Thai and Bangladeshi in-service science teachers' conceptions of nature of science: A comparative study

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Contents

Abstract

Understanding of nature of science (NOS) serves as one of the desirable characteristics of science teachers. The current study explored 55 Thai and 110 Bangladeshi in-service secondary science teachers' conceptions of NOS regarding scientific knowledge, scientific method, scientists' work, and scientific enterprise, by using the Myths of Science Questionnaire (MOSQ). The results revealed that Thai and Bangladeshi science teachers had nine different and five similar conceptions of NOS. The most common uninformed NOS conceptions held by both groups were science as cumulative knowledge and a relationship between theories and laws. The most different conceptions of NOS where Thai had more informed conceptions than Bangladeshi participants were science as individual enterprise, creativity and imagination in science, and scientific knowledge coming from experiments. Interestingly, of four subcategories, there were three (i.e. scientific knowledge, method, and enterprise) that Thai science teachers had more informed conceptions than Bangladeshi teachers. The explicit inclusion of NOS in the national science curriculum should be considered. In addition, the pattern of NOS conceptions that emerged from this study can be utilized for designing NOS professional development programs for Asian science teachers.

Keywords: in-service science teacher, nature of science, Thailand, Bangladesh, comparative study

Introduction

To become a scientifically literate person, learners "should develop an understanding of the concepts, principles, theories, and processes of science, and an awareness of the complex relationships between science, technology, and society ... [and] more important[ly] ... an understanding of nature of science" (Abd-El-Khalick & BouJaoude, 1997, p. 673). Therefore, an adequate understanding of nature of science (NOS) is widely accepted as one desirable characteristic for learners and included in many science curricula worldwide. Driver, Leach, Miller, and Scott (1996) support the inclusion of NOS as a goal of science instruction because NOS enhances learning of science content, understanding of science, interest in science, decision making in science-related issues, and science instructional delivery.

Science teachers are, therefore, responsible for helping learners attain an adequate understanding of NOS. However, numerous studies have shown that many science teachers possess an inadequate understanding of NOS. This situation might be harmful because teachers must have an understanding of what they are attempting to communicate to their students (Lederman, 1992). Without sufficient informed conceptions of NOS, science teachers cannot effectively address NOS in their classroom (Abd-El-Khalick & Lederman, 2000). As Lederman (1992) noted, "the most important variables that influence students' beliefs about NOS are those specific instructional behaviours, activities, and decisions implemented within the context of a lesson" (p. 351). Promoting science teachers' understanding of NOS appears to be a prerequisite for effective NOS science teaching (McComas, Clough, & Almazroa, 1998). In addition, promoting NOS conceptions increases science teachers' efforts to integrate inquiry into their instruction by boosting their confidence in abilities to teach science through inquiry (Atar & Gallard, 2011). However, several studies reveal that many science teachers possess an inadequate, incoherent understanding of NOS (Abd-El-Khalick & BouJaoude, 1997; Lederman, 1992).

Because of the importance of NOS, as mentioned earlier, NOS had been included in many science curricula worldwide. In the Thai context, the first time that NOS had been explicitly mentioned in the basic education curriculum, was 2001 in, The Basic Education Curriculum B.E. 2544 (Ministry of Education, 2001). Since 2001, all science teachers are, therefore, responsible to teach NOS in their science classrooms. A decade ago, NOS was normally expected to take a strong root in science education in Thailand. However, many NOS studies conducted in Thailand revealed that many Thai science teachers displayed uninformed conceptions of NOS (Buaraphan, 2009a, 2009b; Buaraphan et al., 2009). In the same region, that is Southeast Asia, Bangladesh is on the move to explicitly include NOS in the national science curriculum. A comparative study of NOS conceptions held by science teachers in a country with the explicit inclusion of NOS (i.e. Thailand) and a country with implicit inclusion of NOS (i.e. Bangladesh) may provide some useful perspectives for science educators in cultivating NOS education in their countries.

Literature review

Definition of NOS

NOS is a fuzzy construct; it is neither universal nor stable. There are many attempts to define NOS; for example, McComas, Clough, and Almazroa (1998) provide an overall description of NOS as:

> NOS is a fertile hybrid arena, which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours. (p. 4)

From an intensive review of the NOS literature, in-service science teachers' conceptions of NOS can be categorized into four major groups: a) scientific knowledge, b) scientific method, c) scientists' work, and d) scientific enterprise. The next section presents science teachers' conceptions of NOS within these four groups.

In-service science teachers' conceptions of NOS

With the use of different methods and instruments, the literature suggests that many in-service science teachers possess an inadequate, mixed, and incoherent understanding of NOS (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). Also, there is no significant relationship between science teachers' academic background or personal antecedents in school and their conceptions of NOS (Carey & Stauss, 1970; Lederman, 1992; Mellado, 1997). In-service science teachers' conceptions of NOS, in particular to scientific knowledge, scientific method, scientists' work, and scientific enterprise are presented in the following section.

Scientific knowledge: hypotheses, theories, and laws

In various studies, a majority of science teachers had naïve conceptions regarding a hierarchical relationship between hypotheses, theories, and laws (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Rubba & Harkness, 1993). They believed that when a hypothesis is proven correct, it becomes a theory. After a theory has been proved true many times by different people and has been around for a long time, it becomes a law. The availability or accumulation of supporting evidence was also linked with the status of the truth or correctness of hypotheses, theories, and laws (Dogan & Abd-El-Khalick, 2008).

The conception that these constructs are different types of ideas was not grasped (Abd-El-Khalick & BouJaoude, 1997).

Scientific knowledge: tentativeness of science

Regarding the status of scientific knowledge, in-service science teachers can be categorized into two groups using a static-dynamic split. The science teachers in the first group view science as stable or having a static status, while those in the second group view science as tentative or having a dynamic status. In the static-science group, for example, 24.1 per cent of science teachers claimed that science is a collection of facts or a body of knowledge that explains the world (Tairab, 2001). Scientific knowledge, therefore, was regarded as static (Behnke, 1961). The major purpose of scientific research is, therefore, to collect as much data as possible (Craven, Hand, & Prain, 2002; Tairab, 2001). In the dynamic-science group, the science teachers generally believed in the tentativeness of scientific knowledge (Dogan & Abd-El-Khalick, 2008). For example, four of five primary teachers in Lunn's study (2002) believed that science is constantly evolving to adequately give a full world-view, especially some mysterious patterns in nature. Theories, for example, can be renewed and changed both in the light of new knowledge and new facts.

Scientific knowledge: cumulative knowledge

Scientific knowledge as cumulative knowledge was the naïve conception being linked to their status of truth or correctness (Dogan & Abd-El-Khalick, 2008). Most in-service science teachers strongly believed that scientific knowledge is cumulative and its advancement depends heavily on the accumulation of facts or increasing observation rather than changes in theory (Brickhouse, 1990; Haidar, 1999).

Scientific knowledge: scientific model

Scientific models are copies of reality is a popular uninformed conception of NOS for most science teachers (Dogan & Abd-El-Khalick, 2008). Scientific models, in their view, are copies of reality rather than human inventions (Abd-El-Khalick & BouJaoude, 1997) because scientists say they are true or because much scientific observation and/or research have shown them to be true (Dogan & Abd-El-Khalick, 2008). However, many teachers, especially those who hold constructivist views, can articulate the role of scientific models as scientists' best ideas or educated guesses to represent reality rather than exact replicas of experienced phenomena (Haidar, 1999).

Scientific method: universal, step-wise method

The scientific method is commonly perceived by science teachers as a universal step-wise method (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). This can be attributed to the science curriculum that presents the scientific method as a sequence of steps that all students have to follow exactly in order to reach certain results (Haidar, 1999) or an unambiguous scientific truth (Brickhouse, 1990). For a majority of science teachers, good scientists were, therefore, those who follow a recipe - the steps of the scientific method - in their investigations (Abd-El-Khalick & BouJaoude, 1997; Haidar, 1999).

Scientists' work: theory-laden observation and subjectivity

Some of the most common bipolar views of NOS are subjectivity and objectivity, theory-laden and theory-free, or value-laden and value-free. For most science teachers, subjectivity plays a major role in the development of scientific ideas (Abd-El-Khalick & BouJaoude, 1997) because scientists' worldviews or paradigms affect their scientific thinking and decision-making (Lunn, 2002, p. 664). However, many science teachers strongly believed in objectivity in science, which is firmly based upon theory-free or value-free observation. For example, nearly half of the science teachers held the naïve conception that observation is not influenced by the theories that scientists hold (Brickhouse, 1990; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). Most science teachers (71%) adopted the idealistic view that the scientists' interpretation was objective and far from their frames of reference (Abd-El-Khalick & BouJaoude, 1997; Rampal, 1992).

Scientists' work: creativity and imagination in science

The role of creativity and imagination in the construction of scientific ideas is overlooked by most science teachers because they believe that scientists must follow a fixed-step scientific method (Abd-El-Khalick & BouJaoude, 1997). For example, there were less than 10% of science teachers in Rampal's study (1992) who recognized the importance of creativity in scientists' work. In this case, 'creativity seems to be stereotypically dissociated from perceived scientific qualities' (p. 424).

Scientific enterprise: social and cultural influences on science

The social and cultural influences on the scientific enterprise are explicitly recognised by most science teachers (Brush, 1989). For example, 51 per cent and 42.3 per cent, respectively, of science teachers in Haidar (1999) and Rubba and Harkness (1993) indicated that a scientist is influenced by social factors. In addition, 79.6 per cent of science teachers in Tairab's study (2001) expressed the view that science and technology affect society and in turn society affects science and technology. However, only 10 per cent and 26 per cent, respectively, of science teachers believed that while collecting or presenting information a scientist is influenced by social biases and governmental pressure. They regarded the authoritative image of the scientist as accurate (Rampal, 1992).

Scientific enterprise: interaction between science and technology

It is, perhaps, an easy task for in-service science teachers to recognise the interaction between science and technology in such ideas as science is the knowledge base for technology, and technology influences science advancement (Rubba & Harkness, 1993). However, distinguishing between science and technology is probably a very difficult task for them (Rubba & Harkness, 1993). 'Technology is applied science' is their commonplace naïve conception about the relationship between science and technology (Tairab, 2001).

Education and NOS education in the Thai context

Thailand is located in the heart of Southeast Asia. The country is bordered to the north by Laos and Burma, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and Burma. The Thai population was about 67 million. The literacy rate of Thai people is 92.6 per cent. Thailand has never been colonized. Religions espoused by the Thai people are Buddhism (94.6%), Islam (4.6%), Christianity (0.7%), and other (0.1%). The country's official spoken and written language is Thai; while the secondary language is English. Thailand is divided into 77 provinces, which are gathered into six regions - North, North-East, Central, East, West, and South. The capital and largest city of Thailand is Bangkok.

Basic education in Thailand includes 12 years of study (Grades 1-12). The proclamation of the National Education Act B.E. 2542 (A.D. 1999), revised in B.E. 2545 (Office of the Education Council, 2002), in Thailand brings all stakeholders together in joint continuing efforts toward education reform. Science is emphasised and situated in section 23 of the National Education Act (2002):

> Education through formal, non-formal, and informal approaches shall give emphases to knowledge, morality, learning process, and investigation ... scientific and technological knowledge and skills, as well as knowledge, understanding and experience in management, conservation, and utilisation of natural resources and the environment in a balanced and sustainable manner ... (Office of the Education Council, 2002, p. 10)

To support the reform, the Ministry of Education launched a new curriculum, namely, the Basic Education Curriculum B.E. 2544 (A.D. 2001) (Ministry of Education, 2001), which consists of eight Learning Areas: Thai language; Mathematics; Science; Social Studies, Religion, and Culture; Foreign Languages; Health and Physical Education; Arts; and Occupations and Technology.

Specifically, the content of the Science learning area is "Application of knowledge and scientific process for study and search for knowledge and systematic problem-solving; logical, analytical and constructive thinking; and scientific-mindedness". In the Science learning area is the first time that NOS has been explicitly mentioned in the national curriculum. That is, NOS is mentioned in the learning sub-strand 8: Nature of Science and Technology, which consists of one standard (Standard Sc 8.1):

> The student should be able to use the scientific process and scientific mind in investigation, solve problems, know that most natural phenomena have a definite period of investigation, [and] understand that science, technology and environment are interrelated (Institute for the Promotion of Teaching Science and Technology, 2002, p. 7).

Consequently, since 2001, all Thai science teachers must help their students accomplish the NOS standard mentioned earlier.

Before NOS being explicitly mentioned in the national basic education curriculum, there are many studies related to NOS. There are 26 NOS studies published during 1997-2001. These studies are the Master theses which were extensively researched in the Northeastern region. Of 26 Master's theses about NOS, there were 21 studies in relation to in-service secondary science teachers' conceptions of NOS. All of them employed a quantitative approach with the same questionnaire, the

Understanding about Nature of Science Questionnaire (Boonmuangsaen, 1997). Boonmuangsaen created this questionnaire by applying the ideas from various NOS studies, i.e., Palmer (1979), Billeh and Malik (1977), Rubba and Anderson (1978), Pomery (1993), Tamir (1994), Doran, Guerin, and Cavalieri (1974), Fleming (1987), Ryan (1987) and Rubba and Harkness (1993). The questionnaire consisted of 94 items measuring four scales of NOS: Assumptions of the nature (12 items); Scientific knowledge (24 items); Scientific method (24 items), and Interaction between science-society-technology (34 items). All items are a five-rating scale ranging from strongly disagree to strongly agree. An example item of the Assumptions of the Nature is: "Item 11: The natural phenomena must occur constantly." The item-total correlation and the Cronbach alpha coefficient of the Understanding about Nature of Science Questionnaire was between 0.438 to 0.867 and between 0.792 to 0.923, respectively.

The common goal for those 26 studies was to find the relationship between science teachers' gender, teaching experience, and levels or types of schools they taught at and their conceptions of NOS. Two major findings emerged from these quantitative studies. First, a majority of science teachers had a high level of understanding of NOS mentioned in the questionnaire. Second, there was no relationship between teachers' gender, teaching experience, and levels or types of schools taught and their conceptions of NOS.

With the newer instrument, the Myths of Science Questionnaire (MOSQ) (see Figure 1), Buaraphan (2009) discovered that Thai in-service science teachers held eight common uninformed conceptions of NOS: scientific theories can be developed to become laws; accumulation of evidence makes scientific knowledge more stable; scientists are open-minded without any biases; scientific theories are less secure than laws; the scientific method is a fixed step-by-step process; science and the scientific method can answer all questions; a scientific model expresses a copy of reality; and science and technology are identical.

Education and NOS education in the Bangladeshi context

Bangladesh is located in Southern Asia, bordering the Bay of Bengal, between Burma and India. The population in Bangladesh is about 163 million. The literacy rate of Bangladeshi people is 43.1%. The religion espoused by Bangladeshi people Islam (83%), Hindism (16%), and other (1%). The official languages used are Bangla (also known as Bengali) and English. Bangladesh became independent from Pakistan in 1971. There are seven divisions or provinces in Bangladesh: Barisal, Chittagong, Dhaka, Khulna, Rajshahi, Rangpur, and Sylhet. Dhaka is the capital city and largest province.

There are three education systems in Bangladesh: general, madrasa (religious), and technical-vocational and professional. Each of these is divided into five levels: primary (compulsory) (years 1-5), junior secondary (years 6-8), secondary (years 9-10), higher secondary (years 11-12), and tertiary (university).

Before graduating from the secondary education (Grades 6-12), all students must take a national test, the Board Exam, for the junior secondary, secondary, and higher secondary levels. The students in Grades 8 and 10 must take a national test for the Junior School Certificate (JSC) and the Secondary School Certificate (SSC), respectively. Normally, students study junior and secondary levels in the same school and shift to a college and take a national test for Higher Secondary Certificate (HSC) after Grade 12.

Bengali and English (language and literature), mathematics, general science, social science and religious study (Islam, Hinduism, Buddhism and Christianity) are the compulsory subjects until the junior level. During Grades 9-12, students can choose to learn in the Science, Humanities, or Commerce fields. For the science field, the students can choose a specific field of science subject: physics, chemistry, biology, or higher mathematics. For the Humanities field, the students can choose one from these fields: history, geography, economics, or civics. For the Commerce field, the students can choose to learn specifically in accounting, introduction to business, or commercial geography. All fields must choose one optional subject from Agriculture studies, Computer study, or Arabic/ Sanskrit/ Pale.

The National Curriculum and Textbook Board (NCTB) develops the curriculum as well as producing the standard textbooks and assessment papers. The Ministry of Education is responsible for policy making. NOS is not explicitly mentioned in the Bangladeshi science curriculum; therefore, the literature about NOS in the Bangladeshi context is rare. One contemporary study by Sarkar and Gomes (2010) found that a majority of the participating science teachers held uninformed conceptions about most of the target NOS aspects. Also, the teachers were not consistent in expressing their views to a particular NOS aspect and to its associated aspects. They finally suggested doing more research for better understanding about Bangladeshi teachers' mental models of NOS and their NOS classroom practices.

From the literature review, there is no study for comparison of NOS conceptions held by Thai and Bangladeshi in-service science teachers. Such a comparative study may contribute to the NOS literature, especially in the Asian context, about cultivating or developing NOS education.

Research questions

The study was guided by two research questions.

RQ1. What are Thai and Bangladeshi in-service science teachers' conceptions of NOS?

RQ2. What are the similarities and differences between conceptions of NOS held by Thai and Bangladeshi teachers?

Method

Instrument

The Myths of Science Questionnaire (MOSQ) (Buaraphan, 2012) was employed to explore science teachers' conceptions of NOS. MOSQ consists of 14 items and addresses four aspects of NOS: scientific knowledge (Items 1-4, 8, and 9); scientific method (Items 5-7); scientists' work (Items 10-11); and scientific enterprise (Items 12-14). MOSQ respondents are required to select which of three responses, i.e., agree, uncertain, or disagree, best fits their opinion of the item statement and to provide an additional written response to support their selection. The completion of the questionnaire took approximately 45 minutes. The content validity of MOSQ was established by five science educators. The Cronbach's alpha reliability coefficient of MOSQ was .79. All MOSQ items are presented in Figure 1.

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

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

Figure 1 Myths of Science Questionnaire (MOSQ)

When translating MOSQ into the Bangladeshi language (Bengali), the back translation approach was employed. First, three Bangladeshi educators were asked to check the accuracy of translation from English to Bengali. Their comments were used to revise MOSQ in the Bengali version. Next, another three Bangladeshi educators were asked to back translate the revised MOSQ from Bengali to English. The researchers checked the match between both translations. Any mismatch of translation was resolved by consensus in an experts meeting.

Data collection

The participants of this study were derived from purposeful sampling, which is one type of the non-probability based sampling techniques. To elaborate, purposeful sampling avoids random sampling by targeting a specific group of people, often a small group rather than a more general one (Kerlinger, 1986). However, the sample derived from purposeful sampling is not easily defensible as being representative of populations due to potential subjectivity of researcher (Black, 1999). The main objective of this study is not to generalize the findings from a sample to a population, but rather to derive more information about NOS conceptions of science teachers from Thailand and Bangladesh reflected through MOSQ. The criteria for participants in this study were that they must be in-service science teachers, who are responsible for teaching in the secondary level in either Thailand or Bangladesh.

The data were collected from 165 in-service secondary science teachers in the 2011 academic year. Two-thirds of the participants were Bangladeshi (n = 110) and one-third Thai (n = 55). The data collection in Bangladesh occurred in the capital city, Dhaka, and the central region. In Thailand, the data was collected from six regions—North, Northeast, Central, East, West, and South. Three-quarters of Thai participants (76.37%) were female; in contrast, most of the Bangladeshi participants (83.63%) were male. The age range of Thai and Bangladeshi participants is shown in Table 1. Interestingly, nearly half of the Thai participants (49.09%) were more than 46 years old and most of Bangladeshi participants (84.54%) were 26 to 40 years old.

Table 1. Appropriateness of the data for factor analysis

Nationality	Age range (Year)						
	Lower 25	26-30	31-35	36-40	41-45	46-50	Upper 50
Thai	1 (1.81%)	9 (16.36%)	6 (10.90%)	8 (14.54%)	4 (7.27%)	13 (23.63%)	14 (25.45%)
Bangladeshi	0 (0.00%)	30 (27.27%)	34 (30.90%)	29 (26.36%)	7 (6.36%)	6 (5.45%)	4 (3.63%)
Total	1 (0.60%)	39 (23.63%)	40 (24.24%)	37 (22.42%)	11 (6.67%)	19 (11.51%)	18 (10.90%)

Data analysis

From MOSQ, the "agree," "uncertain," and "disagree" responses were, respectively, interpreted as "informed," "uncertain," and "uninformed" conceptions of NOS. However, "one's view of NOS is a complex web of ideas that loses meaning when reduced to simple numbers" (Palmquist & Finley, 1997, p. 601). Therefore, a written response provided by a participant in each item was also considered to support a final categorization. The informed conceptions of NOS (Adapted from Urhahne, Kremer, & Mayer (2011) and McComas (1998)) embedded in MOSQ are illustrated in Figure 2.

MOSQ Item	Informed conception of NOS
1. Hypotheses are developed to become theories only.	The belief in a hierarchical relationship between hypotheses, theories, and laws generally leads to the uninformed conception that “hypotheses are developed to become theories only”. Really, hypotheses can be developed to become theories or even laws. Sonleitner (1989) labeled the hypotheses becoming laws as the “generalizing hypotheses” and the hypotheses becoming theories as the “explanatory hypotheses.”
2. Scientific theories are less secure than laws.	In science, theories and laws are different kinds of knowledge and serve different functions. Scientific theories are highly respected, well trusted, and in themselves consistent explanatory systems. Predictions can be derived from them and tested by observable facts. Laws formally describe the relations between observable phenomena. Laws do not possess a higher rank than theories.

3. Scientific theories can be developed to become laws.	There is a relationship between theories and laws, but it is not the case that one simply becomes the other—no matter how much empirical evidence is amassed. Laws are generalizations, principles or patterns in the nature and theories are the explanations of these generalizations.
4. Scientific knowledge cannot be changed.	The general success of the scientific endeavor suggests that its products must be valid. However, the hallmark of science is that it is subject to revision when new information is presented.
5. The scientific method is a fixed step-by-step process.	Science does not differ from other human endeavors when puzzles are investigated. There is no universal step-by-step scientific method. Scientists approach and solve problems with imagination, creativity, prior knowledge and perseverance.
6. Science and the scientific method can answer all questions.	Some questions simply must not be asked of scientists. Science as a discipline simply cannot answer moral, ethical, aesthetic, social and metaphysical questions, although it can provide some insights which might be illuminating.
7. Scientific knowledge comes from experiments only.	Experimentation is a useful tool in science, but is not the sole route to knowledge. Many scientists use non-experimental techniques to advance knowledge. For example, many fundamental discoveries in astronomy are based on extensive observations rather than experiments.
8. Accumulation of evidence makes scientific knowledge more stable.	Accumulated evidence can provide support, validation and substantiation for laws or theories, but will never prove those laws and theories to be true and guarantee they are more stable. No matter how much evidence accumulated, once disconfirming evidence has emerged, at least we know that those laws and theories are untrue.
9. A scientific model (e.g., the atomic model) expresses a	One limitation of science is that the truenature of reality can never be known because there is no omniscient entity to ask. Science was invented at least in part (as a scientific model is invented) to answer questions about the natural world and get as

copy of reality.	close to the truth as possible.
10. Scientists do not use creativity and imagination in developing scientific knowledge.	The production of scientific knowledge is not a perfectly rational and absolutely logical process. The development of scientific knowledge requires a scientist's creativity and imagination. This is valid for all research processes, from finding research ideas to analyzing and interpreting data. Some scientific concepts are based on enormous intellectual performances, which would not have been possible without the inspiration and imaginative power of scientists.
11. Scientists are open-minded without any biases.	Scientists, like other observers, hold myriad preconceptions and biases about the way the world operates. Scientists, inevitably, employ the theory-laden observation and it is impossible for them to collect and interpret facts without any bias.
12. Science and technology are identical.	The pursuit of knowledge for the sake of knowledge alone is called pure science while its exploitation in the production of a commercial product is applied science or technology.
13. Scientific enterprise is an individual enterprise.	Scientific enterprise is not limited to individual pursuit. Scientists work in research teams with a community of like-minded investigators. Cooperation and collaboration among scientists promote the development of scientific knowledge. Many problems in science are simply too complex for a sole individual to pursue alone due to constraints of time, intellectual capital and financing.
14. Society, politics, and culture do not affect the development of scientific knowledge.	Science is conducted in a cultural context in which scientists are inevitably embedded. So, the scientific enterprise is not value-free, but can be influenced by society, politics, and culture.

Figure 2 Informed conceptions of NOS embedded in MOSQ

Note: Adapted from Urhahne, Kremer, and Mayer (2011) and McComas (1998)

After that, the frequency of each type of NOS conception was counted and calculated for percentage. Finally, a chi-square test was run to examine the differences between Thai and Bangladeshi science teachers' NOS conceptions at the .01 significance level.

Findings

Thai and Bangladeshi science teachers' conceptions of NOS can be compared and shown as Table 2.

Table 2. Thai (T) and Bangladeshi (B) in-service science teachers' conceptions of NOS

Item	Response						Chi-square	Sig.
	Uninformed		Uncertain		Informed			
	T(%)	B(%)	T(%)	B(%)	T(%)	B(%)		
1. Hypotheses are developed to become theories only	25.5	58.2	27.3	17.3	47.3	24.5	15.983	.000*
2. Scientific theories are less secure than laws	42.6	71.8	27.8	17.3	29.6	10.9	16.261	.001*
3.Scientific theories can be developed to become laws	79.2	68.2	17.0	19.1	3.8	12.7	7.621	.055
4. Scientific knowledge cannot be changed	3.6	32.7	3.6	14.5	92.7	52.7	26.354	.000*
5. The scientific method is a fixed step-by-step process	47.3	71.8	10.9	18.2	41.8	10.0	22.717	.000*
6. Science and the scientific method can answer all questions	42.6	35.5	35.2	22.7	22.2	41.8	8.488	.037
7. Scientific knowledge comes from experiments only	5.5	63.6	18.2	17.3	76.4	19.1	59.572	.000*
8. Accumulation of evidence makes scientific knowledge more stable	81.8	78.2	9.1	10.0	9.1	11.8	.342	.843
9. A scientific model (e.g., atomic model) expresses a copy of reality	34.5	53.6	47.3	34.5	18.2	11.8	5.423	.066

10. Scientists do not use creativity and imagination in developing scientific knowledge	7.3	49.1	10.9	18.2	81.8	32.7	37.472	.000 *
11. Scientists are open-minded without any biases	85.5	62.7	10.9	15.5	3.6	21.8	10.930	.004 *
12. Science and technology are identical	45.5	41.8	21.8	21.8	32.7	36.4	.251	.882
13. Scientific enterprise is an individual enterprise	3.6	67.3	1.8	20.0	94.5	12.7	102.296	.000 *
14. Society, politics, and culture do not affect development of scientific knowledge	5.6	40.9	14.8	6.4	79.6	52.7	24.425	.000 *

Note * represents .01 statistical significance level

Holistically, there were both similarities and differences in the NOS conceptions held by Thai and Bangladeshi science teachers. Of 14 items, there were nine that showed significant differences responses between two groups: Hypotheses are developed to become theories only (Item 1) ($\chi2 = 15.983$, $p < .01$); Scientific theories are less secure than laws (Item 2) ($\chi2 = 16.261$, $p < .01$); Scientific knowledge cannot be changed (Item 4) ($\chi2 = 26.354$, $p < .01$); The scientific method is a fixed step-by-step process (Item 5) ($\chi2 = 22.717$, $p < .01$), Scientific knowledge comes from experiments only (Item 7) ($\chi2 = 59.572$, $p < .01$); Scientists do not use creativity and imagination in developing scientific knowledge (Item 10) ($\chi2 = 37.472$, $p < .01$); Scientists are open-minded without any biases (Item 11) ($\chi2 = 10.930$, $p < .01$); Scientific enterprise is an individual enterprise (Item 13) ($\chi2 = 102.296$, $p < .01$);and Society, politics, and culture do not affect development of scientific knowledge (Item 14) ($\chi2 = 24.425$, $p < .01$).

Of nine different conceptions, there were eight where a significant number of Bangladeshi science teachers had more uninformed conceptions than Thai teachers: Hypotheses are developed to become theories only (Bangladeshi 58.2%; Thai 25.5%); Scientific theories are less secure than laws (Bangladeshi 71.8%; Thai 42.6%), Scientific knowledge cannot be changed (Bangladeshi 32.7%; Thai 3.6%); The scientific method is a fixed step-by-step process (Bangladeshi 71.8%; Thai 47.3%); Scientific knowledge comes from experiments only (Bangladeshi 63.6%;

Thai 5.5%);, Scientists do not use creativity and imagination in developing scientific knowledge (Bangladeshi 49.1%; Thai 7.3%);, Scientific enterprise is an individual enterprise (Bangladeshi 67.3%; Thai 3.6%); and Society, politics, and culture do not affect development of scientific knowledge (Bangladeshi 40.9%; Thai 5.6%). Specifically, for five of these eight NOS conceptions, more than half of the Bangladeshi teachers held more misconceptions than Thai teachers: a relationship between hypotheses and theories, a relationship between theories and laws, the step-by-step, scientific method, scientific knowledge coming from experiments, and science as individual enterprise. In contrast, there was only one uninformed conception of NOS which Thai science teachers held significantly more than Bangladeshi teachers: Scientists are open-minded without any biases (Thai 85.5%; Bangladeshi 62.7%).

Interestingly, there were three remarkably differently held NOS conceptions between Thai and Bangladeshi science teachers. More than three-quarters of Thai participants had more informed conceptions than Bangladeshi participants: science as individual enterprise (Thai 94.5%; Bangladeshi 12.7%), creativity and imagination in science (Thai 81.8%; Bangladeshi 32.7%), and scientific knowledge coming from experiments (Thai 76.4%; Bangladeshi 19.1%).

Of 14 conceptions, there were five similar conceptions of NOS shared by Thai and Bangladeshi science teachers: Scientific theories can be developed to become laws (Item 3); Science and the scientific method can answer all questions (Item 6); Accumulation of evidence makes scientific knowledge more stable (Item 8); A scientific model expresses a copy of reality (Item 9); and Science and technology are identical (Item 12). Among these conceptions, science as cumulative knowledge (Item 8) (Thai 81.8%; Bangladeshi 78.2%) and a relationship between theories and laws (Item 3) (Thai 79.2%; Bangladeshi 68.2%) appeared as misconceptions of NOS commonly shared by both groups.

In addition, the participants' conceptions of NOS were analyzed into four subcategories: scientific knowledge (Items 1-4, 8, & 9); scientific method (Items 5-7); scientists' work (Items 10-11); and scientific enterprise (Items 12-14). The findings are presented in Table 3.

Table 3. Thai and Bangladeshi in-service science teachers' conceptions of NOS divided into four subcategories

Item	Response						Chi-square	Sig.
	Uninformed		Uncertain		Informed			
	Thai (%)	Bangladeshi (%)	Thai (%)	Bangladeshi (%)	Thai (%)	Bangladeshi (%)		
Scientific knowledge	37.33	60.45	18.89	18.79	43.78	20.76	57.373	.000*
Scientific method	31.71	57.02	21.34	20.70	46.95	22.28	47.112	.000*
Scientists' work	46.36	55.91	10.91	16.82	42.73	27.27	8.394	.015
Scientific enterprise	18.29	50.00	12.80	16.06	68.90	33.94	59.967	.000*

Note * represents .01 statistical significance level

Table 3 shows that Thai in-service science teachers held significantly more informed conceptions of NOS than Bangladeshi teachers in the scientific knowledge, scientific method, and scientific enterprise subcategories. However, there was no significant difference in NOS conceptions in the scientists' work subcategory for the teachers from both countries.

Discussion

First of all, MOSQ reveals that Thai in-service science teachers do not possess a high level of NOS conceptions as was previously found by a quantitative instrument, The Understanding about NOS Questionnaire (Boonmuangsaen, 1997). This contradictory finding may come from the different instrument used. MOSQ can yield more qualitative data that may provide another perspective for science educators in exploring NOS conceptions.

This study suggests that cultivating NOS education is a difficult and challenging task. For more than a decade of explicit inclusion of NOS in the basic education curriculum of Thailand, NOS is generally believed to have become deeply rooted in Thai science teachers and their classrooms. However, this study reveals that Thai science teachers still possess many uninformed conceptions of NOS. In addition, one NOS study conducted in the Thai context indicates that science teachers' conceptions of NOS are stable and resistant to change. Many Thai science teachers face difficulties in integrating NOS in their teaching because the new science curriculum does not suggest to them how to teach NOS. Embedding NOS in teaching appears as a difficult task requiring a great amount of support from the government (Buaraphan, 2012).

There are two most common uninformed conceptions of NOS held by the science teachers from Thailand and Bangladesh: Scientific theories can be developed to become laws; and Accumulation of evidence makes scientific knowledge more stable.

This study suggests that cultivating NOS education is a difficult and challenging task. For more than a decade of explicit inclusion of NOS in the basic education curriculum of Thailand, NOS is generally believed to have become deeply rooted in Thai science teachers and their classrooms. However, this study reveals that Thai science teachers still possess many uninformed conceptions of NOS. In addition, one NOS study conducted in the Thai context indicates that science teachers' conceptions of NOS are stable and resistant to change. Many Thai science teachers face difficulties in integrating NOS in their teaching because the new science curriculum does not suggest to them how to teach NOS. Embedding NOS in teaching appears as a difficult task requiring a great amount of support from the government (Buaraphan, 2012).

The first uninformed conception of NOS shows that the participants from both countries cannot recognize the difference between scientific theories and laws: Laws are the statement of patterns from observable phenomenon; and Theories are generalized descriptions of those observed patterns. In this case, Thai and Bangladeshi science teachers believed in the laws-are-mature-theories-fables that leads them to perceive theories as being less secure than laws (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999). The misconception regarding laws-are-mature-theories-fables in both Thailand and Bangladesh has generally emerged from the appearance of a hierarchical relationship between hypotheses, theories and laws in many science textbooks as: Hypotheses → Theories → Laws. This misinterpretation of hypotheses, theories, and laws has been embedded in science education of both countries for a long time and is hard to uproot.

The second uninformed conception of NOS shows the popularity of Baconian induction. That is, both Thai and Bangladeshi science teachers view science as a cumulative process—individual pieces of evidence are collected and examined until a law is discovered—rather than revisionary process (Brickhouse, 1990; Haidar, 1999). In this case, they are unaware of the problem of Baconian induction, i.e., "even a preponderance of evidence does not guarantee the production of valid knowledge" (McComas, 1998, p. 58). From the literature, it appears that these two common misconceptions of NOS found in Thai and Bangladeshi science teachers are also common for others around the world (Dogan & Abd-El-Khalick, 2008; Iqbal, Azam, & Rana, 2009; McComas, 2008). The misconception of NOS regarding the Baconian induction may link with the laws-are-mature-theories-fables. As described earlier, some teachers or people strongly believe in the hierarchical relationship between theories and laws. That is, when evidence supporting a theory is continuously accumulated time after time; one day when such accumulated evidence is sufficient, the theory can become a law.

Science educators need to be more aware of the two common uninformed conceptions of NOS mentioned earlier. This implies that despite the explicit inclusion of NOS in the environment as in the Thai context, those uninformed NOS conceptions are still alive. They should be regarded as conceptions of NOS which are resistant to change.

This comparative study reveals the advantage of explicit inclusion of NOS in science curriculum by showing that Thai science teachers hold significantly more informed conceptions of NOS than Bangladeshi teachers: specifically, the NOS conceptions of science as individual enterprise, creativity and imagination in science, and experiments as the way for testing scientific knowledge. When analyzing the participants' conceptions of NOS in four subcategories (scientific knowledge, scientific method, scientists' work, and scientific enterprise), Thai in-service science teachers present more informed conceptions of NOS than Bangladeshi teachers in three subcategories. These findings promote the explicit inclusion of NOS in the national science curriculum rather than implicit inclusion. Without explicit inclusion of NOS in the science curriculum, Bangladeshi science teachers rarely have the opportunity to learn and teach about NOS (Sarkar & Gomes, 2010). NOS understanding should not be anticipated as a side effect of hands-on science (Akindehin, 1988) as previously believed.

Implications

NOS understanding is widely accepted as one important attribute for science students. Therefore, at present, NOS is included in many curricula worldwide. However, this study reveals that cultivating NOS education in the existing science classrooms is not an easy task at all. The requirement for cultivating NOS education is to explicitly include NOS in the national science curriculum. However, including NOS in the science curriculum is not enough to ensure the effective teaching and learning of NOS. Science teachers need well-designed NOS professional development programs teaching how to integrate NOS into their classrooms, including the related curriculum materials.

This study also presents some common uninformed conceptions of NOS being held across contexts that science educators can employ as a basis for designing NOS professional development programs. Clearly, teachers cannot effectively teach what they do not know. Helping science teachers attain adequate understanding of NOS is an essential task for science educators. To do that, at first, information about science teachers' prior conceptions of NOS is needed. MOSQ can be utilized to accomplish this task.

Subsequently, there are many activities that can be used to help improve science teachers' NOS conceptions. Based on empirical evidence, explicit-reflective instruction on NOS has the potential to improve science teachers' conceptions of NOS (Akindehin, 1988; Billeh & Hassan, 1975; Carey & Strauss, 1968; King, 1991; Ogunniyi, 1982). There are myriad activities related to teaching explicit-reflective NOS such as writing assignments defining characteristics for science and pseudo-science (Craven et al., 2002); explicit discussion of NOS and role of NOS in science teaching within conceptual change and cooperative learning environment (Palmquist & Finley, 1997); small-group peer discussions and debates (Craven et al., 2002); and growing awareness of, and commitment to, constructivism (Pomeroy, 1993). However, it must be remembered, explicitly teaching NOS outside a science context has only a limited effect on changing and improving science teachers' understanding of NOS. Therefore, NOS-associated activities and discussions should not be an add-on, but should be tightly linked to science content (Driver et al., 1996).

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