The analysis of how to improve student understanding of the nature of science: A role of teacher

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Introduction

The overall purpose of this analysis is to clarify whether or not teachers' conceptions of the nature of science influence their instructional planning and classroom practices based on several significant research studies which have recently been published. Science process skills provide a basis in the major science disciplines for children to understand their world and the natural phenomena in it (National Research Council, 1996). Understanding the nature of science (NOS) is a central component of scientific literacy (NSTA, 1982). Many argue that the scientifically literate individual is one who holds an in-depth understanding of scientific facts, concepts, and theories in addition to a clear understanding of the nature of science (Lederman, 1986). Improving the scientific literacy of the public is one of the most important challenges facing science educators today. This means assisting all to have a sufficient conception of the NOS. Some argue that it is the distinguishing quality of a scientifically literate individual (Klopfer, 1969; Larson, 2000; Lederman & Zeidler, 1987; Meichtry, 1999). Despite this goal and efforts to achieve it, research has shown that both students and teachers are generally unable to articulate an adequate understanding of the NOS (Bell et al., 2000).

The NOS typically has been used to refer to the epistemology of science, i.e., science as a way of knowing and the values inherent in the development of scientific knowledge (Lederman, 1992). In his paper, an adequate understanding of the nature of scientific knowledge is defined with the following features: (1) tentative (subject to change), (2) empirical (based on/derived from observations of the natural world), (3) theory laden (subjectivity of knowledge), (4) partly the product of human inference, imagination, and creativity, (5) and socially and culturally embedded. Additionally, researchers argue the importance for (6) the functions and relationships between observations and inferences, and (7) the differences between scientific theories and laws (Abd-El-Khalick et al., 1998; Akerson et al., 2000; Bell et al., 2000; Buss, et al., 2002; Dickinson et al., 2000; Lederman & Zeidler, 1987; Lederman & O'Malley, 1990; Lederman, 1999; Meichtry, 1999).

Background

Until late 1900, research focused on student understanding of the nature of science (NOS). After realizing its importance for teachers, many studies have focused on improving teacher conceptions of the NOS for example many argue that to teach science as inquiry and to do it successfully, teachers must understand the NOS (Duschl , 1987). The National Science Education Standards [NSES] (NRC, 1996) reinforce this view and have set standards for teacher knowledge of science and science teaching. The NSES state:

> All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its

> central role in science, and how to use the skills and processes of scientific inquiry. (p.59)

Many have argued that the teacher has a critical role for achieving any curriculum reform (Brown & Clarke, 1960). Such a role has been enlightened and places in context: "teacher understandings, interests, attitudes, and classroom activities influence student learning to a large extent" (Abd-E-Khalick & Lederman, 2000, p. 669). Attempts to improve teacher conceptions of the NOS through inclusion of history and philosophy of science content in teacher education programs have been a challenge since the early 1960s (Gill, 1977; Harms & Yager, 1981; Kimbal, 1967; King, 1991; Mathews, 1990).

Helping teachers to internalize the instructional importance of the NOS increases their attention level to the basic ingredients which determines science (Ogunniyi, 1982; & Akindehin, 1988). There are two assumptions to help students develop adequate understanding of the NOS. The first assumption is that teachers' conceptions of NOS do not affect the instructional strategies they use. The second assumption advocates the idea that teacher conceptions of the NOS do directly transfer into their classroom teaching practices (Ramsey & Howe, 1969; Nott & Wellington, 1996; & Lederman, 1992). The evidence from the literature indicates studies of both pre-service and in-service teachers' beliefs regarding the NOS and their classroom practices as follows.

Research indicate that teacher conceptions of NOS do not affect their instructional strategies that they use

Researchers have indicated that the relationship between teachers' conceptions of the NOS and their classroom practices is more complex than originally assumed. In fact, the relationship between teachers' conceptions and their actual classroom practices is far from being direct or simple (Bell et al., 2000; Lederman & Zeidler, 1987; Abd-El-Khalick et al., 1998; Lederman, 1999; Lederman, 1986; Abd-El-Khalick & Lederman, 2000). Several factors have been shown to mediate and constrain the translation of conceptions concerning NOS and teaching practice. These factors are:

- Pressure to cover the content will appropriate classroom management and organizational principles.

- Concerns for student abilities and motivation
- Curriculum constrains
- Administrative policies
- Institutional constraints
- Teaching experience
- Discomfort with an adequate understanding of NOS
- Lack of recourses and experiences for assessing understanding of NOS (Dushl & Wright, 1989; Bell et al., 2000; Brickhouse & Bodner, 1992; Jones & Beeth, 1995; Abd-El-Khalick et al., 1998).

Lederman and Zeidler (1987) state that teachers' classroom behaviors are not directly influenced by their conceptions of the NOS. In addition, their study showed that many of the classroom variables used for teacher comparisons are significantly related to changes in students' conceptions of the NOS. The results of this investigation indicate that merely possessing valid conceptions of the NOS do not necessarily result in the performance of teaching behaviors which are related to improved student conceptions.

Duschl and Wright (1989) focused on how science teachers' conceptions, beliefs, and judgments affect their pedagogical decisions. They observed and interviewed 13 science teachers in a large urban high school. The results clearly indicated that there was no relationship between teachers' understandings of the NOS and their classroom practices.

In 1992, Brickhouse and Bodner focused on the teaching of science and particular difficulties found in the science classroom. One of the outcomes of their study was that student reactions are an important restriction on the teacher's behaviors. The study showed that teachers have conflicts between what they believe is desirable and what is possible within the limitations of their preparation and the institutions in which they work. Also, teachers struggle about how they prepare their curricula based on their beliefs about informal science or what they face with some institutional constrains in the classroom.

Dickinson et al. (2000) reached interesting outcomes as a result of their study. Firstly, during interviews pre-service teachers did not speak of the role of evidence as being important nor did it affect how science differed in relationship to other disciplines. Instead, they spoke about science being a study of things, while art was subjective, or a way to "prove" something. Science was described things done to prove theories. In contrast, art was seen a way to show a picture of the world. Many pre-service science teachers do not consider the differences between theories and laws. They often believe in a hierarchical relationship between theories and laws (Palmquist & Finley, 1997; Lederman & O'Malley, 1990; Akerson et al., 2000). Others see theory as an unproven, untested, invalidated hypothesis. They report that laws arise from a theory that has been validated, tested, and documented is a truth. Additionally, their research indicates that pre-service teachers frequently fail to recognize that scientists use their imaginations and creativity throughout scientific investigations, especially when interpreting data. Instead many respond that "a scientist only uses imagination in collecting data…But there is no creativity after data collection because the scientist has to be objective" (Dickinson et al., 2000, p. 12). Another interesting point is that many pre-service teachers believe that there is "a single scientific method" (Palmquist & Finley, 1997): "science is an academic discipline that requires the use of methods to ensure it is without bias" (Dickinson et al., 2000, p. 13). However, most of them noted that their varying backgrounds, their theoretical commitments, and their personal views did influence the way they interpreted data (Akerson et al., 2000): "scientists probably interpret the experiments and data differently, or they may have their own pre-determined theories that cause them to view the data in other ways" (Dickinson et al., 2000, p. 16).

According to Bell et al. (2000), teachers' conceptions of the NOS do not necessarily translate into needed classroom practices. Their results show that often participants only verbalize the importance of teaching NOS. However, their instructional objectives and assessment practices were not formally included or related to the NOS objectives.

Research indicate that teacher conceptions of NOS does affect instructional strategies that they use

Science teachers need to recognize importance of NOS and how it relates to science teaching if they are to help students completely understand the content and underlying philosophy of science (Palmquist & Finley, 1997). This is important because science teachers should decide how to teach the scientific information and how that information became known and related to a particular view of the NOS.

Lederman (1992) analyzed the interactions between teachers' understandings of NOS, their classroom practices, their actual curriculum structure, and how they all impact student understanding. Similar analyses were examined by Larson (2000) with chemistry classroom teachers. He tried to determine: "do teachers' conceptions of NOS influence their classroom behaviors and the classroom environment? Do teacher conceptions of NOS directly influence the perspective of their students regarding the NOS? What influences do other contextual factors have upon students' perspectives of NOS?" (p.14). After interviews with the students, Larson found that 75 to 81 % of the students had identical opinions with their teachers about the nature of scientific knowledge. She reported that teachers' perspectives concerning the NOS influence both their classroom practices and the classroom environment. She reported direct and positive influences of teacher conceptions upon the students' conceptions of NOS.

Brickhouse (1990) examined the possible link between teachers' views of the growth of scientific knowledge and the methods they use to help students construct knowledge of science. As a result of her study, classroom practices of two out of three teachers were associated with their personal views and philosophies; whereas a third teacher's classroom practices were not affected at all with their beliefs. She explained that teachers' views about science have an effect on both explicit lessons about NOS and on the stated curriculum concerning NOS. In other words, the teachers' understandings of what science is and how students learn science are formed from use of specific instructional strategies.

Gallagher (1991) qualitatively analyzed experienced secondary teachers' classroom practices. The results indicate that the teachers' conceptions about the NOS affect their classroom practices. Similarly, Buss et al. (2002) found that the instructional practices of experienced teachers expressed views of the NOS that are related to their personal conceptions.

Recently many teacher education programs have focused on helping pre-service teachers to understand NOS. This assumption is that teacher conceptions about the NOS directly translate into their teaching practices (Ochanji, 2003).

Palmquist and Finley (1997) found that the pre-service teachers' views of science mostly matched their teaching methods. The views concerning theory, scientists, and science that were observed in their teaching were fairly contemporary. This supports what Brickhouse (1990) found in her case study that teachers' views of NOS affect what they do in the classroom.

If academic or research interests in teaching for conceptual change are going to have an impact on science teaching, it is clear that the ideas must first be accepted and adopted by those people already established in the profession, such as science teachers, science supervisors, science educators, and administrators (Jones & Beeth, 1995).

Implications of desired teacher preparation and their instructional decisions designed to improve student views of NOS

This paper explored the teacher role to improve student understanding of NOS. I have taken the position that teacher understanding of the NOS affects their classroom practices and curriculum decisions as well as their student understanding of NOS.

Traditional science programs that emphasize only the factual content of science do not promote an understanding of NOS. For this reason; both the scientists and science teachers generally have traditional beliefs about NOS (Akindehin, 1988; Palmquist & Finley, 1997; Pomeroy, 1993). However, as stated in The National Science Education Standards [NSES] (NRC, 1996) teacher knowledge of both science and science teaching are needed:

> All teachers of science must have a strong, broad base of scientific knowledge extensive enough for them to understand the nature of scientific inquiry, its central role in science, and how to use the skills and processes of scientific inquiry. (p.59)

NOS is best taught to students early in their academic careers (NSTA, 1982; Lederman & O'Malley, 1990). This is based on the assumption that students are unable to truly understand scientific laws, theories, principles unless they first have a sufficient understanding of the values, assumptions, and processes inherent in the development of scientific knowledge (Lederman & O'Malley, 1990; Abd-El-Khalick et al., 1998).

Palmquist and Finley (1997) argue that pre-service science teachers have a mixed view of the NOS. They conclude that teachers need the chance to discuss their views of science and of science teaching. Haidar (1999, p.187) indicates that "pre-service and in-service teachers' views are neither clearly traditional nor clearly constructivist.

They have a mixed view about the NOS." Therefore, during the undergraduate education, pre-service teachers should be provided a more concrete context for learning how to teach and learning about the NOS. The course goals should be to help pre-service teachers develop a variety of methods for teaching science, constructive attitudes toward teaching science, a deeper understanding of some science content areas as emphasized in the national Benchmarks (Dickinson et al., 2000). If pre-service science teachers strongly internalize the significance of teaching as a certain outcome, such an outcome would necessarily become part of their instructional objectives and assessment practices (Bell et al., 2000; Palmquist & Finley, 1997; Lederman & O'Malley, 1990). In Brickhouse's (1990) study of the beliefs of three practicing teachers' about NOS and their relationship to their actual classroom practices, she found that their views became more contemporary after the science methods sequence and student teaching.

Teachers construct knowledge about science, their students, and the science classroom during their teacher-education courses. However, pre-service teachers construct most of their pedagogical content knowledge during actual classroom practices (Brickhouse & Bodner, 1992).

More balanced treatments of the philosophy of science; specifically targeted to relate to specific teaching behaviors are needed in pre-service and in-service science teacher education programs if we are to successfully promote more adequate conceptions of NOS among pre-service science teachers (Lederman & Zeidler, 1987). Palmquist and Finley (1997) argue that "teachers could make better curricular decisions with respect to the NOS if they knew how different classroom activities portray the features that concerning the NOS (p.610).

It is clear that implementation of conceptual change into the practices of teachers will not be easy since dramatic changes in traditional pedagogy are required along with their acceptance of conceptual change instruction by those outside the science classroom. This requires an educated community ready for change and varied learning environment (Jones & Beeth, 1995).

A significant goal of science education is to develop more accurate student views of NOS. Therefore, in setting up and establishing the needed classroom environments new types of learning activities are important. To teach NOS as a part of K-12 science courses, teachers should consider that:

- Children learn through hands-on, minds-on activities.
- Children need to be able to make choices.
- Children focus and attend best if the learning is related to their interests.
- Children learn in an integrated fashion. The curriculum areas are not separated in the lives or in the minds of young children.
- Children need interactions with others to confront differing ideas and to realize that there are other options ad perspectives.
- Children need interaction with others to determine common understandings and transmission of culture.
- Children need broad and extended bases of experiences (Driver et al., 2000).

According to Dickinson et al. (2000), MacDonald (1996), and Akerson et al., (2000), a reflective explicit approach to teachers' views of the NOS was more "effective" than an implicit approach that use hands-on, inquiry-based science activities but do not have any explicit references to various aspects of the NOS. An explicit approach suggests that using elements from history and philosophy of science and instruction which uses various aspects of the NOS to improve science teachers' conceptions is important if teaching for scientific literacy is to result. An explicit instructional approach gets learners' attention to related aspects of the NOS through instruction, discussion, and questioning. It makes NOS visible in classroom instruction (Schwartz & Lederman, 2002; Abd-El-Khalick & Lederman, 2000). Rutherford (1964) states that "science teachers must come to know just how inquiry is in fact conducted in the sciences. Until science teachers have acquired a rather thorough grounding in the history and philosophy of the sciences they teach, this kind of understanding will elude them. Until this is done, not much progress toward the teaching of science as inquiry can be expected." (p.84)

Abd-El-Khalick et al. (1998) reported that better than 90% agreement was achieved for explicit references to NOS in successful science classroom. These results show the effectiveness of the explicit approach in enhancing pre-service teachers' conceptions of the NOS. Participants view NOS as less significant than other outcomes such as students' needs and attitudes and specific science content and process skills. Instead they were worried about classroom management and routine tasks. They expressed their discomfort with their own understanding of NOS. They noted a lack of resources and experience for teaching and assessing student understanding of NOS.

Modeling the instructional strategies that are effective with teachers could be an effective tool for affecting how teachers design instruction for their students. Dawkins and Vitale's (1999) study indicated that teachers' instructional practices with students are dependent on the strategies used by them in the professional development which result in their own understanding of NOS concepts.

Helping teachers to internalize the instructional importance of NOS may help avoid the lack of attention to NOS in teachers making instructional decisions. A teacher cannot be expected to teach what he/she does not understand. Therefore, educational programs should be based on improving science teachers' conceptions of NOS with the anticipation that such improved student conceptions can necessarily follow. More professional development activities should focus on teachers' understandings of NOS attention directly to ways these can be translated into understandings of effective classroom practices. Until both in considered and experienced by teachers success will NOS as a required for effective science teaching may continues to elude their success. Looking at the variation in recent reports combine to see NOS as imperative if returns one to succeed!

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