Science teachers' conceptions of nature of science: The case of Bangladesh

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Contents

Abstract

This study explored Bangladeshi science teachers' conceptions of nature of science (NOS) with a particular focus on the nature of (a) scientific knowledge, (b) scientific inquiry and (c) scientific enterprise. The tentative, inferential, subjective and creative NOS, in addition to the myths of the scientific method and experimentation, the nature of scientific laws and theories, the social and cultural embeddedness, and cooperation and collaboration in science were considered in the conceptual framework. Both quantitative and qualitative data were collected concurrently using the Myths of Science Questionnaire (MOSQ) from 145 science teachers. Results showed that the majority of the teachers in this study held uninformed conceptions about most of the target NOS aspects. Also, an inconsistent response pattern was revealed in teachers' response to the aspects directly related NOS. The results suggest that further research is required to better understand how Bangladeshi teachers model NOS in their classes and how the pedagogies of teacher education inform this modelling.

Keywords: Nature of science, teachers' conception, science teaching, Bangladesh.

Introduction

An understanding of nature of science (NOS) is considered as a key element of scientific literacy (American Association for the Advancement of Science [AAAS], 1993; Bybee, 1997; Miller, 1983; Organisation for Economic Co-operation and Development [OECD], 2006; Osborne, 2007), which is advocated worldwide as a goal of school science education (AAAS, 1993; De Vos & Reiding, 1999; Goodrum, Hackling, & Rennie, 2001; Millar & Osborne, 1998; National Research Council [NRC], 1996). Moreover, an understanding of NOS is considered important in enhancing students' understanding of science, successful learning of science content, and participating in socio-scientific decision making (Driver, Leach, Millar, & Scott, 1996; McComas, Clough, & Almazroa, 1998). Science curricula worldwide, therefore aims to help learners attain an adequate understanding of NOS. In line with this global trend, junior secondary science curriculum in Bangladesh includes a goal to help learners develop an understanding of NOS (National Curriculum and Textbook Board [NCTB], 1995).

One of the most important factors to improve students' learning is the teacher (Goodrum, et al., 2001) and the importance of this cannot be overestimate; therefore, teachers may have a vital role in helping their students' understanding of NOS. In conjunction with some other factors (Lederman, 1992), teachers should have an informed understanding of the NOS to be able to teach their students NOS concepts (Abd-El-Khalick & Lederman, 2000b). However, past research in different educational contexts has revealed that science teachers often do not possess informed concepts about NOS (Buaraphan & Sung-Ong, 2009; Lederman, 1992; McComas, et al., 1998). This research aims to explore Bangladeshi science teachers' conceptions of NOS.

To the best of our knowledge, there is a dearth of research exploring science teachers' conceptions of NOS in developing South-Asian countries. However there is no research that has explored Bangladeshi science teachers' conceptions of NOS; this is the first such initiative. This research, therefore, may make a significant contribution to the current understanding of the issue in the context of South-Asian developing countries, particularly in Bangladesh.

Further, scientific activity is not the pursuit of a predetermined end. Neither are the traditions of science teaching fixed and finished; they guide scientific research and teaching, and at the same time they are being extended and enlarged wherever they are practised. Within this research we sought to explore the reality of science teaching in Bangladesh.

Conceptions of NOS

The phrase "nature of science" (NOS) may refer to the epistemology of science or the principles and beliefs inherent to the development of scientific knowledge (Lederman, 1992). However, there is disagreement among the philosophers of science, historians of science, sociologists of science, scientists and science educators about a specific conception of NOS (Abd-El-Khalick & Lederman, 2000a, 2000b). We also acknowledge this lack of agreement, and therefore we will use the phrase 'NOS' instead of 'the NOS' throughout this paper after Lederman and his colleagues (Abd-El-Khalick & Lederman, 2000a, 2000b).

Lederman and his colleagues (Abd-El-Khalick & Lederman, 2000a, 2000b). After synthesising the major NOS literature (Lederman, 2004; McComas & Olson, 1998;

Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003), three NOS aspects are considered in this research: (a) nature of scientific knowledge, (b) nature of scientific inquiry and (c) nature of scientific enterprise, which build the conceptual framework and is discussed below.

Nature of scientific knowledge

Tentative

Even though scientific knowledge is durable, it is never absolute or certain (Lederman, 2004; Osborne, et al., 2003). When new evidence is found against existing knowledge, as a result of advancement of technology or old evidence is reinterpreted in the light of new advanced theory, existing knowledge can be altered (Lederman, 2004). Further, uncertainty of scientific knowledge is observed because it is inferential, subjective, creative and culturally embedded in nature.

Inferential

Although scientific knowledge is "derived from, and/or consistent with observations of natural phenomena" (Abd-El-Khalick, Waters, & Le, 2008, p. 838), it is also inferential in nature. "Observations are descriptive statements about natural phenomena that are 'directly' accessible to the senses (or extensions of the senses)" (Lederman, 2004, p. 304). For example, if we release an object above ground level, we can observe its tendency to fall and hit the ground. On the other hand, the object tends to fall to the ground due to the gravity, which is not accessible to our senses and "can only be accessed and/or measured through its manifestations of effects" (Lederman, 2004, p. 305, emphasis in original). This logical conclusion of the observation is called an inference.

Theory-driven and subjective

Scientist's' theoretical knowledge, training, experience, commitments, religious or other beliefs, political convictions, sex and ethnic origin can form a mind-set that affects scientific investigations (Lederman, 2004). Different scientists holding different values engage themselves in different forms of scientific investigations (Allchin, 1999). Also, these values influence what they observe (and do not observe) and how they interpret these observations. In other words, these observations help find answers to some questions, which are derived from within certain theoretical perspectives.

Scientific knowledge involves human inference, imagination, and creativity

Despite having an empirical basis of scientific knowledge, it involves scientist's imagination and creativity (Lederman, 2004). For example, the concepts of atoms, black holes, force fields and species are not faithful copies of reality, rather they are functional theoretical models as a result of creatively integrating NOS and its inferential nature (Abd-El-Khalick, et al., 2008).

Nature and function of theories and laws

Scientific laws are "statements or descriptions of the relationships between observable phenomena", scientific theories, in contrast are "inferred explanations for observable phenomena" (Lederman, 2004, p. 305). A theory is much more complex and dynamic as it presents the inferred explanations, and it often includes a law(s). For example, in Einstein's theory of relativity, gravity plays a crucial role. In this theory, the basic law of gravity is intact, and the theory expands it to include various and complex situations involving space and time. It is noteworthy that theories and laws are supported by empirical data, are regarded as different kinds of knowledge and one does not become the other (Abd-El-Khalick, et al., 2008). However, it is often believed that after being empirically tested a hypothesis becomes a theory (Haidar, 1999), and "laws-are-mature-theories-fable" (Bell, Lederman, & Abd-El-Khalick, 2000).

Nature of scientific inquiry

Myth of "The Scientific Method"

It is often perceived that there is a recipe-like stepwise procedure in all scientific investigations. However there is no single "scientific method" that would guarantee the development of scientific knowledge (Abd-El-Khalick & Lederman, 2000b; Abd-El-Khalick, et al., 2008; Bell & Lederman, 2003; Lederman, 2004; McComas, et al., 1998). Also, there is no single sequence of practical, conceptual, or logical activities that will accurately lead to valid claims in developing scientific knowledge (Abd-El-Khalick, et al., 2008).

Myth of "The Experimentation"

This myth of NOS refers to the idea that only experimental research characterises scientific inquiry. However, scientific inquiry may take other forms, such as descriptive and correlational (Lederman, 2004). Scientific questions guide the approach employed in getting answers to the questions and the approaches that vary widely within and across scientific disciplines.

Nature of scientific enterprise

Social and cultural embeddedness of science

Science is a human enterprise embedded and practiced in society (Abd-El-Khalick, et al., 2008); therefore, science affects and is affected by different cultural elements, such as social values, power structures, politics, socio-economic factors, philosophy and religion (Lederman & Lederman, 2004). Influence of these factors can be observed by the issue of public funding for scientific research.

Interaction between science and technology

Science and technology have different roles in society. Is important to understand the interaction and have an understanding of the distinctions between science and technology (Buaraphan & Sung-Ong, 2009). However, there are often misconceptions among teachers in this regard, such as "technology is the applied science" (Tairab, 2001).

Cooperation and collaboration in science

Scientific work is a collaborative and collective activity (Lederman, 2004; Osborne, et al., 2003). Although individuals may make significant contributions, scientific work is often carried out in groups. New knowledge claims are generally shared and must go through a double-blind peer review process to be accepted by the scientific community.

Research methods

Instrument

To explore science teachers' conceptions of NOS, we employed an instrument called the Myths of Science Questionnaire (MOSQ). The MOSQ was successfully employed to explore pre-service science teachers' conceptions of NOS in an Asian context (Buaraphan & Sung-Ong, 2009); we therefore assumed that it would also be applicable to Bangladeshi respondents. The MOSQ (see Table Appendix) consists of 14 items and addresses three NOS aspects considered in this research: (a) scientific knowledge (8 items—Items 1, 2, 3, 4, 8, 9, 10, 11); (b) scientific inquiry (3 items—Items 5, 6, 7); and (c) scientific enterprise (3 items—Items 12, 13, 14). In the MOSQ, respondents are required to select which of three responses, i.e., "agree", "uncertain", or "disagree", best fits their opinion on the item statement. They were also asked to provide an additional written explanation to support their selection. The MOSQ, therefore, collects the explanatory data in conjunction with the responses.

We discussed the relevance and suitability of the MOSQ instrument with two Bangladeshi science educators in order to maintain validity. A translated version (in Bengali) of the MOSQ was used as we anticipated that participants will feel more comfortable both in understanding the item statements and explaining the reason for choice in their own language. In order to resolve any translation issue, we at first translated the questionnaire individually, and then discussed it as a group. After a thorough discussion, we came to a consensus on our translation. This translated version was then piloted with 10 science teachers to determine whether they understood the items. Any ambiguities found during this piloting were clarified for the respondents and recorded for further revision of the MOSQ. This final revised version of the MOSQ was given to the participants. It had a Cronbach's alpha reliability coefficient of 0.79, which suggested that the MOSQ items have relatively high internal consistency.

Participants

The first author of this paper arranged five workshops in different regions in Bangladesh for his PhD research. The workshop participants were science teachers. We invited these workshop participants to participate in this study as well. A total of 145 teachers, including 129 males and 16 females, voluntarily agreed to participate in this study.

Data collection and analysis

The volunteer participants were asked to respond to the final version of the MOSQ. They took 30-40 minutes to complete the questionnaire. All data was collected from February to March 2010.

We analysed the quantitative data using the Statistical Package for the Social Sciences (SPSS), version 15.0 for Windows. Frequencies of the responses ("agree", "uncertain" and "disagree") were counted and then presented in terms of percentage to interpret the results. For analysing the explanatory data that was qualitative in nature, we employed the data transformation procedure (Creswell, 2009). In this procedure, themes were identified from the qualitative data, and the frequency of the themes was counted and then presented in percentages.

Findings

The nature of the MOSQ means that the database developed is extensive, particularly in relation to the explanatory data, and it is beyond the scope of this paper to present and discuss all the explanatory findings in detail. Therefore, this paper presents the most notable features of the explanatory data and discusses accordingly. In line with the purpose of this study science teachers' conception of NOS are presented in three sections in terms of their conceptions of the nature of scientific knowledge, scientific inquiry and scientific enterprise.

Teachers' conceptions of the nature of scientific knowledge

Table I presents science teachers' conceptions of the nature of scientific knowledge. An overview of data in Table I shows that the majority of science teachers in this study held uninformed conceptions about six item statements characterising the nature of scientific knowledge. In specific, a majority of science teachers held the uninformed view about the role of hypotheses, theories and laws, in addition to the conceptions about the scientific model and open-mindedness of the scientists. On the other hand, a majority of teachers held an informed view about the tentativeness of scientific knowledge and place of imagination and creativity in the scientific knowledge development process.

Table I. *Science teachers' conceptions of the nature of scientific knowledge.*

Disposition statement	Agree (%)	Uncertain (%)	Disagree (%)
Hypotheses are only developed to become theories	69.0	5.5	25.5
Scientific theories are less secure than laws	59.3	16.6	24.1
Scientific theories can be developed to become laws	73.8	17.2	9.0
Scientific knowledge cannot be changed	28.3	6.2	65.5
Accumulation of evidence makes scientific knowledge more stable	67.6	7.6	24.8
A scientific model (e.g., the atomic model) expresses a copy of reality	59.3	20.0	20.7
Scientists do not use creativity and imagination in developing scientific knowledge	26.9	14.5	58.6
Scientists are open-minded without any biases	71.7	12.4	15.9

A close look at data in Table I shows that a majority of the participants in this research (69%) agreed with the statement, "hypotheses are only developed to become theories." Of written responses, 55.6% argued that developing hypotheses is an obligatory step for developing a theory, while 19% argued that if a hypothesis is proven to be justified by thorough experimentation, it is regarded as a theory.

A majority of science teachers (59.3%) expressed the traditional view that scientific theories are less stable than laws. A major explanation of supporting this view (47%) was that, "laws are proven fact that come from theories and cannot be altered." It was frustrating that none of the participants expressed the equal credibility of scientific theories and laws.

Similarly, almost three-fourths of the participants agreed with the statement "scientific theories can be developed to become laws," which indicated the teachers' belief in "laws-are-mature-theories-fable" (Bell, et al., 2000). Of written responses, almost 60% argued that "a theory can become a law if it is proven by empirical evidence," which indicated their uninformed conception about scientific theories and laws.

Table I also shows that a majority of the participants (65.5%) expressed the informed view about the tentativeness of scientific knowledge. A majority of the written responses (59.3%) provided to support their view stated that "scientific knowledge has a temporary status due to the rapid advancement of science and technology." However, a good number of the participants who did not believe in the tentativeness of science (23.6%) explained that "scientific knowledge is the proven fact; so it cannot be changed."

A majority of the participants (67.6%) held the uninformed view that the "accumulation of evidence makes scientific knowledge more stable." However, a few participants (96) explained their view in this regard, where most (75%) expressed that "evidence is indispensable for the trustworthiness of scientific knowledge."

Teachers' responses on the place of creativity and imaginativeness in science revealed that a majority (58.6%) agreed. However, an interesting finding was that almost an equal number of participants agreed with the statement "a scientific model (e.g., the atomic model) expresses a copy of reality." The credibility of this statement may somewhat be related with the creativity and imaginativeness used in science. However, we were not able to explain this inconsistent response pattern from teachers' explanatory responses.

Most of the teachers in this research (71.7%) held an uninformed conception that scientists are open-minded without any biases. The majority of the written responses (63.5%) supported this view. One in particular reflected that "if a person possesses biases towards anything and if he is not open-minded, I would rather call him 'superstitious' than 'a scientist.'"

Teachers' conceptions of the nature of scientific inquiry

Table II presents science teachers' conceptions of the nature of scientific inquiry.

Table II. *Science teachers' conceptions of scientific inquiry.*

Disposition statement	Agree (%)	Uncertain (%)	Disagree (%)
The scientific method is a fixed step-by-step process	84.1	2.8	13.1
Science and the scientific method can answer all questions	29.0	22.8	48.2
Scientific knowledge only comes from experiments	61.4	4.1	34.5

Most of the science teachers in this study (84.1%) had an uninformed view that the scientific method is a fixed step-by-step process. A major explanation of supporting this view (61.2%) was that "science is a systematic process and that's why it follows the recommended steps; reordering these steps could result in invalid scientific knowledge."

Nearly half of the respondents disagreed with the statement that "science and the scientific method can answer all questions," which may be perceived as their acknowledgement of the limitations of science. While a number of participants (22.8%) were uncertain, a good number (29%) possessed an uninformed view about this issue. Of written responses, a majority (61%) raised issues, such as treatments done by the priests (Hujur in Bengali) in Bangladesh, existence and activities of the God and angels, etc. that science cannot explain. A majority of the respondents (61.4%) expressed an uninformed view that "scientific knowledge only comes from experiments." Many of the written responses (54.3%) exemplified this view seen in various scientific experiments (e.g., Galileo's Experiment at the PISA tower, Galileo's Pendulum Experiments, etc.). However, a good number of respondents (34.5%) had contemporary view in this respect, and many of their written responses reflected that more than one method can be used to develop scientific knowledge.

Teachers' conceptions of the nature of scientific enterprise

Table III presents science teachers' conceptions of the nature of scientific enterprise.

Table III. *Science teachers' conceptions of scientific enterprise.*

Disposition statement	Agree (%)	Uncertain (%)	Disagree (%)
Science and technology are identical	51.0	9.0	40.0
Scientific enterprise is an individual enterprise	26.2	16.6	57.2
Society, politics and culture do not affect the development of scientific knowledge	30.3	13.1	56.6

More than half of the teachers agreed with the statement "science and technology are identical." Written responses of these participants revealed that majority (59.2%) had uninformed conception that "technology is applied science."

A majority of the teachers in this research (57.2%) expressed their informed view about scientific enterprise by disagreeing with the statement "scientific enterprise is an individual enterprise." A major explanation of supporting this view (69.7%) was that "a group of scientists usually work on a project; collaboration among them therefore is necessary for the project."

More than half of the participant teachers (56.6%) believed that society, politics and culture affect the development of scientific knowledge. Of the written responses, many of them exemplified that geocentrism was once established as an influence of socio-religious perspectives.

Discussion and conclusion

This study reveals that majority of Bangladeshi school science teachers held uninformed conceptions about the roles of hypotheses, theories and laws. In particular, none of the respondents believed in equal credibility of scientific theories and laws, rather most of them believed in the myth "laws-are-mature-theories-fable" (Bell, et al., 2000). This result is consistent with other studies conducted on pre-service teachers elsewhere (e.g., Buaraphan & Sung-Ong, 2009).

An important finding of this research is that teachers were not consistent in expressing their views to a particular NOS aspect and to its associated aspects. For example, a majority of teachers acknowledged the place of imagination and creativity in science, which are regarded as important in developing scientific knowledge, particularly to creating scientific models and designing experiments (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, et al., 2000). However, scientific models were viewed as a copy of reality rather than a product of scientist's creativity and imagination by a majority of teachers in this research; this differs from the findings of previous research (Bell, et al., 2000; Buaraphan & Sung-Ong, 2009; Haidar, 1999). Also, most of the teachers viewed scientific experiments as a universal, fixed step-by-step process; they did not acknowledge the place of creativity and imagination in designing an experiment.

This research also found that in many cases, teachers' written responses could not justify their informed view about a particular aspect of NOS. For example, many of the teachers in this research held an informed view about the tentativeness of scientific knowledge; however written explanatory data showed that most acknowledged this uncertainty due to the "rapid advancement of science and technology," rather than a scientist's use of creativity, imagination and human inference in developing scientific knowledge or as a result of applying established scientific knowledge to situations outside of a controlled laboratory context (Ryder, 2001).

In this research, science teachers perceived scientists as open-minded and having no biases. Their written responses did not reflect any notion that scientific investigation could be influenced by scientists' background and mind-set. This view held by the teachers may make them resistant to perceive science knowledge as subjective and theory-laden after Lederman (2004).

As previously discussed, science teachers in this study believed in the myths of the scientific method and experimentation. Teachers may have these uninformed views about scientific inquiry as a result of the traditional portrayal of recipe-like experiments in science textbooks, as textbooks often play a vital role in understanding the process of science (Chiappetta, Fillman, & Sethna, 1991). Like other educational systems (Abd-El-Khalick, et al., 2008), science textbooks in Bangladesh portrayed that there is one general method of conducting a scientific investigation (Siddique, 2008). It may therefore be reasonable to argue that science textbooks should be revised in line with the contemporary conception that there is no single scientific method to be used in developing scientific knowledge (Abd-El-Khalick & Lederman, 2000b; Abd-El-Khalick, et al., 2008; Bell & Lederman, 2003; Lederman, 2004; McComas, et al., 1998) .

A majority of teachers viewed science as a collective activity; they also believed in the influence of society, politics and culture in the development of scientific knowledge. Although these informed conceptions of scientific enterprise are very positive, many of them held an uninformed view that "technology is the applied science," as previous research suggested (Buaraphan & Sung-Ong, 2009). In line with the argument of Buaraphan and Sung-Ong (2009), we would also argue that a clear distinction between science and technology and their associated relationship should be articulated and advocated by science educators through various science education programmes.

In this research, we found that science teachers in Bangladesh held uninformed conceptions about many of the NOS aspects considered in this research. As in some other educational contexts (McComas, et al., 1998), Bangladeshi science teachers rarely have the opportunity to learn about the contemporary NOS in their own studies; therefore, it is not surprising that they would hold uninformed conceptions about the contemporary NOS. As science teachers' conceptions of NOS influence their teaching NOS in the classroom (Buaraphan & Sung-Ong, 2009), learning about NOS should be included in science studies at different levels of education and in different teacher education programmes designed for science teachers in Bangladesh.

But ways of thinking cannot be abstracted from thoughts, in either scientific research or teaching. Thoughts and how to think are indivisibly one. If we could erase all the ideas a person has, we would have erased all intelligence; not left behind the power to think, and with nothing left to think about. The results of this research suggest that further research is required to better understand how Bangladeshi teachers model NOS in their classes and how the pedagogies of teacher education inform this modelling. As Ogborn (1995) has argued, what is needed as a starting point is a modest and realistic view of the natural sciences, no longer tainted by pretending to fulfil an impossible rationalist dream, and similarly, no longer suspect as failing to do so.

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Appendix: The Myths of Science Questionnaire (MOSQ)

Directions: Please select the choice that best reflects your opinion, and provide an explanation supporting your selection.

Statement	Opinion			Explanation
	Agree	Uncertain	Disagree	
Hypotheses are only developed to become theories				
Scientific theories are less secure than laws				
Scientific theories can be developed to become laws				
Scientific knowledge cannot be changed				
The scientific method is a fixed step-by-step process				
Science and the scientific method can answer all questions				
Scientific knowledge only comes from experiments				
Accumulation of evidence makes scientific knowledge more stable				
A scientific model (e.g., the atomic model) expresses a copy of reality				
Scientists do not use creativity and imagination in developing scientific knowledge				
Scientists are open-minded without any biases				
Science and technology are identical				
Scientific enterprise is an individual enterprise				
Society, politics and culture do not affect the development of scientific knowledge				