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# WHAT ARE THE EFFECTS OF TEACHING EXPERIENCE ON IN-SERVICE ELEMENTARY SCIENCE TEACHERS' CONCEPTIONS OF THE NATURE OF SCIENCE?"

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## Abstract

This study investigates relationships between understanding of nature of science and four key factors elementary science teachers possess, which are: (1) Their specializations in different science areas (Physics, chemistry, and biology), (2) Gender issues, (3) How long they have been teaching in elementary school environments, (4) Their perspective and suggestions to acquiring necessary knowledge and understanding of nature of science. This study is also a first part of a big research project. Four elementary science teachers participated in the study. The results showed that participants' views of the target aspects of nature of science were not significantly different according to their major disciplines (Physics, Chemistry, and Biology) but there were some significant differences according to their gender differences.

## 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 data: how they

determine the question to investigate and how they collect the 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, my hypothesis is that with the increased knowledge of in-service elementary science teachers will improve their confidence and abilities to effectively deliver science instruction that is 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. 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 and Abd-El-Khalick (1998), 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. 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 have 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 make 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.

On the other hand, there have been several studies which aimed at in-service teachers instead of pre-service teacher. 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. When 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 assumed originally.

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 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, Abd-El-Khalick, & Lederman, 2000). The prospective or present science teachers' incomplete and flawed non-efficient understanding of the concepts of the NOS is an unfortunate problem that, in turn, leaves our children effectively scientific illiterates. 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 and 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 must be interaction between the researchers and participants in order to increase the longevity of teaching the NOS in teacher education programs.

Science educators and major science education organizations are increasingly supporting the preparation of scientifically literate students (e.g. AAAS, 1990). In 1992, National Research Council (1995) 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 narrow area contact-knowing and keeping up with at least one chosen, even though small, part of science, and (2) range-contact-trying to keep in touch with a variety of other scientific developments" (p.421).

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 curricula in detail instructions, they do not always present desired results. Therefore, the study of pre-service and in-service teachers have been drawn more attention.
In the next paragraph, the literature in the aspects of in-service science teachers' conceptions of the NOS and efforts to escalate the knowledge of in-service science teachers' conceptions of the NOS are reviewed.

In some studies, for example that conducted by Carey and Stauss (1968), the main focus was those science teachers should remove from the emphasis on factual learning-rote memorization and transfer their approach to “conceptual learning” teaching techniques. These researches have studied prospective secondary science teachers being prepared at the University of Georgia. The faculty at this institute possesses a philosophy of science that exhibits an understanding of the NOS as accepted by the science educators and scientists. In conclusion, Carey and Strauss found out that many pre-service secondary science teachers did not possess adequate concepts of the NOS to teach according to modern trends and philosophies.

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 and Hasan (1975) investigated if those factors affect any increase in the 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 and Howse (1998) 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.

Lederman (1992) discussed in his study regarding about improving teachers’ conceptions of the NOS was guided by two assumptions. The first one was that teachers’ conceptions of NOS directly transfer into their classroom practice, and the other one was that teachers’ conceptions of NOS directly affect students’ conceptions of NOS. Such

assumptions, mentioned above, were not explicitly tested but this was the focus of the research.

## 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. This study collected data documenting teacher conceptions of the NOS. It is essential to investigate if teachers improve their knowledge over time because if science teachers do not know as much about the NOS as they should to be effective science teachers. If so, it could be a failure to send children to the students to them. In other words, educators and faculty members have to find possible solutions to get to the bottom of this problem in teacher preparation institutions.

The current study provides information about the NOS, teacher's understanding of various aspects of the NOS, and hopefully will gain information to make some useful comments on how science teachers' knowledge of the NOS can be improved. Describing how experienced teachers' knowledge of the NOS will help to inform instruction and that will provide examples for use in the science methods courses taught to pre-service teachers. 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 the science teacher.

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 similarities and differences of the conceptions of the NOS among elementary science teachers at public elementary schools in the Midwest who specialize in different science areas (Physics, Chemistry, and Biology)?
2. To what extend gender differences affect the conceptual understanding of the NOS?

3. What is the relationship between the length of their teaching experience and their understanding of NOS among elementary science teachers?
4. What important recommendations can be made to elementary science teachers to increase their knowledge of NOS?

## 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, four specific criteria, adapted from the participant selection process of Akerson et al. (2000), which 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 included multiple choice and open-ended questions with discussion part. 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 (1967-68); (2) Nature of Science Test (NOST) which was suggested by Billeh and Hasan (1974); (3) Views of Nature of Science- Elementary School version (V-NOS-E) by Lederman et al. (2001) questions were administered one time during the academic school year.

## Results and Discussions

*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 | ++- | ++ | + | ++- |
| Subjectivity | +++ | +- | + | +++ |
| Empirical | ++ | + | +- | ++ |
| Observation/ Inference | ++ | + | + | ++- |
| Comments about Level of NOS Understanding | High interest; some naïve views | Low interest; many irrelevant views, lack of understanding of NOS No examples. | Low interest; invalid views, recognized weakness and confusion; no elaboration his pre. experience. | High interest appropriate exs explained meanigs |

Key:
+ :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 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 Alex and Kim both lack of understanding aspects of the NOS according to Table 1. 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. They also provided various examples from their teaching and research experiences. However, they possessed some weaknesses included the aspects creativity, empirical, observation/inference. In conclusion, their overall understanding of the seven aspects of the NOS was intermediate but satisfied the desired levels.

The first major finding in the study was that science teaching experience was not importantly related to teachers' gain 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 of Billeh and Hasan (1974), Kimball's (1968) and Lavach's (1969), which was a quantitative and statistical study 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 (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, we claim 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 and Hasan's study (1974). 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.

Final result of the 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 due they differs in terms of the science subjects they had in university. This finding had agreement with the conclusion of Behnke's study (1961).

According to NOSS (Nature of Science Survey), we found out that almost all of participants have shown understanding of what a scientific theory is, what the difference the difference between scientific theory and law is except the 30 years experienced teacher, Kim. This finding expresses that science teachers start to forget major concepts of NOS as time goes by. 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 now even know 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 which was not expected from a 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)

Many interviewees 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), participants science teachers held naïve views of many of the

investigated aspects of the NOS at the end of the study. 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, participants' views of the target aspects of the NOS were not significantly different.

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 learner 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, I strongly recommend 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 useful tool to enhance preservice elementary teachers' NOS views.

As a final point, I 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.

# Appendix

Sample NOST items (multiple choice)

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 (open-ended)

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.

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