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Full Length Research Paper

Preservice and inservice science teachers' responses and reasoning about the nature of science

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An adequate understanding of the nature of science (NOS) is essential for science teachers. The Myths of Science Questionnaire (MOSQ) consisting of 14 items, which comprised both optional and written types of response, was utilised to explore 113 Thai preservice and 101 inservice science teachers' understanding and reasoning about the NOS, particularly scientific knowledge, scientific method, scientists' work and scientific enterprise. A highly consistent pattern of responses emerged regarding the status of theories and laws, a hierarchical relationship between theory and law, tentativeness of science and science as cumulative knowledge. Most of them were uninformed understanding of the NOS. The MOSQ expressed, to some extent, the effectiveness in illustrating respondents' reasoning about the NOS. The implications concerning the MOSQ and science teacher preparation and professional development are also discussed.

Key words: Preservice science teacher, inservice science teacher, nature of science, reasoning, Thailand.

INTRODUCTION

Science is an important subject for all levels of education. However, numerous studies have shown that many students and even teachers understand science and its nature inadequately. This situation might be harmful, as McComas et al. (1998) pointed out, 'particularly in societies where citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence provided in legal proceedings' (p. 511). Understanding of the nature of science (NOS) has been established as one of the desirable characteristics of a scientifically literate person, who, in general, '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 the nature of science' (Abd-El-Khalick and BouJaoude, 1997, p. 673).

Presently, many science curricula, as Thai Science Curriculum (Office of the Education Council, 2002), generally aim to help learners attain an adequate understanding of the NOS. To effectively address the NOS, science teachers must possess adequate understanding of the NOS (Abd-El-Khalick and Lederman, 2000) and model appropriate science-related behaviours and attitudes in classrooms (Murcia and Schibeci, 1999). Teachers' actions presented in classrooms strongly influence their students' views of the NOS (Palmquist and Finley, 1997). As Lederman (1992) pointed out, 'the most important variables that influence students' beliefs about the NOS are those specific instructional behaviours, activities and decisions implemented within the context of a lesson' (p. 351). In the case of language, for example, the way teachers verbally present scientific enterprise has an impact on the way students formulate their views about science (Munby, 1967; Zeidler and Lederman, 1989). Therefore, as McComas et al. (1998) emphasised, promoting science teachers' understanding of the NOS is clearly a prerequisite for effective science teaching.

The nature of science

In general, understanding the NOS involves how scientific knowledge is generated (Lederman, 1992). McComas et al. (1998) identified some salient aspects of the process of scientific discovery in an analysis of eight international science standard documents: scientific knowledge is tentative; scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments and scepticism; there is no universal step-by-step scientific method; laws and theories serve different roles in science; observations are theory-laden; scientists are creative; science and technology feed back on each other; and scientific ideas are socially and culturally influenced.

PRESERVICE AND INSERVICE SCIENCE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE

The literature suggests that most preservice and inservice science teachers possess an inadequate understanding of the NOS. Their understanding of the NOS are also mixed, fluid and incoherent (Abd-El-Khalick and BouJaoude, 1997; Dogan and Abd-El-Khalick, 2008; Haidar, 1999; Lederman, 1992). Preservice and inservice science teachers' understanding of the NOS can be categorised in four major groups: scientific knowledge, scientific method, scientists' work and scientific enterprise.

Scientific knowledge: Hypotheses, theories and laws

Preservice and inservice teachers commonly believed in the hierarchical relationship between hypotheses, theories, and laws, i.e., 'When a hypothesis is empirically tested and 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' (Abd-El-Khalick and BouJaoude, 1997; Dogan and Abd-El-Khalick, 2008; Haidar, 1999; Rubba and Harkness, 1993; Thye and Kwen, 2003). They did not recognise that these constructs are different types of ideas and play different roles in science. Laws are statements or descriptions of discernible patterns developed to account for observable phenomena, while theories are inferred explanations for those phenomena (Abd-El-Khalick and BouJaoude, 1997).

Belief in the hypotheses-theories-laws hierarchical relationship potentially leads teachers to incorrectly perceive that theories are general propositions, more credible than hypotheses but less credible than laws (Ogunniyi, 1982). In fact, credibility, truth, maturity, or correctness of hypotheses, theories and laws all rely heavily on the availability or accumulation of supporting evidence (Dogan and Abd-El-Khalick, 2008).

Scientific knowledge: Tentativeness of science

Regarding the status of scientific knowledge, preservice and inservice teachers can be characterised into two groups by using a static-dynamic split. The former group view science as stable or having a static status (Behnke, 1961; Craven et al., 2002; Murcia and Schibeci, 1999; Tairab, 2001), while the latter group view science as tentative or having a dynamic status (Bell et al., 2000; Mellado, 1997; Palmquist and Finley, 1997). In the static-science group, teachers believed that science is a collection of facts that explains the world with little or no elaboration (Tairab, 2001). The major purpose of scientific research is consequently to collect as much data as possible (Craven et al., 2002; Tairab, 2001). On the contrary, the dynamic-science group views science as tentative (Dogan and Abd-El-Khalick, 2008). For example, four out of five 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 can be renewed and changed both in the light of new evidence. Subjectivity and creativity are commonly regarded as the important factors contributing to the tentative nature of science (Abd-El-Khalick et al., 1998).

Scientific knowledge: Cumulative knowledge

Some preservice and inservice science teachers held uninformed understanding that scientific knowledge is cumulative and its advancement depends heavily on the accumulation of supporting evidence or increasing observation rather than changes in theory (Brickhouse, 1990; Haidar, 1999).

Scientific knowledge: Scientific model

Many preservice and inservice teachers strongly believed that scientific models are copies of reality rather than human inventions (Abd-El-Khalick and BouJaoude, 1997; Dogan and Abd-El-Khalick, 2008) because scientists or scientific research have shown that they are true or various media, especially science textbooks, have publicly presented them as such (Dogan and Abd-El-Khalick, 2008). As found in Thye and Kwen's (2003) study, nearly half of the preservice teachers (42%) were not aware of the limitations of the scientific model, 'since scientists can provide the structure of atom universally in textbooks and reference books, this can imply that they [scientists] are very certain of it. Maybe they look at a microscopic view (p. 6). Similarly, most preservice teachers (70%) in Ogunniyi's study (1982) believed that molecules, atoms and electrons are empirical concepts. However, many teachers, particularly 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 (Bell et al., 2000; Haidar, 1999).

Scientific method: Universal, step-wise method

The scientific method is commonly perceived by preservice and inservice science teachers as a lock-step procedure or a universal step-wise method (Abd-El-Khalick and BouJaoude, 1997; Craven et al., 2002; Dogan and Abd-El-Khalick, 2008; Haidar, 1999). Estimates of the percentage of preservice teachers who believed in a universal step-wise scientific method varied from study to study, for example, 23.5% (Murcia and Schibeci, 1999), 33% (Craven et al., 2002), 60% (Palmquist and Finley, 1997), 65% (Haidar, 1999), or even 100% (Mellado, 1997). Teachers in this category characteristically believe that the ordered, rigid stages of the scientific method lead to objectivity of scientific work and valid scientific claims (Mellado, 1997; Palmquist and Finley, 1997) or unambiguous scientific truth (Brickhouse, 1990). Also, good scientists are defined as those who follow a recipe, or the steps of the scientific method, in their investigations (Abd-El-Khalick & BouJaoude, 1997; Haidar, 1999). This can also be attributed to the science curriculum that presents the scientific method as a sequence of steps that all students have to followed exactly in order to reach certain results (Haidar, 1999).

Scientific method: Scientific experiment

Some teachers held uninformed views regarding scientific experiment. In Thye and Kwen's (2003) study, most preservice teachers (79%) considered scientific experiment a necessary prerequisite to claiming the validity of scientific knowledge. One of them said that 'experiments are necessary to confirm truth and validity of scientific theory and inquiry. Without experimental validity, there is no scientific knowledge. There is only blind faith' (p. 5).

Scientists' work: Theory-laden observation and subjectivity

One of the common bipolar views of the NOS is subjectivity vs objectivity, or theory-laden vs theory-free. Some preservice and inservice teachers believed that subjectivity plays a major role in the development of scientific knowledge (Abd-El-Khalick and BouJaoude, 1997; Palmquist and Finley, 1997). As an example, the individuality of scientists (e.g., personalities, background, motivations, beliefs, worldviews, paradigms, etc.) potentially affect them in selecting, interpreting, recording and reporting evidence (Abd-El-Khalick et al., 1998; Murcia and Schibeci, 1999), generating conclusions or theories (Abd-El-Khalick et al., 1998; Thye and Kwen, 2003) and thinking and decision-making (Lunn, 2002). Similarly, in Thye and Kwen's (2003) study, nearly half of preservice teachers (46%) believed that 'the same piece of evidence or the same set of data can be subject to [scientists'] multiple interpretations' (p. 7). In contrast, many teachers strongly believed in objectivity in science because it is directly related to the validity of scientific knowledge (Brickhouse, 1990; Dogan and Abd-El-Khalick, 2008; Haidar, 1999; Mellado, 1997; Murcia and Schibeci, 1999). To them, a good scientist is accordingly seen as a person who is objective in their work. Hence, scientists' observations and interpretations are not influenced by their theories or frames of reference (Abd-El-Khalick and BouJaoude, 1997; Palmquist and Finley, 1997; Rampal, 1992).

Scientists' work: Creativity and imagination in science

The preservice and inservice teachers who dismissed the objectivity in science acknowledged the role of creativity and imagination in building scientific knowledge (Abd-El-Khalick et al., 1998; Bell et al., 2000), particularly in designing research or experiments, generating new ideas and developing technology (Murcia and Schibeci, 1999). The teachers who overlook the role of imagination in science (Rampal, 1992) believe creativity to be 'stereotypically dissociated from perceived scientific qualities' (p. 424). Some preservice teachers argued that 'science was fact or truth and creativity did not have a place' (Murcia and Schibeci, 1999, p. 1132). Additionally, Thye and Kwen (2003) reported that one third of the preservice teachers did not seem to think that creativity and imagination were required at any steps of scientific investigation. Also, a few of them adamantly stated that 'there must not be any interpretation of the facts; they should speak for themselves' (p. 7).

Scientific enterprise: Social and cultural influences on science

The social and cultural influences on scientific enterprise are recognised by most preservice and inservice teachers (Brush, 1989; Haidar, 1999; Mellado, 1997; Murcia and Schibeci, 1999; Rubba and Harkness, 1993; Tairab, 2001). These influences may come from the larger society or the culture of science itself, including the influences of professional organisations, funding sources and peer review (Bell et al., 2000). Murcia and Schibeci (1999) found that three-quarters of the preservice teachers believed that 'the bodies [government departments] that supply the money for research influence the direction of science' (p. 1135). Of all inservice teachers, 51 and 42.3%, respectively, in Haidar (1999) and Rubba and Harkness (1993) indicated that a scientist is influenced by social factors. Additionally, in Tairab's study (2001), more than three-quarters (79.6%) of the science teachers stated that science and technology affect society and, in turn, society affects science and technology. The influences of social and cultural factors on scientific practice are overlooked by many preservice and inservice teachers, however (Abd- El-Khalick et al., 1998). They neglected the role of science as a social enterprise or a form of human cultural activity (Tairab, 2001) and some highly regard the authoritative image of the scientist. For example, only 10 and 26% of the science teachers believed that in collecting or presenting information, a scientist is influenced by social biases and governmental pressure, respectively (Rampal, 1992).

Scientific enterprise: Interaction between science and technology

It is, perhaps, an easy task for preservice and inservice science teachers to recognise the interaction between science and technology in such ideas as science is the knowledge base for technology and technology influences scientific advancement. However, distinguishing between science and technology often seems to be a very difficult task for them (Rubba and Harkness, 1993). They commonly held the uninformed understanding that technology is applied science (Tairab, 2001).

Thai preservice and inservice science teachers' understanding of the nature of science

Thailand is an independent country, which lies 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. Thailand is considered to be the world's fiftieth largest country in terms of total area and the world's twentieth largest country in terms of population, with approximately 63 million people. Thailand is divided into 76 provinces, which are gathered into six regions, that is North, North-East, Central, East, West and South. The capital and largest city of Thailand is Bangkok.

Thailand has never been colonized and therefore its educational system does not draw from European models to a great extent. Basic education in Thailand includes 12 years of study. According to the Basic Education Curriculum (Ministry of Education, 2001), basic education in Thailand are divided into four major levels: Level 1 (Grades 1 - 3), Level 2 (Grades 4 - 6), Level 3 (Grade 7 - 9), and Level 4 (Grade 10 - 12). According to Section 43 of the Teacher and Educational Personnel Act (Secretariat of the Cabinet of Thailand, 2003), teaching in Thailand is presently regarded as a highly-qualified profession, which requires a Teacher Professional License. Teachers, including preservice teachers, must be qualified in accordance with the Knowledge and Professional Experience Standards and Ethics.

Most of the NOS studies in Thailand are unpublished Master's theses that were extensively conducted during the 1997 - 2001 period in the Northeast. Of 26 studies regarding teachers' understanding of the NOS, almost all of them (23 studies) dealt with inservice teachers. Twenty-one studies involved secondary teachers (e.g., Srithum (1998), Boonmuangsaen (1997), Kuonamon (2000), Pholthum (1997)), while the other two studies involved primary teachers (that is Sriwinetr (2000) and Wangnurat (1999)). There were only three studies that dealt with preservice teachers, that is Jongchidklang (2000), Phiankaew (1999) and Wansudol (2000). All of them strongly emphasised a quantitative approach by using the same questionnaire consisting of 94 items: Assumptions of the Nature (12 items); Scientific Knowledge (24 items); Scientific Method (24 items) and Interaction between Science, Society and Technology (34 items). These studies reported respondents' understanding of the NOS according to those scales as rated on five-point Likert scales.

The key findings related to preservice teachers' understanding of the NOS were that they generally showed a high level of understanding of the four Scales of the NOS (Jongchidklang, 2000; Phiankaew, 1999; Wansudol, 2000); and statistical interactions between the variables of gender and learning programme on their understanding of the NOS were not found to be significant (Wansudol, 2000). Similarly, the studies of inservice teachers' understanding of the NOS generally reported that they had a high level of understanding of the four Scales of the NOS. There was also no relationship between gender, teaching experience, and levels or types of schools taught of inservice teachers and their understanding of the NOS. The latter finding was consistent with Carey and Stauss (1970), Lederman (1992), and Mellado (1997), who reported that there is no significant relationship between inservice teachers' academic background or personal antecedents in school and their understanding of the NOS.

There was one qualitative study exploring three primary inservice science teachers' understanding of the NOS (Promkatkeaw et al., 2007). The key findings were that the participants could not state clearly the characteristics and types of scientific knowledge, that is facts, concepts, principles, theories and laws. One participant viewed scientific knowledge as being fixed, concrete and originated from proper experiments. All of them commonly recognised the relationship between science and technology concerning the application of scientific ideas into numerous useful inventions. They additionally indicated the relationship between science and society in terms of the use of science for daily lives and developing the country.

The current study aimed to explore understanding and reasoning about the NOS held by Thai preservice and inservice science teachers and was guided by two research questions: What are preservice and inservice science teachers' understanding and reasoning about the NOS, particularly scientific knowledge, scientific method, scientists' work and scientific enterprise?; and What are similarities and differences between preservice and

Table 1. The Myths of Science Questionnaire (MOSQ)

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

Statement	Opinion
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 ……………………………………..

inservice science teachers' understanding and reasoning about the NOS? The findings of this study may inform involved stakeholders according to the current state of preservice and inservice science teachers' understanding of the NOS and, subsequently, help them to plan for programmes and curricula to promote understanding of the NOS at the preservice and inservice level.

METHODS

Instrument

The Myths of Science Questionnaire (MOSQ) was used to explore preservice and inservice science teachers' understanding of the NOS. It consists of 14 items and addresses four aspects of the NOS: Scientific knowledge (Items 1, 2, 3, 4, 8 and 9); Scientific method (Items 5, 6 and 7); Scientists' work (Items 10 and 11); and Scientific enterprise (Items 12, 13 and 14). The creation of the MOSQ items was largely inspired by McComas's (1998) article, 'The Principal Elements of the Nature of Science: Dispelling the Myths'. All the MOSQ items are presented as Table 1. MOSQ respondents were required to select from any of three responses, that is, agree, uncertain or disagree, that best fits their opinion of the item statement and to provide an additional written response to support their selection.

The MOSQ was first validated by five science educators. They were asked to examine the items in terms of their relevance to the dimensions of the NOS and their clarity for and suitability to the respondents. A second version, which had been revised according to the experts' comments, was then pilot tested with 21 preservice and 11 inservice science teachers in the central region of Thailand in order to determine whether they understood the items and to assess how much time they would spend completing the MOSQ. Any ambiguities found during this trial were clarified for the respondents and recorded for further revision of the MOSQ. The completion of the questionnaire took approximately 45 min.

Data collection

The data were collected during the first semester of the 2008

Table 2. Number of participating inservice science teachers allocated by regions.

Region	Province	Number of participants
Northern	Chiang Mai	6
	Phitsanulok	13
Central	Bangkok	10
	Nakhon Pathom	16
Northeast	Khon Kaen	8
	Ubon Ratchathani	17
Eastern	Rayong	7
Western	Kanchanaburi	8
Southern	Phuket	16
Total		101

academic year. The researchers administered the MOSQ and collected it back from all of the respondents. The respondents were 113 preservice science teachers in a five-year science teacher preparation programme at one university in the central region of Thailand and 101 inservice science teachers from nine provinces located in six regions around Thailand. The participating inserviceThe majority of preservice science teachers (83.2%) who responded to the MOSQ was female. There were 24.8, 15, 21.2, 17.7 and 21.2% of the preservice teachers studied in the first, second, third, fourth and fifth years of study, respectively. Their fields of study were biology (33.3%), chemistry (30.7%), general science (20%) and physics (16%). In this case, the first year preservice teachers had not yet selected a major field of study.

More than three-quarters (76.2%) of inservice science teachers who responded to the MOSQ were female. Their age range was from 23 to 60 years and nearly half of them (45%) fell within the age range of 46 and 55 years old. Their teaching experience varied from 1 to more than 31 years. Although the ages of nearly half of the participants ranged between 46 and 55 years old, 27% had taught science less than six years. The explanation was that, in the past, science was integrated with health education and social studies as a so-called 'Life Experience' subject. Now, 'Science' has been separated from the two programs according to the proclamation of the 2001 Basic Education Curriculum. The numbers of the teachers in primary (Level 1 - 2) and secondary (Level 3 - 4) levels were nearly the same, that is, Level 1 (19.2%), Level 2 (25.3%), Level 3 (34.3%) and Level 4 (21.2%). Most participants (81.2%) held a bachelors degree, while 13.9 and 5% of them held a masters degree and a science teacher certificate, respectively. Of all inservice teachers, three-quarters graduated with a science major, while the others graduated in other fields such as social studies (5.3%), physical education (4.3%), Thai studies (2.1%) and industrial arts (2.1%).

Data analysis

The frequency of each response (That is "agree", "uncertain" and "disagree") was counted and its percentage calculated. The "agree", "uncertain" and "disagree" responses were then interpreted as informed, uncertain and uninformed understanding of the NOS. However, 'one's view of the NOS is a complex web of ideas that loses meaning when reduced to simple numbers' (Palmquist and Finley, 1997, p. 601). Subsequently, respondents' reasoning supporting their agree/uncertain/disagree responses were categorised. The frequency and percentage for each category were also counted and calculated.

RESULTS AND DISCUSSION

Preservice and inservice science teachers' understanding and reasoning about the NOS: Scientific knowledge

About a half of the preservice and inservice teachers (55.4 and 46.0%) held the informed understanding of hypotheses and theories as Table 3. They did not believe that hypotheses are developed to become theories only and raised two major arguments. Firstly, 44.2 and 38.9% of the preservice and inservice teachers argued that hypotheses are potentially developed to become laws. Secondly, the 'hypotheses may be proven to be false' was supported by 13 and 38.9% of the preservice and inservice teachers. However, about one third of the preservice and inservice teachers (33 and 28%) were uncertain whether or not hypotheses are developed to become theories only.

Nearly half of the preservice and inservice teachers (43.8 and 43%) expressed the uninformed view that scientific theories are less secure than laws. Scientific 'theories can be changed, but laws are fixed' and this argument was supported by 29.2 and 18.8% of pre-service and inservice teachers, respectively. In particular to the inservice teachers, 34.4% of them reasoned that theories can be changed if scientists discover enough supporting evidences, while 28.1% of them reasoned that laws cannot be changed because they have been already proven without any dispute. There were only five preservice teachers who explicitly demonstrated informed understanding that 'theories and laws are equally credible'. In addition, nearly one third of the preservice and inservice teachers (30.4 and 31%) were unsure whether theories are less secure than laws.

Most of the preservice and inservice science teachers (80.4 and 84.8%) held the uninformed view that laws are mature theories. Of the preservice teachers' written responses, 70% argued that when theories have been proved, they can be developed to become laws. As the method for proving a theory, 81% of the inservice teachers suggested gathering enough credible evidence. Two inservice teachers, however, indicated the reverse process that laws can be developed to become theories.

Nearly all of the preservice and inservice science teachers (93.8 and 90%) expressed the informed view about the tentativeness of science. Their major argument was that scientific knowledge can be changed according to the discovery of new knowledge or more credible, supporting evidence. However, one preservice teacher stated that 'theories can be developed to become law, thus scientific knowledge is tentative'. This response demonstrates the conjunction of two beliefs: the first one is incorrect, but accidentally leads to another correct one.

The majority of preservice and inservice teachers (81.1 and 83%) possessed the uninformed understanding that 'accumulation of evidence makes scientific knowledge more stable'. They believed in what we called 'Baconian

Table 3. Preservice and inservice science teachers' responses and reasoning about the NOS: Scientific knowledge.

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre[1]	In[2]	Pre	In	Pre	In
Item 1: Hypotheses are developed to become theories only	13[3] (11.6)[4] (n = 7) Experiment-verified hypothesis becomes theory (6)[5] Shared conclusion among hypotheses becomes theory (1)	26 (25.7) (n = 5) Setting hypotheses is first step of doing science (1) Theory is proven to explain phenomena (1) For example, Newton observed falling apple (1) Hypothesis guides inquiry (1) Hypothesis is guess. It is developed to be theory according to enough supporting evidence (1)	37 (33.0) (n = 14) Credible hypotheses develop to be theory (6) Hypotheses can be developed to be law (3) It is not necessary that hypotheses are developed to be theories (2) Hypotheses can be developed to be inventory (1) Hypotheses may be developed to be other things not only theory (1) Hypotheses may be failed (1)	28 (27.7) (n = 7) Failed hypotheses are not developed to be theory (2) There are many possible hypotheses (2) Hypotheses must be verified (1) Hypotheses may be developed to be things (1) Hypotheses may be developed to be facts (1)	62 (55.4) (n = 56) Hypotheses may be developed to be laws (34) Hypotheses may be failed (10) Hypotheses may be developed to be other things depending on credibility (6) Hypotheses may be developed to be principles (3) Some theories are not come from hypotheses (2) Principles may be developed to be theory (1)	46 (45.5) (n = 36) Hypotheses may be developed to be laws (14) Hypotheses may not true (14) Hypotheses may be practice (2) Hypotheses are only guideline for inquiry (2) Hypotheses may be developed to be technology (2) Hypotheses are individual ideas (1) Hypotheses may develop to be other things not only theory (1)

induction' (McComas, 1998, p. 58). Of written responses, the preservice and inservice teachers who stated that 'the accumulation of evidence increases the credibility of scientific knowledge' were 59.5 and 20.8%, respectively. In addition, a quarter of the inservice teachers indicated that the accumulation of evidence is beneficial for future scientific investigation and increases the validity of scientific knowledge. The majority of inservice teachers (45.5%) expressed the uninformed understanding that a scientific model expresses a copy of reality. Their main argument was that scientific models are created from the results of experiment, nature, theories and laws. In contrast, one-third of pre-service teachers (36%) believed that a scientific model does not express a copy of reality, but that it is created from a scientist's imagination. Five out of 12 inservice teachers also argued in a similar way. Remarkably, 30.6 and 42.6% of the preser- vice and inservice teachers were uncertain whether a scientific model expresses a copy of reality.

Preservice and inservice science teachers' understanding and reasoning about the NOS: Scientific method

Nearly half of the preservice and inservice science teachers (43.8 and 44.6%) held uninformed understanding of the scientific method as Table 4. They believed that scientists must follow a fixed step-by-step method to obtain scientific know-ledge. Three inservice teachers also confirmed that a fixed step-by-step scientific method is publicly presented in textbooks. There were 30.4 and 41.6% of the preservice and inservice teachers who stated that the scientific method could be reordered or that some steps could be removed. The majority of preservice teachers (39.1%) were uncertain whether science and scientific method can answer all questions, while the majority of inservice teachers (49.5%) held the

Table 3 (Cont.)

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 2: Scientific theories are less secure than laws	49 (43.8) (n = 33) Theories can change, proven laws never change (19) Laws are patterns of nature (2) Laws create theories (2) Laws are experiment-based (2) Laws never change (2) Theories can change, laws are hard to change (1) Everyone follows laws, laws are more credible (1) Laws are important than theories (1) Laws can explain everything (1) Theories explain laws. Laws are more acceptable (1) Everyone accepts laws (1)	43 (42.6) (n = 32) Theory change because of emerging credible evidence (11) Laws are proven without disagreement (9) Theories can change, but not for laws (6) Theories develop to be laws (2) Laws are true and credible (2) Laws are proven and used. Theories are invented and can be discarded (1) Failed theories are not laws (1)	34 (30.4) (n = 17) Meanings of theories and laws are different (3) Theories are reasonable (2) Both laws and theories can be discarded (2) Most laws come from theories (1) Both theories and laws are credible, but theories are not verified by experiment (1) Credibility of theories and laws is replication (1) Both theories and laws are credible, but theories explain laws (1) Theories and laws are possible (1) Laws are widely accepted, not for theories (1) Theories come from laws and experiments (1) Theories and laws are scientists' conclusion (1) Accepted theories are credible (1) Some theories are credible as laws (1)	31 (30.7) (n = 7) Theories and laws are equally credible (3) The statement is not true (2) Laws can change (1) Theories change due to conflicts, laws never change (1)	29 (25.9) (n = 15) Theories and laws are equally credible (5) Theories created from experiments, they are more credible than laws (2) Laws are more accurate than theories (2) Both theories and laws are acceptable (2) Credibility depends on supporting evidences (2) Theories explain laws, so they are credible (1) Laws are facts and serve as basis for developing theories (1)	26 (25.7) (n = 8) Theories and laws are equally credible according to supporting evidences (4) Theories are part of laws (2) Some widely-use theories are credible (1) Theories never change, laws can change (1)

Table 3. (Cont.)

Item statement	Responses and reasoning					
	Agree		**Uncertain**		**Disagree**	
	Pre	**In**	**Pre**	**In**	**Pre**	**In**
Item 3: Scientific theories can be developed to become laws	90 (80.4) (n = 51) Proven theories become laws (42) Theories explain laws (5) Widely-accepted theories become laws (2) Science is continual work (1) Theories are basic concepts of laws (1)	84 (83.2) (n = 21) Proven or evidence-supported theories can be develop to be laws (17) Theories can change due to new discovery (2) Theories are ideas that require supported principles to develop to become laws (1) Science grows and laws continuously discovered (1)	18 (16.1) (n = 6) Credible theories develop to become laws (4) Agreement of majority allows theories to become laws (1) For example, Newton's laws developed to become theory of relativity (1)	13 (12.9) (n = 2) It depends on accuracy of theory (1) Some theories never develop (1)	4 (3.6) (n = 3) Laws are possibly developed to be theories (1) Some theories are congruent with reality (1) Laws affect development of theories (1)	2 (2.0) (n = 2) Laws can be developed to become theories (2)
Item 4: Scientific knowledge cannot be changed	2 (1.8) (n = 0)	5 (5.0) (n = 0)	5 (4.5) (n = 1) Discovery changes scientific knowledge (SK) (1)	5 (5.0) (n = 0)	105 (93.8) (n = 89) More new, credible evidence changes SK (85) SK changes because scientists continue doing experiments (2) SK changes all the time (1) Theories are developed to become laws or discarded (1)	91 (90.0) (n = 55) Supporting evidence changes SK (24) New emerging knowledge changes SK (14) Time, nature, and environment change SK (8) Pluto is discarded from solar system (6) Technology advancement changes SK (3)

Table 3. (Contd.)

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 8: Accumulation of evidence makes scientific knowledge more stable	90 (81.1) (n = 61) Accumulative evidences enhance confidence of SK (44) The more study, the more SK (7) The more evidence, the more SK (3) Repeated-experiments confirm SK (3) Accumulative evidences enhance SK development (3) Past-evidences verify present SK (1)	83 (82.2) (n = 24) Accumulative information help science study (6) Accumulative information makes knowledge valid and accurate (6) Accumulative evidences enhance credibility of SK (5) Clear evidences makes SK stable (4) Basic evidences make SK stable (3)	17 (15.3) (n = 9) I am not sure, maybe evidences are wrong (1) Evidences can change because of time (1) Experiment is more reliable than accumulative evidences (1) New knowledge may be more credible, old knowledge is rejected (1) Amount of accumulative evidences is not important than they are true every time (1) It is bad if we accumulate wrong evidence (1) Some contradictory evidences make SK unstable (1) Evidences must be acceptable (1) If theories are rejected, accumulated evidences are useless (1)	11 (10.9) (n = 3) Environment can change evidence (2) Evidence may be wrong (1)	4 (3.6) (n = 4) SK comes from many sources (1) Some accumulated evidences may be forgotten (1) Accumulated evidences may not enable explanation that make SK unstable (1) Accumulation of wrong evidence is useless (1)	6 (5.9) (n = 2) Some information may change, SK can change (2)

uninformed understanding. Of 16 written responses, six inservice teachers argued that science and scientific method can answer all questions because they are causal, reasonable and explainable, while five teachers also argued that science is true and provable. For some dif-

Table 3 (Cont.)

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 9: A scientific model (e.g., the atomic model) expresses a copy of reality	37 (33.3) (n = 23) Scientific model is supported by experiment (6) The statement is true (5) Scientists created scientific model based on reality of nature (5) Scientific model can practically be used in learning (2) Scientific model can explain phenomena (2) Scientific model is evidence-based (1) Scientific model is real (1) Scientific model can be used for prediction (1)	46 (45.5) (n = 10) Scientific model is created from experiment (4) Scientific model comes from nature (3) Scientific model help understand phenomena (1) Scientific model is created from law (1) Scientific model is created from theory (1)	34 (30.6) (n = 18) Scientific model is true (11) Scientific model is rough (2) Some scientific model contradict nature (2) Some scientific model is created from imagination (2) Scientific model is evidence-based (1)	43 (42.6) (n = 10) Scientific model comes from imagination (4) Scientific model cannot cover every reality (2) I am not sure whether nature looks like such as in atom (1) Scientific model is abstract (1) Scientific model explain results of experiment indirectly (1) Scientific model can change regarding new emerging ideas (1)	40 (36.0) (n = 33) Scientific model explains abstract things and relies on imagination such as atomic structure (26) Scientific model is created to be closely to nature as possible (5) Scientific model may not true (4) Scientific model is used for learning, it is not real as nature is (2)	12 (11.9) (n = 9) Scientific model is scientists' guess with imagination (5) Scientific model is used to explain abstract phenomena (3) Scientific model cannot answer all problems (1)

ficult questions, two inservice teachers raised the issue of time by predicting that at some point in the future scientist will come up with the answers or explanations. In contrast, 36.4 and 20.2% of the preservice and inservice teachers, respectively indicated that science and the scientific method cannot answer all questions. One third of their written responses raised many issues that science can not explain, e.g., ghosts, spirits, the devil, black magic, the supernatural, fortune-tellers, etc.

Most of the preservice and inservice science teachers (60.4 and 82.2%) expressed the informed understanding that scientific knowledge is not originated from experiments only. They raised many alternative methods to build scientific knowledge such as observation, seeking further information and investigation.

Preservice and inservice science teachers' understanding and reasoning about the NOS: Scientists' work

Most preservice and inservice science teachers

Table 4. Preservice and inservice science teachers' responses and reasoning about the NOS: Scientific method.

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 5: The scientific method is a fixed step-by-step process	49 (43.8) (n = 34) Scientists follow fixed-steps in seeking for answers (31) If scientists do not follow fixed-steps, they cannot get right answer (2) Observation followed by experiment lead to SK (1)	45 (44.6) (n = 14) Scientific method (SM) consists of five stages: identifying problem, setting hypothesis, experimenting, analyzing data, and making conclusion (6) SM leads to correct, confident answer (3) SM is used in classroom (3) There are fixed-steps to seek for answer (2)	29 (25.9) (n = 15) Alternation of some steps of SM is possible (15)	14 (13.8) (n = 5) Alternation of some steps of SM is possible (4) Changing some steps of SM can lead to different results (1)	34 (30.4) (n = 26) Alternation of some steps of SM is possible (22) Different scientists may use different methods (3) Other convenient methods can be applied instead of SM (1)	42 (41.6) (n = 17) Alternation of some steps of SM is possible (15) There are many types of experiments (2)

(91.0 and 80%) believed in the roles of creativity and imagination in science as Table 5. The preservice teachers believed that scientists' creativity and imagination is involved in creating scientific models (18.4%) and designing scientific experiments (14.5%). In view of the inservice teachers, scientists' creativity and imagination are involved in the discovery of new scientific knowledge (34.8%) and the creation of novel inventions (21.7%). However, two inservice teachers asserted that scientists always employ the scientific method and never rely on creativity and imagination in developing scientific knowledge because they may distort the data.

The majority of preservice and inservice science teachers (62.2 and 86.1%) highly regarded scientists as open-minded, unbiased people. Of preservice teachers' written responses, 60% regarded being open-minded with unbiased as a desirable characteristics of scientists that may potentially lead them to succeed in their scientific works. Only a few preservice and inservice science teachers (6.3 and 10%) correctly stated that scientists, as human beings, are not absolutely open-minded and unavoidably possess some biases.

Preservice and inservice science teachers' understanding and reasoning about the NOS: Scientific enterprise

The majority of the inservice science teachers(51.5%) held the uninformed understanding that science and technology are identical, while 38.7% of the preservice teachers were uncertain as Table 6. The inservice teachers' favourite argument was that technology is originated from science. One third of the preservice and inservice teachers' written responses also expressed their uninformed understanding, that is, technology is applied science. Of all preservice teachers' written responses, three sets of relationships between science and technology emerged: technology originated from science (54.4%); science and technology interact with each other (28.9%); and science creates technology and technology develops science (2.2%). Similarly, in the inservice teachers' written responses, there were three patterns of relationship between science and technology: technology originated from science (45.45%); science and technology support and develop each other (22.7%) and science and technology are a part of each other (4.5%). About thirty six and twenty seven percents of the preservice and inservice science teachers correctly stated that science and

Table 4. (Cont.)

Item statement	Responses and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 6: Science and the scientific method can answer all questions	27 (24.6) (n = 12) SM can provide answers (7) Science explains nature (2) Everything has its explanation (1) Science has principles and reasons to answer questions (1) It takes time to answer some questions, however, we finally find it (1)	49 (48.5) (n = 16) Science is reasonable and explainable (6) Science is real and provable (5) SM only can answer questions in science (3) Science is always real, but take time to answer (2)	43 (39.1) (n = 18) Science cannot answer some questions e.g. black magic, ghosts, spirit, or devil (13) No experiment, no answer (1) There are many ways to find answers (1) SM plays some parts in answering questions (1) There are many factors in seeking for answers (1) Some questions take time to answer (1)	30 (29.7) (n = 9) Science cannot answer some questions e.g. ghosts, spirit, or devil (6) Environment affects seeking for answers (1) Technology affects seeking for answers (1) More studies are needed to answer some questions (1)	40 (36.4) (n = 60) Science cannot answer some questions e.g. black magic, ghosts, spirit, or devil (47) Science can answer only experimentable questions (9) Some questions are obvious (3) Some questions take time to answer (1)	20 (19.8) (n = 12) Science cannot answer some questions e.g. black magic, ghosts, spirit, or devil (8) We sometimes lack information (1) Science is continual work (1) Some questions need imagination to answer (1) Some questions cannot answer by SM (1)

technology are different.

Most preservice and inservice science teachers (74.8 and 96%) viewed scientific enterprise as a social, collaborative activity. Two inservice teachers explicitly stated that 'science is an activity for all.' In the preservice teachers' view, collaboration, multidisciplinary scientific research and peer review in scientific works is beneficial for more clarified knowledge. The inservice teachers further articulated four advantages of collaborative scientific enterprise: deriving more quality data, gaining a variety of perspectives, enhancing opportunity to success and enhancing the credibility of studies.

The majority of preservice and inservice science teachers (64 and 74%) believed that society, politics and culture potentially affect, to some extent, the development of scientific knowledge. For example, 19.6 and 25% of the preservice and inservice teachers' written responses mentioned that specific cultural or value frameworks embedded in some societies, like religion and government-supported grants, may impede scientific advancement.

Preservice and inservice science teachers' understanding and reasoning about the NOS: Holistic view

The overall responses of the preservice and inservice science teachers are illustrated in Figure 1. When comparing the preservice and inservice teachers' responses, three types of patterns were noticed: a highly consistent pattern (Items 2, 3, 4 mature-theories fable (Abd-El-Khalick et al., 1998; Abd-El-Khalick and BouJaoude, 1997; Dogan and Abd-El-Khalick, 2008; Haidar, 1999; Rubba and Harkness, 1993; Thye and Kwen, 2003); (b) Theories are less secure than laws (Bell et al., 2000; Ogunniyi, 1982); (c) The universal, stepwise scientific method, (Abd-El- Khalick and BouJaoude, 1997; Craven et al., 2002; Dogan and Abd-El-Khalick, 2008; Haidar, 1999; Mellado, 1997; Murcia and Schibeci, 1999; Palmquist and Finley, 1997); (d) Scientific knowledge is cumulative knowledge (Haidar, 1999; McComas,

Table 4. (Cont.)

Item statement	Responses and reasoning					
	Agree		**Uncertain**		**Disagree**	
	Pre	**In**	**Pre**	**In**	**Pre**	**In**
Item 7: Scientific knowledge comes from experiments only	12 (10.8) (n = 5) Experiment proves reality (3) Experiment is used to test and discover SK (2)	5 (5.0) (n = 1) Experiment verifies accuracy of SK (1)	32 (28.8) (n = 17) SK may be originated from observation (6) SK may come from collecting information (4) SK may come from imagination (3) Some knowledge exists out there, no need of experiment (2) SK may come from discovery (1) Some topics (e.g. black magic) cannot do experiment (1)	13 (12.8) (n = 3) SK may come from thinking (1) SK may come from theories (1) SK may come from study (1)	67 (60.4) (n = 65) SK may come from observation (26) SK comes from many ways e.g. observation, information collection, or discovery (20) Some knowledge exists out there, no need of experiment (6) SK may be accidentally found (3) SK may come from calculation (2) SK may come from scientific model (2) SK may come from imagination and logic (2) SK may come from theories (1) SK comes from previous studies (1) SK may come from experience (1) Experiment is only one of many methods to find SK (1)	83 (82.2) (n = 63) SK may come from observation (21) SK may come from information collection (20) SK may come from survey (9) SK may come from theories (3) SK may come from imagination (2) SK may come from nature (2) SK may come from scientific model (2) SK may come from logical thinking (1) SK may be accidentally found (1) SK may come from trial and error (1) SK may come from technology (1)

Promkatkeaw et al., 2007; Rampal, 1992; Thye and Kwen, 2003). For them, the status of and relationship between, theories and laws rely heavily on the availability of accumulative, supporting evidence. Scientific progress is seen as a cumulative process rather than a revisionary process (Brickhouse, 1990; Haidar, 1999). The presence of a fixed-step scientific method or of verification-type laboratory activities in various school science textbooks also persuade teachers to believe in the universal step-wise scientific method (Haidar, 1999; Palmquist and Finley, 1997), which unfortunately leads some of them to portray science as objective rather than subjective (Gallagher, 1991; Mellado, 1997). Objectivity, or being open-minded, unbiased, is also regarded as one of essential characteristics of a good, successful scientist (Palmquist and Finley, 1997).

However, the preservice and inservice science teachers in this study widely held informed understanding of the NOS regarding hypotheses and theories, science as tentative (Bell et al., 2000; Mellado, 1997; Palmquist and Finley, 1997); scientific experiment; creativity and imagination in science (Abd-El-Khalick et al., 1998, 2000; Murcia and Schibeci, 1999); science as social enterprise; and social, cultural and political

Table 5. Preservice and inservice science teachers' responses and reasoning about the NOS: Scientists' work.

Item statement	Response and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
Item 10: Scientists do not use creativity and imagination in developing scientific knowledge	7 (6.3) (n = 3) Science has clear reasons (1) Scientists use data to prove reality (1) Development of SK requires theories (1)	10 (9.9) (n = 2) Using creativity and imagination (C&I) may distort data (1) Scientists use SM (1)	3 (2.7) (n = 1) Some SK come from C&I (1)	10 (9.9) (n = 1) Some SK come from imagination before experiment (1)	101 (91.0) (n = 72) SK development come from scientists' imagination (17) C&I help create scientific model (15) C&I help design experiment (11) Scientists imagine first and later do experiment (8) C&I help set hypotheses (10) C&I help create new knowledge (5) Scientists must use C&I because they cannot reach reality of some topics (4) Without C&I leads to incomplete SK (2) C&I help communication (2) C&I help create inventions (2) C&I create technology (2) Imagination help create theory (2) Scientists use imagination (1) Using C&I depends on individual scientists (1)	80 (79.2) (n = 23) C&I help explore new knowledge (8) C&I help create invention (5) Some topics need imagination e.g. human wants to fly (5) Scientists must have C&I (2) Imaginatioin is more important than thinking(2) C&I create new question (1)

Table 5. (Cont.)

Item statement	Response and reasoning					
	Agree		**Uncertain**		**Disagree**	
	Pre	**In**	**Pre**	**In**	**Pre**	**In**
tem 11: Scientists are open-minded without any biases	69 (62.2) (n = 51) Scientists must be open-minded for different ideas help get correct answers (12) Being open-minded without any biases is good characteristic of scientists (11) Biases distort data (11) Being open-minded without any biases leads to more accurate findings (9) Biases is obstacle for success (5) When discover new thing, we must take old one out (2) Scientists must be open for new knowledge for self-development (1)	87 (86.1) (n = 8) Being open-minded leads to new information (3) Being open-minded without any biases leads to correct findings (3) Scientists must not possess any personal biases (2)	29 (26.1) (n = 16) Being open-minded without any biases depends on individual scientist (12) Some scientists are self-centered and block other ideas (3) Being open-minded without any biases is good characteristics of scientists (1)	12 (11.9) (n = 3) Human always possesses biases (3)	13 (11.7) (n = 18) Being open-minded without any biases depends on individual scientist (18)	2 (2.0) (n = 1) Being open-minded without any biases depends on individual scientist (1)

influences on science (Brush, 1989; Haidar, 1999; Mellado, 1997; Murcia and Schibeci, 1999; Rubba and Harkness, 1993; Tairab, 2001). They did not raise subjectivity or creativity as an important factor for tentative science, as Bell et al. (2000) noticed. Cautiously, the laws-are-mature-theories fable might lead teachers to mistakenly answer the tentativeness of science item correctly (Bell et al., 2000; Thye and Kwen, 2003).

A high uncertainty of the preservice and inservice teachers in this study is demonstrated in the items relating to hypotheses and theories, theories being less secure than laws, scientific method, scientific explanation, scientific model and science and technology.

The teachers raised many phenomena that science cannot explain (Lunn, 2002). In agreement with Tairab (2001) and Promkatkeaw et al. (2007), we found that teachers dominantly view technology as applied science. The distinction between science and technology also appeared as a difficult task for them (Rubba and Harkness, 1993). Therefore, a clear distinction between and the ‘interactionist perspective’ (Tairab, 2001, p. 245) of science and technology should be advocated among them.

IMPLICATIONS

Science teachers’ understanding of the NOS potentially influence their actions in classrooms. Therefore, helping science teachers to acquire an

Table 6. Preservice and inservice science teachers' responses and reasoning about the NOS: Scientific enterprise.

Item statement	Response and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
12. Science and technology are identical	28 (25.2) (n = 18) Science is developed along with technology. Both depend on each other (11) Science creates Technology (6) Science creates technology, technology helps science (1)	52 (51.5) (n = 18) Science creates or develops technology (10) Science depends on technology (3) Science is developed along with technology (2) Science is related to technology (2) We must use both science and technology (1)	43 (38.7) (n = 22) Science creates technology (10) Some SK is not applied to be technology. Some technologies are not created from science (4) Technology is human-created (2) Meaning of science is different from technology (2) Science pairs technology (1) Science creates technology, technology develops science (1) Science is related to technology, but both are not identical (1) Science and technology develop each other (1)	22 (21.8) (n = 10) Science creates or develops technology (4) Science pairs technology (2) Science depends on technology (1) Some technologies are not related to science (1) Technology is new (1) Science is part of technology (1)	40 (36.0) (n = 50) Science is knowledge, technology is SK application (30) Science differs form technology, both depend on each other (12) Science creates technology (3) Technology comes from creativity, science comes from reality (1) Science is experiment, technology is progression (1) Technology is invention that might be involved science (1) Science is study of nature, technology changes nature (1) Science and technology develop each other (1)	27 (26.7) (n = 16) Science creates or develops technology (6) Technology is applied science (5) Science is reality, technology is development (1) Technology is part of science (1) Science supports technology (1) Science emerges prior technology (1) Technology helps science find answers (1)

adequate understanding of the NOS should be a basic requirement for science teacher preparation curriculum and science teacher professional development programmes. In the case of science teacher education, some preservice teachers begin programmes with largely unexamined understanding of the NOS and too often, leave without these understandings being challenged (O'Brien and Korth, 1991). This study revealed that, presently, a significant number of Thai preservice and inservice science teachers need urgent help from involved stakeholders to remedy their uninformed understanding of the NOS. Science teacher preparation curricula and science teacher professional development programmes should employ these uninformed understandings as a basis for designing their curriculum or programmes.

The NOS should be explicitly mentioned and included in science teacher education curriculum and science teacher professional development programmes. It should not be, as previously, anticipated as a side effect or secondary product of hands-on inquiry programmes (Akindehin,

Table 6. (Cont.)

Item statement	Response and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
13. Scientific enterprise is an individual enterprise	4 (3.6) (n = 0)	2 (2.0) (n = 0)	24 (21.6) (n = 3) Research assistants may involve (1) Scientists work alone in some project (1) Some scientists prefer working alone (1)	2 (2.0) (n = 0)	83 (74.8) (n = 88) Science need team work for clearer knowledge (48) Science is social enterprise that involves others (20) Science involves all (6) SK must be publicized for acceptance (6) Science need team work from different disciplines (3) Science can do both individual and group (2) Scientific enterprise is not for individual only (1) Working-alone scientist may make mistake (1) Science needs proof and shared understanding (1)	97 (96.0) (n = 45) Science can do in group (15) Group work helps get better data (11) Group work creates more diversity of perspectives (9) Group work helps science succeed in short time (7) Science is activity for all (2) Working-alone scientist may possess biases that lead to inaccurate interpretation (1)

1988). Based on empirical evidence (Akindehin, 1988; Billeh and Hassan, 1975; Carey and Strauss, 1968; King, 1991; Ogunniyi, 1982), explicit instruction on the NOS has the potential to improve science teachers' understanding of the NOS. The examples of explicit teaching approaches are: writing assignments, defining characteristics of science and pseudo-science (Craven et al., 2002), explicit discussion of the NOS and its role in science teaching (Palmquist and Finley, 1997), small-group peer discussions and debates (Craven et al., 2002) and surveys of students' alternative conceptions to be used in designing inquiry activities for conceptual change (Tsai, 2006). However, explicitly teaching the NOS outside science content has only a limited effect on changing and improving science teachers' understanding of the NOS. Therefore, as Driver et al. (1996) suggested, NOS-associated activities and discussions should not be an add-on, but should be tightly linked to science content. Science teachers' different views of science possibly arise from their views about how children learn; consequently, the constructivist epistemology should be included as one essential aspect of science teacher education curriculum and science teacher professional development programmes. Growing awareness of, and commitment to, constructivism among science teachers have the potential to improve their understanding of the NOS, especially the tentativeness of science and theory-laden observation (Pomeroy, 1993).

The two-tier items (That is, optional plus written responses) of the MOSQ demonstrate their potential in articulating and characterising a respondent's understanding of the NOS, especially a written response part. However, because of time usage in responding to the questionnaire and the need for large-scale implementation, in the further step, the researcher plans to revise the MOSQ to be the empirically focussed multiple-choice MOSQ. The revised MOSQ will consist of two main parts. The first part is agree or disagree multiple-choices, which are constructed from the written responses empirically derived from this study. The open-ended part of the revised MOSQ may appear as: "None of the above choices fits my viewpoint, I think that…" This revised MOSQ might be more convenient and useful for science teacher preparation curriculum and science teacher professional development programmes in exploring teachers' understanding of the NOS. Nonetheless, the present version of the MOSQ is useful to some extent in capturing science teachers' under-standing of the NOS both quantitatively and qualitatively.

The final implication is to study the relationship between preservice and inservice science teachers' understanding of the NOS and their classroom practices in the Thailand

Table 6. (Cont.)

Item statement	Response and reasoning					
	Agree		Uncertain		Disagree	
	Pre	In	Pre	In	Pre	In
14. Society, politics, and culture do not affect the development of scientific knowledge	12 (10.8) (n = 4) Science is continual developed independent from society (3) Society, politics, and culture do not affect science (1)	13 (12.9) (n = 1) Science, society, politics, and culture are different from science (1)	28 (25.2) (n = 6) Changes of politics, and culture impact science (2) Science advancement must respond to human and social needs (2) Some societal, political, and cultural issues affect science advancement (1) Religion affects science advancement (1)	13 (12.9) (n = 0)	71 (64.0) (n = 56) Society, politics, and culture affect science advancement (21) Society may block science advancement (11) Religion may impede science advancement (5) Society determines interest and direction of science (5) Society, politics, and culture prohibit some experiments such as Cloning (4) Society gives budget to do science (2) Science is not progress if government do not support (2) Science develops for, society, politics, and culture needs (2) Politics may impede science advancement e.g. GMOs (1) Change of society effects change of knowledge (1) Society, politics, and culture have scientific knowledge (1)	74 (73.3) (n = 32) Society, politics, and culture support science (12) Society, politics, and culture impede science (8) Government gives budget to do science (6) Science is in our daily lives (3) Science can solve some societal, political, and cultural problems (1) Politics problems impede science advancement (1) Society bans some experiment such as GMOs (Genetically Modified Organisms) (1)

context. There are, of course, limitations to this study. The assertions made cannot be generalised from this small sample, which was not randomly selected to represent all preservice and inservice science teachers in Thailand.

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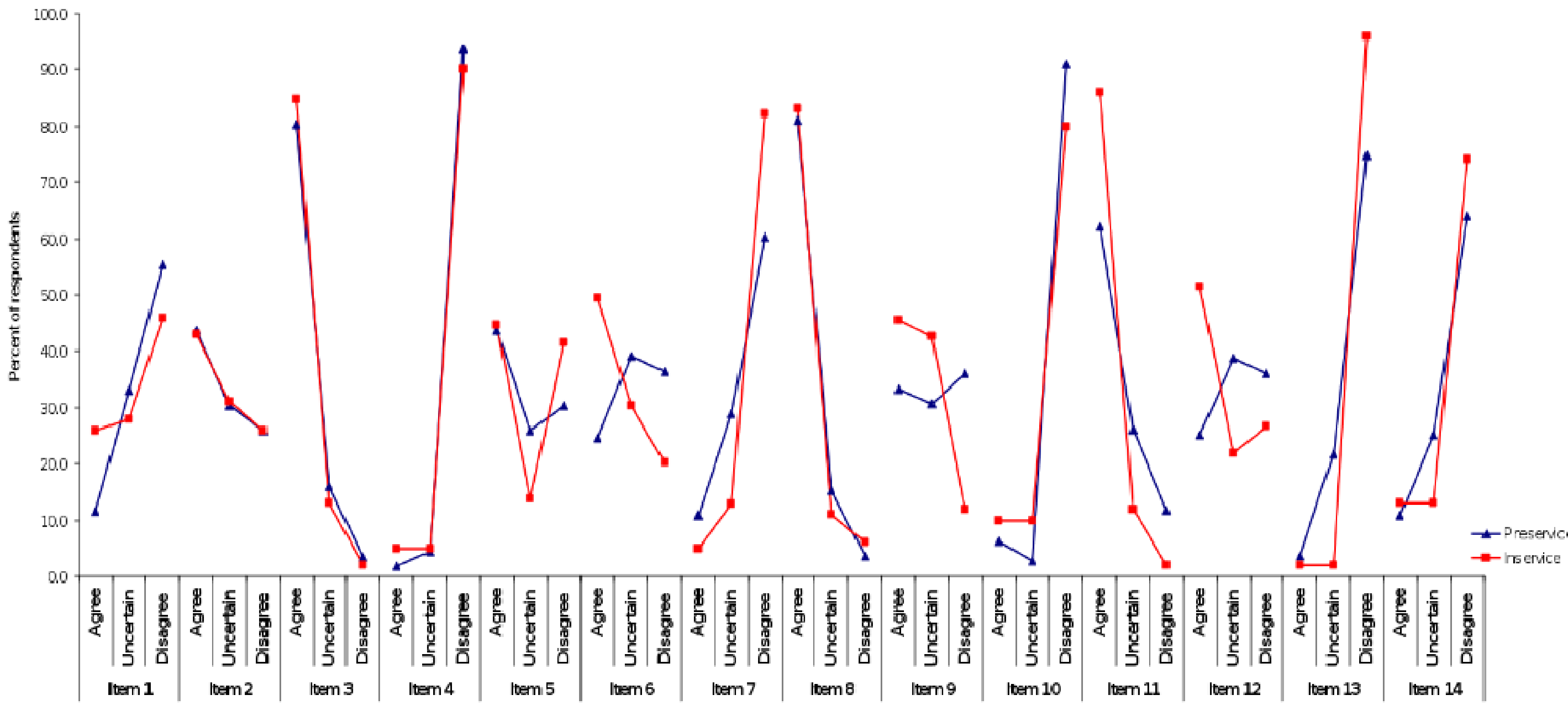

Figure 1. Preservice and inservice science teachers' conceptions of the nature of science.

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