils' understanding of the nature of science: teachers' specialization in different science areas (physics, chemistry, and biology), gender issues, teaching experience in elementary school environments, and the perspectives of acquiring necessary knowledge. This study is the introduction part of a research project which will be initiated soon. Four elementary science teachers participated in the study. The results reveal that participants' views of the aspects of nature of science are not solely diverged, based on their major disciplines, but there exist significant distinctions according to gender differences.

Keywords: nature of science, science education, teaching and learning

Introduction

According to science educators in public schools, particularly in the universities, the understanding of the Nature of Science (NOS) is extremely significant and crucial topic to be taught. The term "NOS" are going to be repeatedly used in the present study because this phrase cannot be avoided due to grammatical and linguistic considerations. Typically**,** the NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Furthermore, the NOS is knowledge about how scientists use and develop scientific views: how they determine the question to investigate and how they collect data and analyze their findings from the observation of scientific facts about the world around us.

The preparation of scientifically literate students is a continuing goal of science education and current reforms in science education focus on the need for students to conceptually understand science rather than knowing a breadth of scientific facts (AAAS, 1993). For instance, National Research Council has focused on this goal in their national reforms (NRC, 1996). Since the NOS is an essential topic for the students, it requires further investigation in different perspectives. In this current study, it is hypothesized that if their knowledge of the NOS are increased, in-service elementary science teachers can improve their confidence and abilities to effectively deliver science instruction at the level of national reforms.

There have been many disagreements about the true definition or meaning of the NOS among philosophers, historians, and science educators.

In general, science educators typically define the NOS as the epitemology of science, science as a way of knowing, of the values of beliefs inherent to the development of scintific knowledge. However, historians and philosophers of science do not agree with this scientific definitions because they find it too general. The issue of the existence of an objective reality as compared to phenomenal realties is a case in point.

More specifically, those disagreements have been discussed by Lederman & Abd-El-Khalick (2002), but they claimed many of the disputed issues as irrelevant to K-12 instruction. Also, they suggested that there is an acceptable level of generality regarding the NOS that can be made accessible to K-12 students and relevant to their daily lives.

Among the characteristics of the scientific enterprise corresponding to this level of generality are the following aspects: that scientific knowledge is tentative (subject to change); empirically based (based on and/or derived from observation of natural world); subjective (theory-laden), necessarily involves human inference, imagination; and creativity (involves the invention of explanations); and is socially and culturally embedded (Lederman, 1992).

Two additional aspects are the distinction between observations and inferences, and the functions of, and relationships between scientific theories and laws. Those aspects of the NOS are generally adopted by teacher educators in science and they will be emphasized in the present study. There have been some enhanced investigations that have examined how pre-service teachers could increase their conception of the NOS. Among those, many studies have been conducted about teacher preparation programs (Akindehin, 1988; Ogunniyi, 1983). As a result, these researchers have suggested two distinctive approaches: *the explicit approach,* which basically makes use of the relationships between the philosophy of science and the instruction of the NOS to improve pre-service or in-service science teachers' conceptions.

In contrast, as a second type of approach, *implicit approach* does not make use of specific attention to the NOS and implicit messages are exemplified. However, this approach assumes that every necessary knowledge of the NOS is acquired during the learning process natuarally without any explicit effort. On the other hand, there have been several studies which aimed at in-service teachers instead of pre-service teachers. Such as, Lederman (1992) claimed that research regarding improving in-service elementary science teachers' conceptions of the NOS was influenced by two assumptions. Firstly, teachers' conceptions of the NOS directly affect their classroom practices. Secondly, teachers' conceptions of the NOS have a cognitive impact on students' conceptions. Although Lederman (1992) made this assertion, he did not explicitly test these two assumptions. Then these assumptions were later explored in classroom science, the research that resulted from testing the first assumption showed that the relationship between teachers' conceptions of the NOS and their classroom practice was more complicated than they originally assumed. Based on the previous research conducted on pre-service or in-service teachers' understanding the NOS, it is clear that teachers definitely cannot teach what they do not understand (Akindehin, 1988).

In order to be able to instruct the NOS to their students, teachers should possess adequate knowledge of scientific enterprise. Studies on the conveying of teachers' conceptions into classroom practices mainly support the idea that, even though teachers' conceptions of the NOS can be considered as an important condition, these conceptions are not sufficient (Lederman, 1992). It has been shown that elementary pre-service science teachers do not generally have acceptable conceptions of the NOS (e.g., Lederman, 1992). Even those interventions attempting to teach the NOS have proven difficult and did not sufficiently help pre-service teachers learn and retain appropriate conceptions (Akerson et al., 2000). The prospective or present science teachers' incomplete, flawed, and non-efficient understanding of the concepts of the NOS is an unfortunate problem that, in turn, leaves our children as scientific illiterate individuals. Thus, some improvements or solutions will be suggested here and then they must be considered for applying to the science teacher preparation programs to prevail over this vital problem.

Schwartz & Lederman (2002) conducted a case study of two science teachers in terms of how they learn and address the NOS in their classroom. It was one of the recent studies, and an influential one, that had been done with only two science teachers selected from the group of participants because of their different levels of the NOS understanding and difference science background knowledge and science teaching experience. First, the participants participated in series of activities, embedded in specific subject matter in nature, to teach about aspects of the NOS. Then, they joined in a science research internship associated with NOS instruction. Next, they were observed while they were teaching science in their science classroom environments. The researchers, afterward, collected the participants' NOS knowledge, instructional plans through questionnaire, interviews, lesson plans, and classroom observations. In conclusion, they recommended that there should be some interaction between science educators (as researchers) and participants in order to increase the longevity of teaching the aspects of the NOS in teacher education programs. Because with the help of NOS courses and faculty members' continous effort to include the aspects of the NOS (implicitily or explicitly) can help students to retain the NOS.

Physics educators and major science education organizations are increasingly supporting the preparation of scientifically literate students (e.g., AAAS, 1993). In 1996, National Research Council (1996) expressed that the goal of national science education standards is to "create a vision for the scientifically literate person and … and will serve to guide the science education system toward its goal of scientifically literate citizenry in productive and socially responsible ways". In spite of that, scientifically literate citizen is supposed to possess knowledge of scientific theory, laws, principle, concept, technology and relationship to society. Moreover, this person should reveal the understanding of the NOS.

Finally, according to Gerald Holton (DeBoer, 1991) a scientifically literate person is described as having two facets which are: "(1) some content understanding-knowing and keeping up with at least one chosen, even though small, part of science, and (2) some understanding of application-trying to keep in touch with a variety of other scientific developments."

According to Lederman's (1992) review of literature of research on the NOS, various different groups of students, especially high school students, have been studied regarding their conceptions and understanding of the NOS almost every year since 1960. Yet, the results of these fifty years of investigations advocated the idea that science teachers do not possess adequate conceptions of the NOS and irrespective of the instrument used to assess understanding (Lederman, 1992). Although science teachers are provided with the detail instructions of curriculum, they often do not posses adequate knowledge and understanding of the NOS. Therefore, the study of pre-service and in-service teachers have been drawn more attention.

Kleinman (1965) conducted a study of teachers' questioning. He observed elementary science teachers three times each week during a semester. He concluded that when student ability was held constant, it was noted that teachers who asked more critical thinking questions impart a better understanding of the NOS to both Grade 7 and Grade 8 males and females than teachers who asked fewer questions of this type.

In a similar study, Behnke (1961) focused on the comparing 200 biology teachers and 421 physical science teachers' understanding of the NOS, science and society, scientist and society, and the teaching of science. He found no significant difference between those two groups of teachers.

Billeh & Hasan (1975) investigated whether those factors cause any increase in the teachers' understanding of the NOS by science 186 secondary teachers in Jordan. The teachers were included from various disciplines: physics, biology, chemistry, and physical science. They used the Nature of Science Test (NOST) to assess understanding of the NOS. Discenna & Howse[1)] assessed a research on the NOS at the elementary level in the 1990s.

They analyzed reflection essays of twenty-two American pre-service elementary science teachers, which took place throughout 15 weeks of biology or physics course. They investigated problem solving and inquiry-based activities and concluded that these views of science were not changed during the semester.

Overall, importance of investigating the aspects of and more importantly adequate knowledge of them have been proven an important research area since mid 20th century. The term “scientific literacy” was born because of the NOS. Even though conception of the NOS was studied for a long time, still, it is necessary to investigate from different perspective as Schwartz & Lederman (2002) suggested NOS aspects should be learned starting in elementary school environment therefore prospective science teachers should possess adequate knowledge of the NOS. Recent NOS studies invetigates both pre-service and in-service teachers’ understanding of the NOS aspects and seek possibles solutions to increase the knowledge. This study serves for this purpose as one of its goals.

Purpose of the study

The purpose of this study is to investigate the extent of science teachers’ understanding of NOS. It will also compare this knowledge with the length of their science teaching experience and the braches of science they studied in teacher preparation colleges, e.g. physics, chemistry, or biology.

Describing how experienced teachers’ knowledge of the NOS will help to reform instruction and that will provide examples for use in the science methods courses taught in science teacher preparation programs. It is essential to investigate whether teachers improve their knowledge of the NOS at the end of their college education.

This is important because many science teachers do not know as much as they should about the NOS to become effective science teachers. For this reason, educators and faculty members have to find possible solutions to get to the bottom of this problem in teacher preparation institutions. If the science teachers' knowledge and understanding of the NOS is not at the desired level, then the teacher preparation programs should be looked over and must, if necessary, be revised accordingly to resolve the deficiencies of pre-service science teachers.

Specifically, the present study seeks to investigate and propose possible solutions to improve science teachers' knowledge of NOS. The research questions that will guide the present study are: (1) what are the key factors that cause conceptions of the NOS among elementary science teachers at an US elementary school in the Midwest who specialize in diverse science areas; (2) what is the relationship between the length of their teaching experience and their understanding of NOS among elementary science teachers.

Participants

This study was purposefully designed as a small part of a big research and the data collection of the second part is still continuing. It was conducted in a Midwestern Public School District with four primary elementary science teachers. The participants selected for the study were selected through a careful consideration among the elementary science teachers in the district. In the selection process, we purposefully decided to have science teachers with different disciplines and also different genders for the sake of the research questions. Specifically, four specific criteria, adapted from the participant selection process of Akerson et al. (2000), were as follows: (1) two groups of sample that consists of two women science teachers and two men science teachers; (2) one of the participants in each gender group should be at least five years or more teaching experience in his or her discipline in the same district; (3) science was taught as a separate subject; and (4) teachers hold as least a bachelor degree in science.

Pseudonym is used in order not to reveal the identities of teacher participants. Four in-service elementary science teachers, two females and two males, participated in the study. Harry and Alex were male participants with Harry holding a bachelor of physics degree with two years teaching experience in science and Alex holding a bachelor of chemistry degree with five years teaching experience. Kim and Berry were female participants and Kim had a bachelor degree in biology with 30 years teaching experience. Berry holds a Bachelor degree in Physics with two years teaching experience. The reason for selecting both types of gender was to compare the differences of each gender's conceptual understanding of the Nature of Science. Similarly, it is also desired to identify teachers' conceptualizations of the concepts of NOS in relationship with length of their teaching experience and specialization of different disciplines.

Data collection

Main data source of the current study was teacher interviews. All four interviews were carried out in the school where the participants were teaching at the time of study. Each interview took place approximately one hour which included semi-structured set of interview questions. Interview questions consist of both multiple choice and open-ended items with follow-up discussion questions. All interviews were audio taped and transcribed for analysis by the authors later.

Teacher interview protocol was developed among three different NOS questionnaires. Particularly, an analysis of three different types of interviews questions used as a research instrument in the questionnaire were as follows: (1) Nature of Science Survey (NOSS) questions which was first proposed by Kimball (1967); (2) Nature of Science Test (NOST) which was suggested by Billeh & Hasan (1975); (3) Views of Nature of Science- Elementary School version (VNOS-E) by Lederman et al. (2001) questions were administered one time during the academic school year.

Sample questions of NOSS and NOST and full version of VNOS-E are included in appendix section (Appendix). Full version of NOSS and NOST can be found in above original papers of Kimball (1967) and Billeh & Hasan (1975).

Results and discussion

Table 1. *Analysis of the aspects of NOS among the elementary school teachers participated in the study*

NOS aspect	Harry	Alex	Kim	Berry
tentativeness	+++	++	++	+++
creativity	++-	++	+	++-
emperical	++	+-	+	++
observation	++	+	+	++-

\+ :provide a definition or affirmative response
++ :provide a description in own words, examples from class
+++ :provide a description in own words and additional supporting examples
\- :inconsistent statement or inappropriate example given

Table 1 indicates the findings obtained from VNOS-E survey questions and presents the results of the five aspects of NOS through two NOS assessments (VNOS-E, interviews) administered during academic semester. Data analysis resulted in rich understanding of aspects of the NOS for both Harry and Berry. On the other hand, it showed that both Alex and Kim possess inadequate of understanding aspects of the NOS. The results of data analysis for all participants are discussed separately later.

Both Harry and Berry presented an outstanding understanding of the NOS aspects. Especially, at the aspects of tentativeness and subjectivity that are two most important aspects, their understanding exceeds average level because they defined tentativeness as dynamic property of science and subjectivity as science is affected by scientists' own opinion. Above descriptions are almost the same descriptions of tentativeness and subjectivity of science as scientifically. They also provided various examples from their teaching and research experiences for example scientific advances lead to technological advances and new technology assists scientific advances. However, they didn't possess same degree of knowledge of the aspects of creativity, empirical, observation/inference. For example, they didn't claim that creativity as well as observation didn't play an important role in the progress of science, which opposes teru scientific explanations. In conclusion, their overall understanding of the seven aspects of the NOS was intermediate but satisfied the desired levels.

Participant science teachers' responses in Table 1 also pointed out that although two of them, Alex and Kim, didn't possess expected degrees of knowledge (which is: +++), they indicated based knowledge and understanding aspects of the NOS with only providing adequate definitions. In addition, according to table1, all of them indicated they have satisfactory understanding and knowledge of the NOS. On the other hand, on some aspects, tentativeness andsubjectivity, Harry and Alex excelled and showed knowledge and understanding of the NOS above average level. The reason for why they achieved this level may be related to which disciplines (both physics) they mostly studied in college because students of physics usually show high degree of analytical thinking than other students. Scientific reasoning reflects one's knowledge and understanding of the NOS properties at some level intentionally or unintentionally. Finally, with this finding it can be stated that at some level, length of teaching experience affect knowledge of the NOS at some degree because Berry has 30 years of teaching experience and Harry has only two.

The first major finding in the study was that science teaching experience was not importantly related to teachers' understanding of science based on the NOST (Nature of Science Test). That was actually one of the claimed hypotheses at the beginning. It stated that the more elementary teacher holds teaching experience, the less they possess understanding of the NOS concepts. This finding cannot be generalized because of the sample size in the current study. However, the conclusion had agreement with the findings of the studies (Billeh & Hasan (1975); Kimball (1967); Lavach (1969)), where quantitative and statistical studies were conducted to investigate elementary in-service science teachers' conceptual understanding of the NOS.

A second major outcome was identified as academic status and teaching experience of participants' disciplines (physics, chemistry, and biology) were related with each other according to their scores on the NOST. It is also shown that they shared similar results in terms of the university graduation, educational qualification, teaching experience and previous in-service teaching. Taking these facts into account, it is claimed that there were no significant relations between teachers' gain scores on NOST and their educational qualification according to the current study. Also, this finding was consistent with Billeh & Hasan's study (1975). Therefore, it is convenient, regarding findings of this study, to state that the pre-service training had been equally effective with both groups of science teachers.

Another finding of this study was that the teachers' scores of NOST questions are significantly related to the subject they teach. Hence, it can be concluded, without generalizing, that no differences in concepts can be found corresponding to the science disciplines they studied in college. This finding had agreement with the conclusion of Behnke's study (1961).

According to NOSS (Nature of Science Survey), it was discovered that almost all of participants have shown understanding of what a scientific theory is, what the difference between scientific theory and law is, except the 30 years experienced teacher, Kim. This finding may imply that science teachers start to forget major concepts of NOS as they teach science without including the NOS aspects in their teaching plans as time passes. This apparent lack of change in understanding of the NOS with time and experience is the same findings as Kimball (1967) found in his study. Indeed, this participant did even described what a law or theory means:

> "Yes. I think there is a difference between theory and law. However, honestly I do not know difference now. As far as I know, theory is a frame for certain phenomena. Law is just one of the rules in this frame." (Her answer to question #3 in NOSS: Is there a difference between scientific law and theory?)

In other words, this participant seemed to believe that theory is more structured than law and this is not expected from an experienced science teacher. Moreover, half of the participants showed that they truly knew tentativeness aspect of the NOS. Especially Berry seemed to have a good understanding of it:

> "Theories do change only laws don't change. You only can find the laws through theories. They are scientific steps… That is how they find the scientific laws." (NOSS question #1)

Another interviewee, Harry, noted that "Yes, they (theories) do change… Scientists keep adding to the theories so that they become better as discoveries are made" (Harry, NOSS #1). Nevertheless, as evident in this quotations, most participants believed that some theories will eventually be proven and change into laws, in which case they are not liable to change. This result is nonetheless consistent with previous research (Behnke, 1961).

Consistent with research in science teachers' views of the NOS (e.g., Aguirere et al, 1990; Carey & Stauss, 1968), participanting science teachers held naïve views of many of the investigated aspects of the NOS at the end of the study. However, as indicated in table 1, Harry and Berry did prove some new findings of the NOS concepts learning because they possess high level of knowledge of tentativeness and subjectivity of the NOS. Overall, they showed that science teachers are able to learn NOS concepts if they are prepared adequate in teacher preparation programs.

Participants' views also lacked consistency; features which were expected given the teachers are often not provided with opportunities to reflect on and clarify their views of the NOS (Abd-El-Khalick, 1998). Moreover, the participants' views of the target aspects of the NOS were not significantly different. For the cases of Alex and Kim, they showed similar understandings of the NOS aspects. They did possess adquate knowledge of tentativeness and creattive aspects of the NOS but they didn't have enough understanding of empirical and observational aspects.

If we evaluate them individually, Harry demonstrated that he helda high interest but some naïve views of the NOS concepts. On the other hand, Berry showed similar pattern but with appropiate examples which is used to describe aspects. Alex showed low interest, many irrelavant views and largely very low level of understanding of the NOS with no examples. Similarly, Kim had a low interest, invalid views, some weakness and confusion. She wasn't able to elaborate and explain aspects of the NOS based on her background knowledge and experience, either.

The results of this study were nevertheless compatible with previous studies conducted on alternative conceptions (Akerson et al, 2000) and promoted to illustrate the cohesive conceptions with which learners persist their own views. Nevertheless, participants' views of NOS have been constructed over years of elementary education and teaching experience they have gathered while teaching science. It is unlikely that elementary science teachers would achieve true knowledge and understanding of the NOS in the process of teaching or college education unless it is offered in an elementary science method course in the teacher preparation program. However, investing more time to concentrate on the NOS in method courses may not be realistic. This is particularly so unfeasible that there are only few science method courses in teacher preparation program. Consequently, in order to improve science teachers understanding of NOS, it is strongly recommended that the number of hours dedicated to it, in the science method course in science teacher preparation programs, should be increased.

In addition to that recommendation, there is another approach, which can be carried out in the science method courses. Participants in the current study were not informed about inadequacies of their views of the NOS. They were not offered any NOS instruction materials, either. In other words, they did not experience any cognitive dissonance regarding their NOS views, and so correcting their misconceptions of the NOS might be easily accomplished.

Therefore, when conducting a study on science teachers' conceptions of the NOS, it would be very constructive to set up NOS instruction during investigation and devote it mostly to conceptual changing from misconceptions of NOS the participants possess.

Thus, explicit reflective instruction about NOS integrated within a complete conceptual change approach (Hewson & Hewson, 1983) might be very effective and a useful tool to enhance pre-service elementary teachers' NOS views.

As a final remark, findings of this study strongly disagree with the idea of overstressing the NOS instruction, best undertaken in the teacher preparation institutions. On the other hand, the NOS instruction is not covered by the curricula of the traditional science content courses offered at these institutions. Reforms in science education agenda at the college level seminar course seems to be capable of enhancing future science instructors' views of the NOS, teaching in both elementary and secondary level classrooms. Consequently, aspects of the NOS should be emphasized both NOS courses and other science courses such as freshman physics, chemistry, and biology in college in order to overview them at the beginning of the semesters. By achieving that, pre-service science teacher will be able to retain any knowledge they learned in college so will be ready for teaching science courses afterwards. In the same token, at elementary and secondary schools, it is suggested that every science teacher should spend at least a week to go over the NOS aspects and review them to remind himself/herself and students what it is. We could achive our ultimate goal of creating science literate individuals in all nations.

APPENDIX

Sample NOST items (Kimball, 1967)

Scientists use classifications in science to:

(a) explain scientific observations.

(b) organize scientific observations.

(c) predict scientific observations.

(d) favor scientific observations.

Which statement best describes scientific models?

(a) models faithfully describe and represent natural phenomena.

(b) models illustrate relations among phenomena.

(c) models simplify natural phenomena.

(d) models represent patterns of relations inherent in nature.

Sample NOSS items (Billeh & Hasan, 1974)

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories do change, explain why we bother to teach scientific theories. Defend your answer with examples.

2. Is there a difference between scientific law and scientific theory? Explain.

Views of Nature of Science Elementary School Version (VNOS-E) items
(Lederman et al., 2001)

1. What is science?
2. (a) What are some of the other subjects you are learning?
   (b) How is science different from these other subjects?
3. Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?
4. (a) How do scientists know that dinosaurs once lived on the earth?
   (b) How sure are scientists about the way dinosaurs looked? Why?
5. A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists all have the same facts about dinosaurs, then why do you think they disagree about this
6. TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help them make these pictures. How sure do you think the weather people are about these pictures? Why?
7. (a) Do you think scientists use their imaginations when they do their work?
Yes No
(b) If **No**, explain why?
(c) If **Yes**, then when do you think they use their imaginations?

NOTES

1. Discenna, P. & Howse, J. (1998). Biology and physics students' beliefs about science and science learning in non-traditional classrooms. Paper presented at the Annual Meeting of the American Educational Research Association (AERA), San Diego.

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