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SCIENCE TEACHERS' VIEWS ON NATURE OF SCIENCE: A CASE OF BANGLADESHI SECONDARY SCHOOLS

[1]Muhammad Nur-E-Alam Siddiquee, [2]Hideo Ikeda
Hiroshima University, Japan

Abstract. The present study aims to explore the science teachers' views on nature of science (NOS) in secondary schools of Bangladesh. By using Views of Nature of Science form-B (VNOS-B) questionnaire survey and follow up interviews, qualitative data was collected from purposively selected forty five science teachers. The VNOS-B data collection instrument is a six item, open ended questionnaire designed to elicit descriptive responses to generally agreed NOS aspects: tentative, empirical, inferential, creative, and subjective NOS, as well as the functions of, and relationships between theories and laws. Responses were analyzed into coded categories of informed, uninformed /naïve, and ambiguous. The results of the study revealed a picture of the secondary science teachers' views as well as misconceptions on nature of science. Their views on nature of science are mostly traditional (naïve) and incoherent. The results of the study indicated that science teachers held traditional views regarding inference and theoretical entities, distinction and relationship between theories and laws, empirical, creative and imaginative nature of scientific knowledge. On the other hand, the participants have contemporary views (informed) on tentative and subjective nature of scientific knowledge. Analysis of interviews also supported these findings. Therefore, this study suggests further investigating on how the pedagogies of teacher education represent the NOS and what aspects of the NOS are communicated to the teachers through these pedagogies to find deeper understanding about the NOS.
Keywords: nature of science, teachers' view, science teaching, secondary school, Bangladesh

Introduction

The preparation of scientifically literate students is a perennial goal of science education (American Association for the Advancement of Science [AAAS], 1990, 1993; Millar & Osborne 1998; De Vos & Reiding, 1999; Goodrum et al., 2001; National Research Council [NRC], 1996). However, an adequate understanding of the nature of science (NOS) is a pre-requisite as well as a key element for obtaining scientific literacy (Shamos, 1995, cited in McComas et al., 1998, p.515; AAAS, 1993, 1990; Bybee, 1997; Miller, 1983, 1989, 1998; OECD, 2006; Osborn, 2007; National Science Teacher Association [NSTA], 1982).

Although there is a controversy (*controversy about the NOS discuss elsewhere in the article*) regarding the NOS but for the past 85 years, most scientists and science educators agreed on the objective of helping students develop adequate understanding of NOS. Recently, it has been reemphasized in the major reform efforts in science education (AAAS, 1990, 1993, Millar & Osborne, 1998; NRC, 1996). The notion of NOS has been emphasized not only in the US but also in other countries reform efforts, for example, National *Curricula* in Australia, New Zealand, Canada, and England and Wales (McComas & Olson, 1998; cited in Osborne, et al., 2003). Fostering scientific ideas (ideas of NOS) have been given stress through problem solving in Japanese course of study (MEXT, 2008).

In line with this global trend, secondary teacher education curriculum in Bangladesh includes a goal to help learners develop an understanding of NOS (MoE, 2006). The goal states as follows:

Involve students in activities that clarify the nature of science and take account of and contribute to development of their personal beliefs, values, attitudes, especially where these affect or are affected directly by modern theories of science and /or their application through technology (ibid.).

A similar goal is also set in junior secondary science curriculum in Bangladesh (National Curriculum and Textbook Board [NCTB], 1995). To attain these goals, a highly participatory teaching approach has been suggested for science teachers (MoE, 2006, p. 97). The main spirit of participatory teaching is to involve learners actively in the process of teaching and learning through varieties of teaching methods. This approach of teaching includes more than 30 teaching and learning methods for example, simulations, microteaching tasks and presentations, group or peer discussion, brainstorming, modeling, mind/concept mapping, storytelling, demonstration, dramatization and so on (ibid.). It is now evident that 49% of teachers are following participatory method satisfactorily (Teaching Quality Improvement-Secondary Education Project [TQI-SEP], 2009). In Bangladesh context, hence understanding NOS is deem necessary to employ participatory teaching approach in teaching science.

Although an understanding of the nature of science is considered to be one of the primary goals of science education for many years, previous studies for example, Bauraphan and Sung-Ong, (2009); Lederman, (1992, 2007); McComas et al., (1998); Abd-El-Khalick & BouJaoude, (1997); Pomeroy (1993) *cited in* Abd-El-Khalick and Lederman (2000), show that both students and teachers have inadequate conceptions about the NOS. Without taking into account of the assessment instruments used, studies repeatedly indicated that elementary and secondary science teachers' views were not consistent with contemporary conceptions of NOS (e.g., Abd-El-Khalick & BouJaoude, 1997; Pomeroy, 1993; Iqbal et al., 2009; Akherson et al., 2002). Science teachers held naïve/uninformed views of several important aspects of NOS. A remarkable proportion of teachers, for example, did not support the tentative nature of scientific knowledge. Rather, they believed that science is a body of knowledge that has been "proven" to be correct (Augirere et al., 1990). Many teachers held naive views of the meaning and function of scientific theories and laws and/or ascribed to a hierarchical view of the relationship between the two, whereby theories become laws with the accumulation supporting evidence (Abd-El-Khalick & BouJaoude, 1997). A majority of teachers still held a positivistic, idealistic view of science (Pomeroy, 1993); others believed in a universal stepwise procedure, "The Scientific Method," for "doing science," thus dismissing the creative and imaginative nature of the scientific endeavor (Abd-El-Khalick el al., 1997; Lederman, 1992). Researchers argue that the main reason for students' naïve conception is the naïve conceptions of teachers who are the responsible person to develop such an understanding of their students (Erdoğan, 2004). On the other hand, as per as the researcher's concern, in Bangladesh understanding the NOS, as one of the most important goals of science teaching, has not properly been investigated. Therefore, the present study aims to determine the views of science teachers' on the NOS issues.

Concept of Nature of Science

The nature of science is multifaceted concepts that cannot be defined by simple definition. It includes aspects of history, sociology, and philosophy and has variously been defined as science epistemology, the characteristics of scientific knowledge, and science as a way of knowing (Bell, 2009). Science educators have identified three domains of science critical to developing scientific literacy. The first of these is the body of scientific knowledge, scientific methods and process comprise the second domain, and the nature of science constitutes the third domain which is by far the most abstract and least familiar of the three. The third domain seeks to describe the nature of scientific enterprise and the characteristics of the knowledge. According to Bell (2009), a key set of ideas are converged for describing the NOS. These include the following aspects:

Tentativeness: All scientific knowledge is subject to change in light of new evidence and new ways of thinking-even scientific laws change. New ideas in science are often received with a degree of skepticism, especially if they are contrary to well-established scientific concepts. On the other hand, scientific knowledge, once generally accepted, can be robust and durable. Many ideas in science have survived repeated challenges, and have remained largely unchanged for hundreds of years. Thus, it is reasonable to have confidence in scientific knowledge, even while realizing that such knowledge may change in the future.

Empirical evidence: Scientific knowledge relies heavily upon empirical evidence. Empirical refers to both quantitative and qualitative data. While some scientific concepts are highly theoretical in that they are derived primarily from logic and reasoning, ultimately, all scientific ideas must conform to observational or experimental data to be considered valid.

Observations, Inference, and Theoretical Entities in Science: Students should be able to distinguish between observation and inference. Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses) and about which observes can reach consensus with relative ease. For example, objects released above ground level tend to fall to the ground. By contrast, inferences are statements about phenomena that are not directly accessible to the senses. For example, objects tend to fall to the ground because of gravity. The notion of gravity is inferential and the sense that it can be accessed and/or measured only through its manifestations or effects. An understanding of the crucial distinction between observation and inference is a precursor to making sense of a multitude of inferential and theoretical entities and terms that inhabit the worlds of science. Examples of such entities include atoms, molecular orbital, species, genes, photons, magnetic fields, and gravitational forces.

Scientific laws and theories: In science, a law is a succinct description of relationships or patterns in nature consistently observed in nature. Laws are often expressed in mathematical terms. A scientific theory is a well-supported explanation of natural phenomena. Thus, theories and laws constitute two distinct types of knowledge. One can never change into the other. On the other hand, they are similar in that they both have substantial supporting evidence and are widely accepted by scientists. Either can change in light of new evidence.

Myth of Scientific methods: There is no single universal scientific method. Scientists employ a wide variety of approaches to generate scientific knowledge, including observation, inference, experimentation, and even chance discovery.

Creativity: Creativity is a source of innovation and inspiration in science. Scientists use creativity and imagination throughout their investigations.

Objectivity and subjectivity: Scientists tend to be skeptical and apply self-checking mechanisms such as peer review in order to improve objectivity. On the other hand, intuition, personal beliefs, and societal values all play significant roles in the development of scientific knowledge. Thus, subjectivity can never be (nor should it be) completely eliminated from the scientific enterprise.

The above mentioned aspects of the NOS are generally agreed by the scientific communities (McComas et al., 1998). However, beyond these general agreements no consensus presently exists among philosophers of science, historians of science, scientists, and science educators on a specific definition for NOS. The definition of the

NOS made by the science educators does not agree by the others science community members because they find it too general (Akarsu, 2010). The issue of the existence of objective reality as compared to phenomenal realties is a case in point (ibid.). At the close of this millennium, the favored dichotomy features (Holton, 1996) a supposed battle called "the science wars." The subject of the attacks was the analysis of science coming out of literary studies and the social sciences called the nature of science (NOS). In the USA the best known names are Paul Gross, Norman Levitt, and Alan Sokal (Osborne et al., 2003). In Britain the most aggressive science warrior is biologist, Lewis Wolpert. The two sides in this hypothetical struggle have been dubbed "realists" who uphold the objectivity and progressive nature of scientific knowledge, and "relativists", who recognize the culturally embedded status of all claims for universal factuality (Gould, 2000). Authors, for example, Gross & Levitt (1994) and Sokal & Bricomont (1998) reacted strongly to the suggestion that much of scientific knowledge is a social construction. The case made against science has been one where Popperian notions of an objective reality and the truth-seeking goal of science have been replaced instead by the idea that the best that science can achieve are socially determined theories that are internally coherent and instrumentally viable but bear no necessary relation to any ontological reality (Osborne et al., 2003). Rather they (relativists) identify science as nothing more than a "narration", a "myth" or a social construction among many others (Sokal & Bricomont, 1998; Holton, 1996). Not only the suggestion of socially constructed knowledge, but also they countered on manipulating the phrase, for example "the NOS", and sentences that are, in fact, meaningless which exceedingly has a hazy idea (Sokal & Bricomont, 1998; Holton, 1993). Assert on that to use scientific terminology without bothering much about the words actually mean (ibid.). Displaying a superficial erudition by shamelessly throwing around technical terms in context where they are completely irrelevant (Sokal & Bricomont, 1998). However, conceptualizations of the NOS have changed with developments in history, philosophy, and sociology of science: disciplines that systematically investigate the scientific endeavour (Abd-El-Khalick & Lederman, 2000a). These developments have, in turn, resulted in changing the ways in which science educators and science education organizations have defined the phrase 'NOS' since the turn of the century.

Research Method

An interpretative research framework (Strauss & Cobin, 1990) was chosen to conduct this study. It focuses on the in-depth meanings that participants ascribed to the emphasized NOS aspects. The data was collected from January 10, 2011 to February 5, 2011. The purpose of this study is to investigate the views of Bangladeshi science teachers on the nature of science concepts.

Participants

Forty five science teachers from fifteen government secondary schools were purposively selected as sample (Table 1). Among them 13 was female. The teaching experiences of the participants ranging between 5 to 10 years, held Bachelor Degree in Education (B.Ed.), have studied separate subjects of Physics (P) and Chemistry(C) along with either Mathematics(M) or Biology (B) at graduation level and received training including Subject Based Cluster (SBC) training; Continuous Professional Development (CPD) training and Teaching Quality Improvement(TQI)training. TQI training, which started in 2006, mainly focuses on the participatory teaching approach to develop students' knowledge and thinking skills of science.

Data collection instrument

The instrument of data collection of the study is a translated version (*in Bengali*) of Views of Nature of Science questionnaires form B (VNOS-B), originally designed by Abd-El-Khalick et al. (1998). The VNOS-B instrument is a six item; open-ended questionnaire design to elicit descriptive responses to generally agreed NOS aspects like tentative, empirical, inferential, creative and subjective NOS, as well as the function of, and relationship between theories and laws (Abd-El-Khalick et al., 1998). In particular, teachers were asked to respond to the following open-ended questions:

1. After scientists have developed a theory (e.g., atomic theory, kinetic molecular theory, cell theory), does the theory ever change? If you believe that scientific theories do not change, explain why and defend your answer with examples. If you believe that theories do change: (a) Explain why. (b) Explain why we bother to teach and learn scientific theories. Defend your answer with examples.

2. Science textbooks often represent the atom as a central nucleus composed of positively charged particles (protons) and neutral particles (neutrons) with negatively charged particles (electrons) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine the structure of the atom?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform experiments/investigations when trying to solve problems. Other than in the stage of planning and design, do scientists use their creativity and imagination in the process of performing these experiments/investigations? Please explain your answer and provide appropriate examples.

6. In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while

others believed that it is shrinking, still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?

The use of open-ended questionnaire was intended to avoid the problems inherent in the use of standardize force-choice (agree/disagree, Likert scale and multiple choice) paper and pencil NOS assessment instrument (Lederman et al., 1998 cited in Tan & Boo, 2003). Therefore, six items open-ended questionnaires used in the present study was previously used and validated with expert and novice groups (Lederman et al., 2002), pre-service elementary teachers (Akerson et al., 2000; Akerson & Abd-El-Khalick, 2000), and pre-service secondary teachers (Bell et al., 2000).

Data collection procedure

With due permission of the school heads, the questionnaire was given to selected science teachers. They were allowed to take the questionnaire at their home, so that they can have much time to think for answering the questions. The next day, the researcher collected the questionnaire and requested them to sit for an interview after class hour. Five participants out of forty five willingly agreed to give interview. The participants were provided their completed questionnaires during these interviews and asked to explain and elaborate on their responses. Apart from VNOS-B questionnaire, the study did not use separate questionnaire for conducting interview. Interviews were conducted to check instrument's validity and to generate in-depth profiles of participants view. Assert on that the principal source of the instrument's validity evidence stems from the follow-up interviews, where it is possible to check respondents' understanding of each items (Lederman et al., 2002). It lasted for about 30-35 minutes and audio-taped and transcribed for analysis.

Table 1. Distribution of sample by gender, subject studied at graduation level, and teaching experience

Participants (P)	Gender (M/F)	Subjected studied at graduation level*	Teaching Experience(years)
P1	M	PCB	9
P2	F	PCM	5
P3	F	PCB	7
P4	M	PCM	6
P5	M	PCM	8
P6	M	PCB	7
P7	M	PCB	10

►

Participants (P)	Gender (M/F)	Subjected studied at graduation level*	Teaching Experience(years)
►			
P8	M	PCM	9
P9	F	PCB	7
P10	M	PCB	8
P11	M	PCM	8
P12	M	PCM	6
P13	M	PCB	5
P14	M	PCM	5
P15	F	PCM	7
P16	F	PCM	10
P17	M	PCB	8
P18	M	PCB	7
P19	F	PCB	6
P20	M	PCM	7
P21	M	PCB	9
P22	M	PCB	6
P23	M	PCM	5
P24	F	PCB	7
P25	M	PCB	6
P26	M	PCB	8
P27	M	PCB	7
P28	F	PCM	9
P29	F	PCB	8
P30	M	PCB	7
P31	F	PCB	6
P32	M	PCB	6
P33	M	PCM	8
P34	M	PCM	7
P35	F	PCM	9
P36	M	PCM	5
P37	M	PCB	7
P38	F	PCM	6
P39	M	PCM	7
P40	M	PCM	5
P41	M	PCM	6
P42	F	PCM	6
P43	M	PCM	8
P44	M	PCB	7
P45	M	PCB	6

*PCB=Physics, Chemistry & Biology; PCM= Physics, Chemistry & Mathematics

Data analysis procedure

The NOS questionnaires and corresponding interview transcripts of the participants were analyzed and compared to validate participants' response to the NOS questionnaire items. Next, all NOS questionnaires and interviews transcripts were analyzed separately to generate the profiles of participants' views of the NOS. The completed questionnaires were used to generate summaries of each participant's views. After that, the summaries were searched for pattern and /or categories. These categories were then checked against confirmatory or otherwise contradictory evidence in the data and modified accordingly. Thus, conducted several rounds of category generation, confirmation, and modification to satisfactorily reduce and organize the data. Same procedure was followed for analyzing interviews transcripts. Finally, the profiles generated from the analysis of the questionnaires and corresponding interviews were compared. When discrepancies between the two profiles were evident, the data were reexamined to determine which profile reflected the participant's views. This process was repeated for all questionnaires.

Categorizing and coding methods were adapted from the studies conducted by Akerson, et al. (2000); Akerson et al. (2006); Küçük (2008). Responses were categorized as '*informed*', '*uninformed/naïve*', and '*ambiguous*' views of the NOS (Appendix)**.** A response was considered as an *informed view*, if it was consistent with contemporary thought on the NOS theme as described in the introduction section in this paper. Responses that involved either misconceptions or self contradicting statements were categorized as *uninformed/naïve* view. Any response that represented partially informed views or failed to provide reasons for justification of their statements were categorized as *ambiguous* view. For example, if a participant responded that '*scientific theories change because of new evidence'* this response was categorized as "informed view of the tentative nature of scientific theories" and coded as "+" sign. If the participant responded that" *theories will never change or change only to develop law"* then the response was categorized as" naïve/uninformed" view of tentative nature of scientific theories" and coded as "-" sign. If a participant responded that **"***Theory and law is a kind of knowledge"* no more explanation and fail to provide example then the response was categorized as "ambiguous" view of tentative nature of scientific theory and coded as "±" sign. After that, percentage distribution of "informed" category under each one of the NOS aspect were calculated. For the discussion, some direct quotations were taken from the interviews.

Results

Table 2 presents summary of results according to participants along with their background. It shows the number of participants who held informed views on the NOS aspects with "+", naïve/uninformed view with "-"and ambiguous view with "±" signs for each of the targeted theme. Fig. 1 shows theme-wise participants' views on the NOS. Analysis

Table 2. Number of the participants with “informed” views of the target NOS aspects

Participants (P)	Gender (M/F)	Subjected studied at graduation level	Teaching Experi-ence (years)	Target aspects of NOS					
				Tentative Nature of scientific theory	Inference and theo-retical entities in sci-ence	Distinction and relation-ship between scientific theories and laws	Empirical nature of Scientific knowledge	Creative and imagi-native nature of scientific knowledge	Subjective nature of scientific knowledge
P1	M	PCB	9	-	+	+	+	+	+
P2	F	PCM	5	-	-	-	-	-	+
P3	F	PCB	7	+	-	-	-	-	-
P4	M	PCM	6	+	-	-	-	-	-
P5	M	PCM	8	+	+	-	+	+	+
P6	M	PCB	7	+	-	-	-	-	+
P7	M	PCB	10	-	-	-	-	-	-
P8	M	PCM	9	+	+	-	+	+	+
P9	F	PCB	7	-	+	±	+	+	-
P10	M	PCB	8	+	-	-	-	-	+
P11	M	PCM	8	+	+	-	+	-	+
P12	M	PCM	6	-	-	-	-	-	-
P13	M	PCB	5	+	-	-	+	-	+
P14	M	PCM	5	-	-	-	-	-	+
P15	F	PCM	7	+	-	-	-	-	-
P16	F	PCM	10	+	-	-	-	-	-
P17	M	PCB	8	+	+	-	-	+	-
P18	M	PCB	7	+	-	-	-	-	+
P19	F	PCB	6	-	-	-	+	-	-
P20	M	PCM	7	+	+	-	-	-	+
P21	M	PCB	9	+	+	+	+	+	-
P22	M	PCB	6	+	-	+	+	-	+
P23	M	PCM	5	+	-	-	-	-	-
P24	F	PCB	7	+	+	-	+	+	-
P25	M	PCB	6	+	-	-	-	-	+
P26	M	PCB	8	+	+	-	+	+	+
P27	M	PCB	7	+	+	+	+	+	+
P28	F	PCM	9	+	-	-	-	-	-
P29	F	PCB	8	-	-	-	-	-	+
P30	M	PCB	7	-	-	-	-	-	-
P31	F	PCB	6	+	+	+	+	-	+
P32	M	PCB	6	+	+	+	-	+	+
P33	M	PCM	8	+	-	-	-	-	-
P34	M	PCM	7	+	-	-	-	-	+
P35	F	PCM	9	-	-	-	-	-	+
P36	M	PCM	5	+	-	-	-	-	-

►

Participants (P)	Gender (M/F)	Subjected studied at graduation level	Teaching Experi-ence (years)	**Target aspects of NOS**					
				Tentative Nature of scientific theory	Inference and theo-retical entities in sci-ence	Distinction and relation-ship between scientific theories and laws	Empirical nature of Scientific knowledge	Creative and imagi-native nature of scientific knowledge	Subjective nature of scientific knowledge
►									
P37	M	PCB	7	+	-	-	-	-	+
P38	F	PCM	6	-	-	-	-	-	+
P39	M	PCM	7	+	-	-	-	+	-
P40	M	PCM	5	+	-	-	-	+	+
P41	M	PCM	6	+	-	-	-	-	+
P42	F	PCM	6	+	+	+	-	-	+
P43	M	PCM	8	+	-	-	-	-	-
P44	M	PCB	7	+	-	-	-	-	-
P45	M	PCB	6	-	-	-	-	-	+
Total				**33**(73%)	**14**(31%)	**7**(16%)	**13**(29%)	**12**(27%)	**26**(58%)

of the results organized by themes with direct quotations selected from the interview response of the participants regarding each theme/aspect.

Tentative nature of scientific theory

In responding to VNOS-B # 1 referred to the tentative nature of scientific theory; thirty three (73%) participants out of forty five held informed view. They indicated that the reason for a change in scientific claim was due to new evidences and that creates better explanation. Two of the participants claimed that:

P2: *If scientists get new proof (evidence) theory change…Proof is required for changing theory.*

P4: *Gathering new proof, I mean evidence by observation scientific theory can change. Scientist collects evidences by doing experiments or investigation on the basis of that evidences theory changes.*

Two (4.44%) of the participants identified theory as a tool for guidance for further investigation of scientific knowledge. The respondents explain their views as:

P1: *Theory gives us clue to set experiment. We use it during experimentation.*

P3: *Actually theory gives us a kind of guidance. On the basis of it during investigation /experimentation we set our experiment, select tools, determine time and location, etc…*

Twelve (27%) out of forty five of the participants possessed uninformed views of this aspect of the nature of science. They all believed that scientific theory change, but only because they change into law. This kind of response is an indication of objective nature of scientific knowledge. One of them asserted that:

P5: Of course theory changes. I really believe it. Many evidences support it. Having evidences, theory becomes a law and does not change.

Inferences and theoretical entities in sciences

In response to VNOS-B #2, referred to the NOS aspect inferences and theoretical entities; fourteen (31%) out of forty five participants indicated informed views. They ascribed a role for indirect evidences and or/ inference in the construction of the atomic models. They identified scientific model as an artificial construct which is a resultant of scientist's interpretation or scientists' educated guesses. Two of the respondents stated that:

P1: *The structure of atom is kind of scientist's explanation (Interpretation).To create this, they use theoretical knowledge, evidences and their imagination. It's kind of artificial construct (structure).*

P4. *Actually atom structure is kind of scientist's thinking (Interpretation).To draw this structure they use their knowledge and creativity. This is not a real thing.*

Thirty one (69%) out of forty five participants believed that an atom looks like exactly as the model itself. They explicitly stated that a scientist is very sure about the structure of atom through direct observation with high power microscope. They overlooked scientific limitation and treated science as an objective endeavor. Three of the respondents advocated that:

P2: *What is going on the space and under the deep sea is known to all by high power technology. Atom structure is very simple. They (scientists) can see it very easily with the help of electronic microscope.*

P3: *Scientists are very sure to draw the structure of atom because of technology… I mean the high power microscope.*

P5: *Science progresses a lot and can do everything. So drawing structure of atom is possible by using technology. Test-tube baby, clone, genetically modified food etc. What not science are doing today.*

Distinction and relationship between scientific theory and laws

In responding to VNOS-B#3; thirty seven (82%) of the participants held 'naïve' views about theories and laws. Many believed in the notion that theories are simply a means to develop law and in hierarchical relationship between them which indicated that the teachers' belief in "laws-are-mature-theories-fable" (Bell et al., 2000). Most of the participants believed that with supportive evidences, theories would develop into law. Therefore, the kind of knowledge explained by theories and laws were not different, just different in terms of the amount of "evidence" that supported each other. This led to the believe that laws were absolute and did not change because they had been "proved" and were the ultimate source of scientific knowledge. Three of the participants stated that:

P2: *Because law cannot change. But theory can change on available evidence (proof) and ultimately becomes law. Its acceptability is lower than laws.*

P3: *Law is kind of established thing. It does not change. On the other hand, theory changes a lot on the basis of available evidences getting through experiment.*

P5: *Law and theory are different kind of knowledge. Scientific law developed from scientific theory with proper experiment. Scientist do experiment for collecting data, on the basis of it theory becomes law.*

Among participants, seven (16%) held informed view that scientific theories and laws were different kinds of knowledge and they did not develop into one another. The participant stated that:

P1*: Yes…theory is a kind of knowledge of science that* ***explains*** *nature, on the other hand, law* ***describes*** *the things what scientist sees (observes). Theory has its own function same as laws. They are not the same.*

Ambiguous category of the participants 'response of this study emerged also in this aspect (Table 2 & Fig. 1).

Empirical nature of scientific knowledge

Concerning the empirical nature of scientific knowledge referred to the VNOS-B# 4, the respondents separated science from the art in terms of evidences, data**,** and method (scientific method). They explained that experiments are conducted in science disciplines e.g. physics, chemistry and biology. However, not in other disciplines, for example, in religion and philosophy. Thirteen (29%) out of the forty five respondents believed that science rely on empirical data derived from experiment/ observation. Two of them claimed that:

P2: *Science and art are different kind of disciplines. Science discipline like physics, chemistry and biology require evidences or proof. By doing experiments and observations, more authentic knowledge could be found. But in religion, the situation is quite different. It does not require any proof.*

P4. *By Observing nature, scientists get evidences to explain phenomena. But artists do not use this type of evidence.*

On the other hand, thirty two (71%) of the respondents naively believed that scientists follow a general method when they do science. In contrast, artists do not follow any method to create their quilt, they use their imagination only. Two of the participants stated that:

P3: *They are different kinds of knowledge. Science follows step-wise procedure to come up with conclusion but art is not like that. Artists use their imagination to draw a picture, sculpture and so on.*

P5: *There is set rule for doing science. But in art, you cannot find any set rule or such a type rule.*

Creative and imaginative nature of scientific knowledge

In responding to the VNOS–B# 5; thirty three (73%) out of forty five participants did not seem to think that creativity and imagination were required at all steps of investigation/experimentation. Hence, they held traditional views. Some of them explicitly stated that only the time of data collection rather than planning, designing or interpreting, scientists use their imagination and creativity, and otherwise they just follow the books or manuals. This kind of response reflects the existence of universal step-wise procedure for doing science as well as human independent rhetoric of conclusion. Hence, dismissing the creative and imaginative nature of scientific endeavor. Three of the respondents expressed their views as follows:

P2: *Everything is written in the book (practical) accordingly. So they (scientists) just follow the instruction written in the book while setting experiment/ investigation.*

P3: *In the time of data generation, scientists try to use all sorts of their knowledge including imagination to produce valid data. After getting data, it automatically tells the result. To see the results scientists can say whether their investigation is correct or not.*

P4: *To generate data is a difficult process. So during data collection, they (scientists) use their creativity. Actually, they use scientific procedure to set investigation.*

On the other hand, twelve (27%) of the respondents believed that creativity and imagination are required from the very beginning to the end of the scientific investigation. Two of them stated that:

P1: *A Scientist has to think a lot when doing investigation. Thinking starts from data collection (e.g., where, when and what to collect for experiment) to the end (conclusion). Data cannot tell us anything without being analyzed/interpreted.*

P5. *Scientist is itself creative. Whatever they do they do creatively. From starting to end of experiment, they use their creativity.*

Subjective nature of scientific knowledge

In responding to the astronomical controversy referred to the VNOS-B#6; twenty six (58%) of the participants recognized the role of background knowledge, sociocultural factors and experiences in the development of scientific knowledge. Two of the respondents stated that:

P2: *Man's habit, attitude, and behavior are controlled by society as well as personal knowledge. Although we see (observe) the same thing, but we think differently due to our knowledge in particular subject. My major is zoology; I may be good at animal but may not be good in plants/others.*

P4. *Look…observation differs from person to person. For example… my observation and your observation are not similar. May be you have very good knowledge, I do not have or I may have very good knowledge in other subject you may not have…*

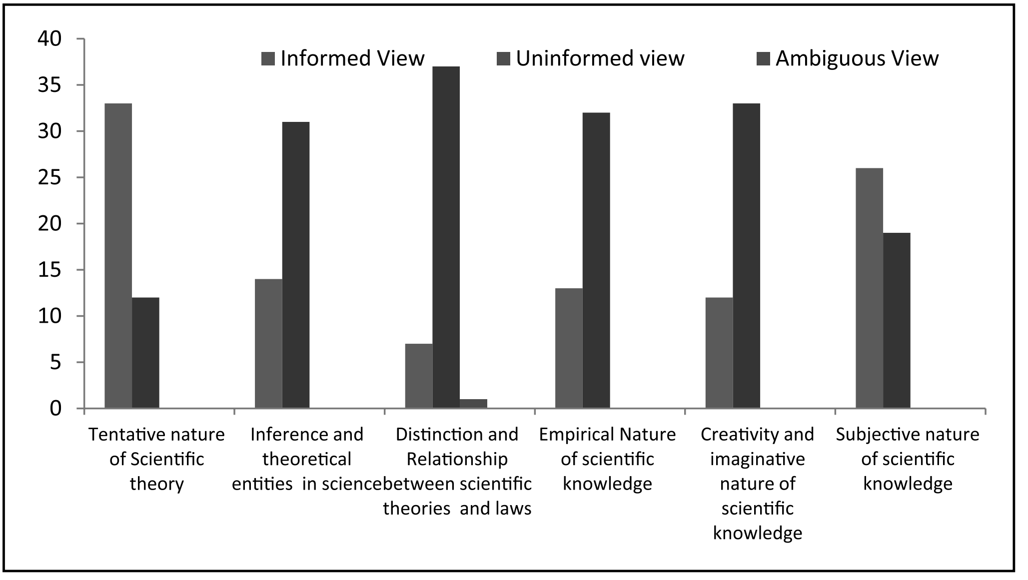

Fig. 1. Theme-wise participant's views

Although the participants in this study could not recognize directly the religious factor but indirectly they ascribed its role for constructing scientific knowledge. One of them stated that:

P1: *I think those who believe in Almighty/God, they must believe that earth doesn't change at all. It says in the holy Quran that earth is neither shrinks nor expands.*

Nineteen (42%) of the participants did not seem to think that background knowledge and other factors influence in developing scientific knowledge. They described the reason of it as being the lack a full set of data. Response like this reflects a more objective view of science. Two of the respondents stated that:

P3. *Knowledge and technology can make difference conclusion in observation. e.g. we cannot think highly because our knowledge is limited, besides we do not have high power technology. Those who have very good data by using technology, their result might be different although they observe the same thing.*

P5. *I think…reliable data source is very important for making good conclusion. Using technology and experience they get data on it. I mean astronomy. This is the data that make variation in conclusion.*

According to the discussion on findings, it can be concluded that secondary science teachers' views are mostly traditional (naïve), incoherent and fragmented on most of the aspects of NOS. Conversely, they have some contemporary views on some other aspects.

Misconceptions of Nature of Science

Although, the intension of this study is not directly to state the misconceptions of science teachers but due to the sensitiveness of the instrument some misconceptions of the respondents on the NOS had been recognized indirectly through this study (Table 3).

Table 3. Participants' misconceptions on the nature of science

Theory becomes law in available evidences
Hypotheses become theories that in turn become laws
Scientific laws and other such ideas are absolute
A general and universal step by step scientific method exists
Scientists are objective
Science model represents reality
Science is a solitary pursuit

Discussions and conclusion

The most promising and encouraging result of the present study is that most of the participants [33(73%)] are aware of the tentative nature of science. They believed that the reason for a change in scientific claim was due to new evidences that create better explanation. However, four of them 'naively' hold positivistic, idealistic view (Pomeroy, 1993). They believed that science is a body of knowledge that has been "proven" to be correct (Augirere, et al., 1990). The tentative characteristic of science explains that scientific knowledge is subject to change with new observations, discoveries and re-interpretations of existing observations (Lederman et al., 2002). This finding parallels the results of Liang et al., (2008), Erdoğan (2004), Sarker & Gomes (2010), Tan & Boo (2003), and Küçük (2008). Kuhn (1970) states that science textbooks convey an image of what science is and how it works (cited in McComas et al., 1998). Therefore, it can be speculated that science teachers in Bangladesh have got the image of the tentative nature of science from textbooks because science curriculum portrays scientific knowledge as tentative (Siddique, 2008).

Concerning the inferences and theoretical entities (model) in science, most participant [31(69%)] teachers have 'naïve' views. They considered atomic model as faithful copies of reality rather than a product of scientists' creativity and imagination. This finding does not agree with previous research findings (Haidar, 1999; Bell et al., 2000; Abd-El-Khalick et al., 1998). Bangladeshi teachers may gain this distorted views regarding inference and creativity, as a result of confusing portrayal (Siddique, 2008) of this aspect in the curriculum. The textbook portrays the aspect as incomplete ways it has must affects on teachers' understanding (Akerson et al., 2000). However, some of the participant in-service teachers recognized the involvement of human imagination and creativity in generating scientific knowledge. They ascribed a role for indirect evidences and or/ inference in the construction of the atomic models. They identified scientific model as an artificial, construct which is a resultant of scientist' inference; a precursor to making sense of a multitude of inferential and theoretical entities (Lederman et al., 2002).

An important finding of this research is that teachers were incoherent in expressing their views to a particular NOS aspect and to its associated aspects. For example, most of the teachers in this study believed in tentative nature of scientific theory which is supposed to change in light of evidence or the reconceptualization of existing evidence and knowledge (AAAS, 1990; National Science Teachers Association, 2000). However, the participant teachers could not believe 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 led to the believe that laws were absolute and did not change because they had been "proved" and were the ultimate source of scientific knowledge. This result is consistent with other studies conducted by Abd-El-Khalick et al. (1998), Liang et al., (2008), Erdoğan (2004), Sarker & Gomes (2010), and Tan & Boo (2003). It can be speculated that teachers might construct this dogmatic assumption and myth on the relationship between theories and laws without being communicated from textbooks or in classrooms. According to Siddique (2008), this aspect of the NOS are hardly discussed or separated in science curriculum of Bangladesh.

In the current study, the majority of the participants [32 (71%)] did not demonstrate the informed views of the empirical NOS. They could not recognize science reliance on data, proof or evidence rather they believed in myth of the "scientific method". They explicitly stated that science follows step-wise procedure to come up with valid and accurate results. This finding is in agreement with the study conducted by Küçük (2008). The myth of the scientific method is regularly manifested in the belief that there is a recipe-like step-wise procedure that all scientists follow when they do science. However, there is no single scientific method that would guarantee the development of infallible knowledge (AAAS, 1993; NRC, 1996). Traditional portrayal of recipe-like experiments in science textbooks to be the reason here. Like other educational systems, science textbooks (*e.g. in physics textbook*) in Bangladesh portray that there is one general method of conducting a scientific investigation (Siddique, 2008).

Concerning the creative and imaginative nature of scientific knowledge, most of the participants [33 (73%)] in this study did not seem to think that creativity and imagination are required at all steps of scientific investigation or experimentation. Some of them explicitly stated that only during the time of data collection rather than planning, designing or interpreting, scientists use their imagination and creativity, otherwise they just follow the books or manuals. The participants did not appreciate the creative work in searching for patterns in data, drawing inference from analysis, or developing models and theories. This result of the study is consistent with the previous studies (Tan & Boo, 2003; Küçük, 2008). The participants' expression of their views is quite similar to authoritarian views (Duschl, 1988, p.51). The rhetoric nature of science textbooks about ideas of science and improper practice of laboratory experiment could help to explain why the participant teachers of Bangladesh dismiss the creative and imaginative nature of scientific endeavor. Like other countries (McComas, 1998), the science curriculum of Bangladesh portrays science as a human independent rhetoric of conclusion through the recipe style practical work (Siddique, 2008).

An important finding is that the participants [26(58%)] in this study could able to recognize the role of scientists' background knowledge, socio-cultural factors and experiences in the development of scientific knowledge. They believed that science and scientific knowledge are subject to change and acknowledge the subjective aspect of the nature of science. This is in agreement with the study by Tan & Boo (2003) and Abd-El-Khalick et al. (1998). Conversely, nineteen [19 (42%)] of the participants failed to identify the fact that background knowledge and other factors has influence in developing scientific knowledge. They believed that science and scientific knowledge are objective and are not affected by subjective values such as personal experiences, preferences, and philosophical assumptions of scientists. Munby (1976) argues that science is being taught as a way of source of truth, reliable, and dependable knowledge (cited in McComas et al., 1998). Thus, it can be assumed that the participants' 'naïve' conception regarding the subjectivity of science may be the result of instructions in which science is taught as an objective way at schools.

This study revealed that science teachers in Bangladesh held traditional and incoherent views along with misunderstanding about many aspects of the NOS considered in this study. It is not surprising at all to find the NOS views of these teachers with teaching experience ranging between 5 to 10 years are at the uninformed state because like other educational contexts (McComas, 1998), Bangladeshi science teachers seldom have the opportunity to learn about the contemporary NOS in their own training. In addition, like in other countries (Abd-El-Khalick, 1998), Bangladeshi teachers are often not provided with opportunities to reflect on and clarify their views of the NOS. In an exam-driven and mechanical type educational system, the pertinent NOS issues may not appear in high-stake science examination, and therefore are rarely discussed in science classrooms in Bangladesh. To make science teachers aware of misconception and better understanding about the NOS, cognitive dissonance regarding the NOS issues together with explicit reflective instruction are being suggested (Akerson et al., 2000). Therefore, this study suggests further investigating on how the pedagogies of teacher education represent the NOS and what aspects of the NOS are communicated to the teachers through these pedagogies to find deeper understanding about the NOS.

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APPENDIX

Illustrative example of teachers' (P1) responses to the open-ended questions by NOS theme, category and code

…	NOS theme	Summary of the response	Category			Code
			In-formed views	Naïve views	Am-biguous views	
1	Tentative nature of Scientific theory	Theories are highly developed. It cannot change. For example, cell theory; it is same as before, there is no change. It is knowledge (facts) of science so we teach it.		×		-
2	Inference and theoretical entities in science	It's a kind of understanding of scientist about atom. They use evidences to create this construct. This is kind of explanation (interpretation –during interview).	×			+
3	Distinction and Relationship between scientific theories and laws	Theory is kind of detail of something (i.e. observation). It is kind of analysis (explanation) For example, why cyclones occur? Detail of the cyclone occurrence can be given by explaining nature). They never change into one another.	×			+
4	Empirical Nature of scientific knowledge	Science and arts are created by human being. Science need evidence (proof) but arts do not need. Both science and arts are human creation.	×			+
5	Creativity and imaginative nature of scientific knowledge	During entire process of investigation scientist use creativity. When, how and what data are being collected (we need) scientist need think and use creativity.	×			+

6	Subjective nature of scientific knowledge	Different culture' people think differently. Muslims thought is different with others thought. So various conclusions may be the reason of various cultures.	×			+
Educational Background		Science graduate, having Biology along with Physics and Chemistry at graduation level. 9 years teaching experience, received B.Ed., TQI, CPD & SBC.				

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✉ **Muhammad Nur-EAlam Siddiquee**
PhD fellow, ID: D114545
Graduate School for International Development and Cooperation (IDEC),
Hiroshima University
1-5-1 Kagamiyma, Higashi-Hiroshima 739-8529
E-mail. alam920@gmail.com

Hideo Ikeda
Professor, Graduate School for International Development and Cooperation,
Hiroshima University, Japan
E-mail: hikeda@hiroshma-u.ac.jp