IN-SERVICE SCIENCE TEACHERS' COMMON UNDERSTANDING OF NATURE OF SCIENCE

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Abstract: Nature of science (NOS) has been underscored as a critical component of scientifical literacy. To help students attain adequate understanding of NOS; first of all, science teachers themselves must possess adequate understanding of NOS. This study aims to explore Thai in-service science teachers' conceptions of NOS. The participants were 139 in-service science teachers from Nakhon Pathom, Thailand. A majority of the participants are primary (grades 1-6) (63.30%), secondary (grades 7-12) (20.10%), and educational extension school teachers (grades 1-9) (16.50%). The participants were responded to the View on Nature of Science (form C+) questionnaire (VNOS-C+). The data were read, coded, and categorized. The frequencies and percentages of each responses were counted and calculated, respectively. The results revealed these common understanding of NOS help by Thai in-service science teachers. Science is defined as a subject (35.51%), knowledge (27.54%), and process (10.14%). Science differs from other disciplines (99.32%) because it proves realities by experiments (28.77%), is a process for seeking knowledge (23.29%), and can be proven (22.60%). Scientific experiments are a process for proving realities (40.65%), testing hypotheses (37.42%), and seeking new knowledge (12.90%). Science needs experiments because experiments are a process for proving realities (40.65%), confirming knowledge (37.42%), and providing students direct experiences and deep memorization (11.72%). Scientific theories are tentative (89.60%) because of new evidences (16.80%), advancement of tools, methods, or technologies (15.20%), and the changing world (14.40%). Scientific theories differ from laws because scientific theories can be changed (25.60%) and they come from scientists' thinking (6.40%). Scientists are confident in atomic models (66.95%) because the models come from experiments. Scientists use creativity and imagination (92.80%) during the designing experiments (39.20%), all steps (12.80%), and data collection (12.00%). Scientists provide different explanations within the same evidence because they have different ideas, beliefs, or imagination (57.25%). Science is culturally and socially influenced (62.48%) because science responds to social needs (11.20%), the advancement of science changes society and culture (10.40%), and the change of society and culture forces science to change accordingly (8.80%). These common understanding of NOS can be utilized as a basis for designing NOS-based science teacher professional development programs.

Keywords*:* Nature of science, In-service science teacher, Common understanding, Thailand

INTRODUCTION

To be 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. Also, 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. However, several studies reveal that many science teachers possess an inadequate, incoherent understanding of NOS (Abd-El-Khalick & BouJaoude, 1997; Norman G. Lederman, 1992). This situation might be harmful because teachers must have an understanding of what they are attempting to communicate to their students (Norman G. 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) pointed out, "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 as a prerequisite for effective NOS science teaching (McComas, Clough, & Almazroa, 1998).

In the Thai context, in 2001, it is the first time that NOS had been explicitly mentioned in the basic education curriculum, namely, "the Basic Education Curriculum B.E. 2544" (Ministry of Education, 2001a). Since 2001, all science teachers are, therefore, responsible to teach NOS in their science classrooms and ensure that their students attain adequate understanding of NOS. At present, NOS is 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 possessed uninformed conceptions of NOS (Buaraphan, 2009a, 2009b; Buaraphan & Sung-ong, 2009). Thus, this study aims to investigate more in-depth details regarding Thai in-service science teachers' common understanding of NOS, which may be benefit for further developing science teachers' understanding of NOS.

LITERATURE REVIEW

The literature review section is consisted of three main parts, i.e. the definition of NOS, in-service science teachers' conceptions of NOS, and NOS education in Thailand.

Definition of NOS

NOS is a fuzzy construct; it is neither universal nor stable. There are many attempts to define NOS such as 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).

Based on Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) and related literature, NOS can be considered as consisting of seven main aspects: a) Tentativeness, b) Empirical basis, c) Subjectivity, d) Creativity, e) Social and cultural embeddedness, f) Observation and inference, and g) Theories and laws. The next section presents the details about seven aspects of NOS and some related studies about in-service science teachers' conceptions of NOS.

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; Norman G. Lederman, 1992; Mellado, 1997). Seven main aspects of NOS and related studies regarding in-service science teachers' NOS conceptions can be illustrated as follows.

Tentativeness in science

Scientific knowledge is never absolute or certain; it is subject to change. The reasons for change may include the discovery of new evidence from advancement of thinking and technology, the reinterpretation of existing evidence with the new theoretical lens, or the changes in the cultural and social spheres. Contrary to common belief, scientific hypotheses, theories, and laws can never be absolutely proven irrespective of the amount of supporting empirical evidence (Popper, 1963). For example, to be proven, a law should account for every instance of the phenomenon it purports to describe. It can logically be argued that one such future instance, of which we have no knowledge whatsoever, may behave in a manner contrary to what the law states. Thus, the law can never acquire an absolutely proven status. This equally holds in the case of theories.

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% of the 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.

Empirical basis in science

Science is at least partially based on observations of the natural world, and ''sooner or later, the validity of scientific claims is settled by referring to observations of phenomena'' (American Association for the Advancement of Science, 1990, p. 4). Unluckily, scientists do not have direct access to most natural phenomena. Observations of nature are always filtered through scientists' perceptions and/or their instruments. Data emerged from such observations are empirically based. They are subsequently interpreted within related theoretical frameworks and/or assumptions of scientific instruments.

Scientific theories and laws

In general, scientific laws are descriptive statements of relationships among observable phenomena; scientific theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. For example, Boyle's law states the pressure of gas to its volume at a constant temperature; while the kinetic molecular theory serves to explain Boyle's law. The common misunderstandings about theories and laws are: (a) a hierarchical relationship between theories and laws—theories becoming laws depending on the availability of supporting evidence; and (b) laws having a higher status than theories. Both notions are inappropriate. Theories and laws are different kinds of scientific knowledge and one does not become another.

In various studies, a majority of science teachers had naïve conception 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). 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).

Creativity and imagination in science

Even though the development of scientific knowledge involves making observations of nature, generating scientific knowledge involves human imagination and creativity. Science, contrary to common belief, is not a lifeless, entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. This aspect of science, coupled with its inferential nature, entails that scientific entities (e.g. atoms) are functional theoretical models rather than copies of reality.

The role of creativity and imagination in the construction of scientific ideas is overlooked by most science teachersbecause 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). In addition, 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 followed exactly in order to reach certain results (Haidar, 1999) or 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). '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 observations 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).

Subjectivity in science

Scientific knowledge is theory-laden. It is influenced by scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations. Scientists' background factors form a mindset affecting the problems they investigate and the ways they conduct their investigations, what they observe (and do not observe), and how they interpret their observations. Indeed, contrary to common belief, science never starts with neutral observations (Popper, 1992).

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 can 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 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).

Social and cultural embeddedness in science

Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion.

The social and cultural influences on the scientific enterprise are explicitly recognized by most science teachers (Brush, 1989). For example, 51% and 42.3%, 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% 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% and 26%, 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).

NOS education in Thailand

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. Thailand is considered to be the world's fiftieth largest country in terms of total area. The area of the country is 513,120 km sq and the coastline was 3,219 km. Thailand is divided into 77 provinces, which are gathered into six regions—North, North-East, Central, East, West, and South. The capital city of Thailand is Bangkok. Thai population was 67 millions. The Human Development Index of Thailand was 0.786. The GDP per capita in Thailand was $10,000 US. The Literacy Rate of Thai people was 92.6%. The Political System is democracy constitutional monarchy. Thailand is never colonized; it is an independent country. Religions for Thai people was Buddhist (94.6%), Muslim (4.6%), Christian (0.7%), and other (0.1%). The country's official spoken and written language is Thai; while the secondary language is English.

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), being 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 has launched a new curriculum, namely, the Basic Education Curriculum B.E. 2544 (A.D. 2001) (Ministry of Education, 2001b), 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, it is the first time that NOS has been explicitly mentioned in the basic 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 science teachers must teach NOS and help students accomplish the NOS standard as 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 conducted 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 called "the Understanding about Nature of Science Questionnaire" (Boonmuangsaen, 1997), which is 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. The 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. There are 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 called "the Myths of Science Questionnaire" (MOSQ), Buaraphan (2009) revealed that a majority of in-service science teachers in Thailand held eight common uninformed conceptions of NOS: a) scientific theories can be developed to become laws; b) accumulation of evidence makes scientific knowledge more stable; c) scientists are open-minded without any biases; d) scientific theories are less secure than laws; e) the scientific method is a fixed step-by-step process; f) science and the scientific method can answer all questions; g) a scientific model expresses a copy of reality; and h) science and technology are identical. However, there is a lack of study to explore more in-depth details about Thai in-service science teachers' understandings of NOS.

RESEARCH QUESTION

The research question for this study was: What are Thai in-service science teachers' common understandings of NOS?

METHOD

This study is one part of a large study entitled "The Exploration and Development of In-Service Science Teachers' Understanding of NOS", which was funded by Mahidol University, Thailand. The methodology for this phase is a survey research.

Data collection

The data were collected from in-service secondary science teachers in the 2011 academic year. The participants of this study were 139 in-service science teachers from Nakhon Pathom province, Thailand. Of 139 participants, 88 (63.3%) taught at primary schools (Grades 1-6); while 18 (20.1%) and 23 (16.5%) participants taught at secondary schools (Grades 7-12) and extended education schools (Grades 1-9), respectively. Most of the schools they taught having students less than 500 students (70.5%). There were 15.8% and 13.7% of the participants taught at the schools having students between 500 to 1.499, and more than 1,500, respectively. The percentages of the participants in each age range were: less than 26 years old (4.3%), 26-30 years old (13.7%), 31-35 years old, 12.9%), 36-40 years old (9.4%), 41-45 years old (7.2%), 46-50 years old (17.3%), 51-55 years old (28.1%), and 56-60 years old (7.2%). Regarding this, the age range of more than a quarter of the participants was 51-55 years old. The teaching experiences of the participants were: less than six years (39.9%), 6-10 years (17.4%), 11-15 years (8.0%), 16-20 years (7.2%), 21-25 years (10.3%), 26-30 years (12.3%), and more than 30 years (4.3%). About one-third of the participants of this study were young science teachers, who gained experiences in teaching science less than 6 years.

Instrument

The Views of Nature of Science Questionnaire form C (VNOS-C) created by Lederman et al. (2002) was adapted to explore in-service science teachers' understanding of NOS in this study. The adapted version of VNOS-C was named "VNOS-C+". There were three adaptations of VNOS-C. First, Item7 in VNOS-C was removed because it was similar to Item4.

Item7: Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specificevidence **do you think** scientists used to determine what a species is?

Item4: Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?

Second, the remaining items was rearrange. Third, Item 1 of VNOS-C was separated into Items 1 and 2 of VNOS-C+. The total items of VNOS-C+ are depicted as Figure 1.

VNOS-C+

Instructions:

Please answer each of the following questions. Include relevant examples whenever possible. You can use the back of a page if you need more space. There are no "right" or "wrong" answers to the following questions. We are only interested in your opinion on a number of issues about science.

1. What, in your view, is science?
2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
3. What is an experiment?
4. Does the development of scientific knowledge **require** experiments?
   If yes, explain why. Give an example to defend your position.
   If no, explain why. Give an example to defend your position.
5. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   If you believe that scientific theories do not change, explain why. Defend your answer with examples.
6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example. If you believe that scientific theories do change:
   (a) Explain why theories change?
   (b) Explain why we bother to learn scientific theories. Defend your answer with examples.
7. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?
8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
   If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
   If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.
9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?
10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
    If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
    If you believe that science is universal, explain why and how. Defend your answer with examples.

Figure 1: VNOS-C+ items

The NOS aspects embedded in VNOS-C+ and their descriptions can be elaborated in Table 1.

Table 1: NOS aspects and descriptions serving as a basis for evaluation of VNOS-C+ responses

Aspect	Description
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical basis	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Social and cultural embeddedness	Science is a human endeavour and, as such, is influenced by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted.
Observations and inferences	Science is based on both observations and inferences. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
Theories and laws	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

Data analysis

The participants' responses on VNOS-C+ were carefully read and constantly seek for embedded meanings. Each unit of meaning was assigned a code. The codes with similar meanings were grouped into the same category. The category with complex meanings, then, may be consisted of many codes as well as sub-codes. At final, the frequencies of codes were counted.

The example of category and codes related to VNOS-C+ Item 1: "What, in your view, is science?" can be illustrated as:

Category	Code
Meaning of science	I01: Science is knowledge about nature.
	I02: Science is knowledge coming from logical proves.
	I03: Science is knowledge coming from investigations.

The description of NOS aspects mentioned in VNOS-C+ can shown as Table 2.

Table 2: VNOS-C+ item description

Item	Description
1 and 2	This question aims to assess respondents' views regarding science as a discipline to address questions about the natural world, the role of science in providing explanations for natural phenomena, and the role that empirical evidence plays in science that separates science from other "ways of knowing." Responses to this question often reveal a common misconception regarding the use of the "Scientific Method" as an objective process by which the knowledge is discovered. Such a view is often presented as an explanation for how science differs from other disciplines of inquiry.
3 and 4	Questions 3 and 4 are used in combination to assess respondents' views of investigative processes in science. Question 4 elicits responses regarding the existence of multiple methods of investigation (such as experimentation involving controlled variables, correlational studies, and descriptive investigations) that do not all follow the traditional "Scientific Method" or set of pre-established logical steps requiring a testable hypothesis. Responses to Question 3 clarify respondents' ideas of "experiment," as often this term is defined differently. Question 4 is then interpreted in relation to the provided description of "experiment." Question 4 also may elicit views of subjectivity and creativity in science.
5	This question assesses respondents' understanding of the tentative nature of scientific theories and reasons why science is tentative. Respondents often attribute change solely to the accumulation of new observations or data and/or the development of new technologies, and they do not consider change that results from reinterpretation of existing data from a different perspective. Views of the theory-laden nature of scientific investigations, the notion that the prevailing theories of the time impact the direction, conduct, and interpretation of scientific investigations, are assessed through the explanation of the role of theories in science. Additionally, responses often indicate views of the role of subjectivity, creativity, inference, and the sociocultural embeddedness of the scientific endeavor, as well as the interdependent nature of these aspects.
6	This question assesses respondents' views of the development of and relationship between scientific theories and laws. The common misconception of the existence of a hierarchical relationship is often revealed. This misconception is presented by the explanation of a progression from scientific theory to law with the accumulation of more and more evidence until the theory has been "proven true" at which time it becomes a law. Views regarding distinctions between observation and inference are also commonly elicited. Additional ideas are often expressed by respondents as they attempt to describe the differences between scientific theories and laws.
7	This question refers respondents to a concept from the physical sciences to assess their understandings of the role of human inference and creativity in developing scientific explanations and models based on available data, and the notion that scientific models are not copies of reality.
8	This question assesses respondents' views of the role of human creativity and imagination in science, and the phases of scientific investigations at which respondents believe these aspects play a role. Often creativity is described relative to design only, and usually in regard to resourcefulness necessary to set up and conduct investigations. Respondents are less likely to recognize the role of creativity in question development, data analysis, and interpretation. Ideas of "discovery" versus "created patterns" are elicited.
9	This question assesses respondents' understandings of reasons for controversy in science when scientists use the same available data. Ideas of subjectivity, inference, creativity, social and cultural influences, and tentativeness are often elicited. The question aims to assess respondents' beliefs about what influences data interpretation including personal preferences and bias (personal subjectivity) to differing theoretical commitments and impacts of social and cultural values.
10	This question assesses respondents' views of the impact of social and cultural values and expectations on the scientific endeavor. Naïve views are often indicated by responses describing science as "value free" and stating that different cultures and belief systems do not impact the way science is conducted or the interpretation or use of scientific knowledge. Views of connections between sociocultural influences on science and subjectivity, creativity, inference, and tentativeness are often elicited.

FINDINGS

This section presents Thai in-service science teachers' understandings of NOS reflected by VNOS-C+.

Meaning of science

When responded to Item 1: What, in your view, is science? The results are as follows.

Table 3: In-service science teachers' understanding of NOS: VNOS-C+ Item 1

Conception	Frequency (f)	Percentage (%)
Science is subject/ discipline	50	36.32
• Subject/ discipline about nature	30	21.74
• Subject/ discipline about reasoning	14	10.14
• Subject/ discipline about reality proving	3	2.17
• New subject/ discipline	2	1.45
• Subject/ discipline about developing thinking	1	0.72
Science is knowledge	38	27.54
• Knowledge about nature	20	14.49
• Knowledge coming from logical proves	13	9.42
• Knowledge coming from investigations	5	3.62
Science is process	14	10.14
• Process for seeking knowledge	8	5.80
• Process for reasonable explanations	3	2.17
• Process for proving realities	1	0.72
• Is scientific process	1	0.72
• Process leading to technology	1	0.72
Science is body of knowledge and process	14	10.14
Science is reality	9	6.52
Science is everything surrounding	8	5.80
Science is experiment for seeking reality	3	2.17
Science is teaching and learning	2	1.45
Total	**138**	**100.00**

The most common understanding about meaning of science for the participants was "science is subject/ discipline" (36.32%). The major reason was "Science is subject/ discipline about nature" (21.74%). For example, one participant reflected that:

Science is knowledge about nature around us including both living and non-living things. (P01-1*)

*Note: P means Primary science teacher (S means Secondary science teacher)
01-1 means the participant no. 1 from the school code 01.
P01-1 means the primary science teacher no. 1 from the school code 01.

Only 10.14% of the participants had informed understanding of meaning of science that science is both knowledge and process as:

> Science is consisted of two main parts. The first part is bodies of knowledge being discovered by scientists. Such bodies of knowledge are basically characterized into scientific principles, theories, or laws, which will be discovered more and more by next generations. The second part is ways of investigating that mean scientific inquiry for seeking new knowledge continuously and endlessly (S03-2).

Differences between science and other disciplines

When responded to Item 2: What makes science different from other disciplines of inquiry? The results are as follows.

Table 4: In-service science teachers' understanding of NOS: VNOS-C+ Item 2

Conception	Frequency (f)	Percentage (%)
Science differs from other disciplines because…	145	99.32
• Science proves realities by experiments	42	28.77
• Science can be proven	34	23.29
• Science employs specific process for seeking knowledge	33	22.60
• Scientific knowledge is real, reasonable, and concrete	19	13.01
• Science emphasizes practice leading to reasonable knowledge	4	2.74
• Scientific knowledge is in-depth and can be utilized in daily lives	3	2.05
• Scientific knowledge is changeable	3	2.05
• Scientific knowledge comes from scientific process	3	2.05
• Scientific knowledge comes from continuous investigations	2	1.37
• Scientific knowledge comes from nature	1	0.68
• Science emphasizes systematic problem solving and accountability	1	0.68
Science does not differ from other disciplines because…		
• Science is a part of Buddhism	1	0.68
Total	**146**	**100.00**

Almost all participants (99.32%) believed that science differs from other disciplines. The main reason was science proves realities by experiments (28.77%). One participant stated that "Science differs from other disciplines because it can be proven and experimented and yields concrete results" (P02-1). Only one participant who believed that science does not differ from other disciplines stated that: "Scientific process does not differ from the process in Buddhism. Science is a discipline discovered after the Buddhism age. So, science is a part of religion especially Buddhism" (S05-1).

Scientific experiment

When responded to Item 3: What is an experiment? The results are as follows.

Table 5: In-service science teachers' understanding of NOS: VNOS-C+ Item 3

Conception	Frequency (f)	Percentage (%)
Scientific experiment is process for proving realities	63	40.65
Scientific experiment is testing hypotheses	58	37.42
Scientific experiment is process for seeking knowledge	20	12.90
Scientific experiment is process for students in learning science	3	1.94
Scientific experiment is trial-and-error	3	1.94
Scientific experiment is setting hypothesis, doing lab, observing, and making conclusion	3	1.94
Scientific experiment leads to theories	2	1.29
Scientific experiment is process to make things better	1	0.65
Scientific experiment seeks for new methods	1	0.65
Scientific experiment is systematic investigations	1	0.65
Total	**155**	**100.00**

Nearly half of the participants (40.65%) stated that scientific experiment is a process for proving realities. Three participants linked scientific experiment with science learning, for example, "Scientific experiment is a process for learning science in order to enhance student understanding and prove existing theories. In this process, students have opportunity to practice observation, data record and analysis, seeking relationships, and explaining results correctly"

(P31-1). A minority of the participants (1.94%) stated that scientific experiment is trial-and-error. For example, one participant stated that "Scientific experiment is trial-and-error that can lead to facts or nothing" (P14-1).

Relationship between scientific experiment and development of scientific knowledge
When responded to Item 4: Does the development of scientific knowledge require experiments? The results are as follows.

Table 6: In-service science teachers' understanding of NOS: VNOS-C+ Item 4

Conception	Frequency (f)	Percentage (%)
Development of scientific knowledge requires experiments because…	136	93.79
• They proves realities	37	25.52
• They lead to correct bodies of knowledge	18	12.41
• They provide direct experience for students and make them remember longer	17	11.72
• They find answers of problems	14	9.66
• They show credibility of reasons	11	7.59
• Science demands evidence	9	6.21
• They are the heart for deriving bodies of knowledge	7	4.83
• They are one scientific process	6	4.14
• They lead to new bodies of knowledge	4	2.76
• They show the origin of knowledge	3	2.07
• They improve things	2	1.38
• They are concrete that make students understand easily	2	1.38
• They are process for finding out clear answers	1	0.69
• They make students as center of learning	1	0.69
• They make science lessons meaningful	1	0.69
• They are ways to learn science	1	0.69
• Scientific knowledge is changed	1	0.69
• They make confidence in new bodies of knowledge	1	0.69
Development of scientific knowledge does not require experiments because…	4	2.76
• We can do other types of investigation	1	0.69
• They are not necessary	1	0.69
• We can improve students without doing experiments	1	0.69
• Some topics had been experimented before	1	0.69
Development of scientific knowledge may require and not require experiments because…	5	3.45
• It depends on sufficiency of data	1	0.69
• It depends on situations of problems	1	0.69
• It depends on needs. Sometimes, we observe, collect data, and make conclusion	1	0.69
• We do experiments for some topics and do surveys for others.	1	0.69
• We do experiments for proving in some topics; but, for some topics, we just want to know, not prove	1	0.69
Total	**145**	**100.00**

Almost all participants (93.79%) stated that the development of scientific knowledge requires experiments. The most favorite reason was experiments prove realities (25.52%). One participant stated that: "The development of scientific knowledge require experiments because they empirically prove realities" (P06-1). A minority of the participants (2.76%) stated that the development of scientific knowledge does not require experiments. In addition, 3.45% of the participants stated that the development of scientific knowledge may require and not require experiments by raising other methods such as observation or survey.

Tentativeness of science

When responded to Item 5: After scientists have developed a scientific theory, does the theory ever change? The results are as follows.

Table 7: In-service science teachers' understanding of NOS: VNOS-C+ Item 5

Conception	Frequency (f)	Percentage (%)
Scientific theories can be changed because…	112	89.60
• There is discovery of new emerging data/ evidence	21	16.80
• There is new experiments leading to new theories	19	15.20
• There is advancement of tools/ methods/ technologies	19	15.20
• The world is changing	18	14.40
• There is better reasons emerged	15	12.00
• There is discovery of new knowledge	5	4.00
• There is new discovery	4	3.20
• Time is changing	4	3.20
• For example, the atomic theories are changed	2	1.60
• New theory is proven better than previous ones	1	0.80
• Scientists' ideas are changed	1	0.80
• New theory are more closer to realities than previous ones	1	0.80
• Theories are infinite and waiting for discovery	1	0.80
• There is new knowledge adding up existing knowledge	1	0.80
Scientific theories cannot be changed because…	13	10.40
• They were proven by many experiments	5	4.00
• Atoms are not changed	2	1.60
• Scientists use the same principles or theories as previous scientists did	2	1.60
• There is no new theory to defend existing theories	2	1.60
• Theories are added up, not changed	1	0.80
• They come from careful examinations with enormous supporting evidence	1	0.80
Total	**125**	**100.00**

Most of the participants (89.60%) reflected that scientific theories can be changed. The main reason for change was the discovery of new emerging data or evidence (16.80%). For example, one participant responded that "The discovery of new, more clear, evidence can lead to the eradication of old theories such as the discovery of real shape of the world leads to the eradication of the flat world theory" (P09-3). Only 10.40% of the participants believed that scientific theories cannot be changed. One teacher stated that "Scientific theories are not changed because they were experimented by previous scientists until reached certain conclusions" (P25-1).

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Scientific theories and laws

When responded to Item 6: Is there a difference between a scientific theory and a scientific law? The results are as follows.

Table 8: In-service science teachers' understanding of NOS: VNOS-C+ Item 6

Conception	Frequency (f)	Percentage (%)
Scientific theories differ from laws because…	117	93.60
• Theories can be changed; while laws cannot be changed	32	25.60
• Theories come from thinking; laws are used as guidelines for practice	8	6.40
• Theories are proven hypotheses; laws are principles showing logical relationships	8	6.40
• Theories come from experiments; laws are rules	8	6.40
• Laws are proven theories	4	3.20
• Theories come from experiments and cannot disputed; laws employ theories	3	2.40
• Laws lead to theories	3	2.40
• Hypotheses are proven to become theories; theories are used without dispute until they become laws	3	2.40
• Theories are proven hypotheses; laws occur from nature	2	1.60
• Theories can be changed; laws are hard to change	2	1.60
• Theories are divided into many topics; laws are used for practice	2	1.60
• Theories are tested hypotheses; laws are rules	2	1.60
• Theories are proven facts	2	1.60
• Theories are beliefs/ ideas that are tested until they are confident; laws are realities that cannot dispute	2	1.60
• Theories are created and can be changed; laws are discovered and cannot be changed	2	1.60
• Theories are discovered; laws are facts	1	0.80
• Theories are uncertain; laws are certain	1	0.80
• Theories come from experiments; laws are clear and certain	1	0.80
• Theories come from experiments or thinking that can be changed; laws come from scientific proves and cannot be changed or disputed	1	0.80
• Theories are proven facts; laws are definite fixed	1	0.80
• Theories come from repeated experiments for realities; laws are definitions of theories and can be applied	1	0.80
• Laws are accepted more than theories	1	0.80
• Theories can be used to explain phenomena; set of related theories will become laws	1	0.80
• Theories are educational guesses; laws are patterns in the nature that can be discovered	1	0.80
• Theories are hypotheses being repeatedly tested and can be used to explain and predict events; laws are facts being proved as real	1	0.80
• Theories are discoveries that are consensus; laws are rules to follow	1	0.80
• Theories can re-created; laws are for follow	1	0.80
• Theories can be changed when there are better supporting data; laws are conclusions from investigations that are reasonable and applicable	1	0.80
• Theories are hypotheses that can be changed; laws come from experiments until finding answers	1	0.80
• Theories are unproven ideas; laws are scientific explanations based on empirical observations	1	0.80
• Theories are proven knowledge; laws are proves for advantages or	1	0.80

cautions		
• Theories are hypotheses being proved by experiments; laws are proven realities	1	0.80
• Laws are used to explain theories	1	0.80
• Theories are set for explaining things; laws are definite fixed	1	0.80
• Laws are proven many times and yield the same results	1	0.80
• Theories come from proving realities and be generally accepted; laws are created by human beings	1	0.80
• Theories are proven by repeated experiments; laws divide theories into many branches	1	0.80
• Theories are systematic guidelines for practice; laws are rules to follow	1	0.80
• Theories are ideas	1	0.80
• Theories are proven many times and broader than laws	1	0.80
• Theories are educational guesses; laws are proven principles by enormous supporting evidence	1	0.80
• Theories are discovered by many people; laws are belong to a person who did related experiment	1	0.80
• Theories are explanations that can be changed; laws use theories to explain realities	1	0.80
• Theories are explanations of phenomena; laws are developed theories being proven as real	1	0.80
• Theories are experiments; laws are operational definitions	1	0.80
• Laws are narrower than theories	1	0.80
• Theories are broad principles for explaining phenomena; laws are principles explaining cause and effect	1	0.80
• Theories are hypotheses being repeatedly tested that can be used to explain, refer, or predict; laws are hypotheses being repeatedly tested and generally accepted	1	0.80
• Theories are explanations being systematically examinations; laws are agreements of particular groups of scientists	1	0.80
Scientific theories do not differ from laws because…	8	6.40
• Laws based on theories	2	1.60
• Both theories and laws can be changed according to new better data/ evidence/ reasons	2	1.60
• Laws are theories	1	0.80
• Laws are consisted of many theories	1	0.80
• Both theories and laws can be changed according to new more credible theories and laws. Both theories and laws are human created.	1	0.80
• Both theories and laws prove realities	1	0.80
Total	**125**	**100.00**

Almost all participants (93.60%) stated that scientific theories differ from laws. However, the reasons to support the differences between scientific theories and laws are much varied. Up to this, the major reason (25.60%) was "Theories can be changed; while laws cannot be changed". On the contrary, only 6.40% of the participants stated that scientific theories do not differ from laws. One participant stated that "Both theories and laws can be changed according to new more credible theories and laws. Both theories and laws are human created" (P29-1).

Creativity and imagination in science

When responded to Item 7: Science textbooks often represent the atom as a central nucleus composed of protons and neutrons with electrons orbiting that nucleus. 7.1 How certain are scientists about the structure of the atom? 7.2 What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like? The results are as follows.

Table 9.1: In-service science teachers' understanding of NOS: VNOS-C+ Item 7.1

Conception	Frequency (f)	Percentage (%)
Scientists are certain about the structure of the atom because…		
• They come from experiments	79	66.95
• Many scientists study about this topic	9	7.63
• They come from proven theories	8	6.78
• They come from investigations	6	5.08
• Scientific models can explain it	3	2.54
• Scientists set hypotheses	2	1.69
• It follows the law	2	1.69
• They come from electrical charges	2	1.69
• They come from repeated tests that yield the same results	2	1.69
• They come from existing data	1	0.85
• Objects occupy mass; mass is consisted of atoms	1	0.85
• They come from provable evidence	1	0.85
• They come from the strength of matters	1	0.85
• They come from pictures	1	0.85
Total	**118**	**100.00**

More than half of the participants (66.95%) believed that scientists are certain about the structure of the atom because they come from experiments.

Table 9.2: In-service science teachers' understanding of NOS: VNOS-C+ Item 7.2

Conception	Frequency (f)	Percentage (%)
What specific evidence scientists used to determine what an atom looks like		
• Results from experiments	63	60.00
• The atomic models	8	7.62
• Pictures of atoms from electromicroscope	7	6.67
• The use of atomic models to explain related phenomena	5	4.76
• Nuclear bomb	4	3.81
• Science textbooks	3	2.86
• Existing scientific tools or technology	3	2.86
• Nothing	2	1.90
• Examinations and data analysis	1	0.95
• The atomic theories	1	0.95
• From hypotheses	1	0.95
• From scientific proves	1	0.95
• From investigations	1	0.95
• From scientists' ideas	1	0.95
• From related natural phenomena	1	0.95
• From shared beliefs and acceptance among scientists	1	0.95
• From chemical structures of substance	1	0.95
• From lives of living things	1	0.95
Total	**105**	**100.00**

More than 60% of the participants stated that the results from experiments are evidence scientists used to determine what an atom looks like.

When responded to Item 8: Do scientists use their creativity and imagination during their investigations?

The results are as follows.

Table 10: In-service science teachers' understanding of NOS: VNOS-C+ Item 8

Conception	Frequency (f)	Percentage (%)
Scientists use their creativity and imagination during their investigations	116	92.80
• Use in designing experiments	49	39.20
• Used in every steps of investigation	16	12.80
• Use in data collection	15	12.00
• Use in setting hypotheses	9	7.20
• Use in designing experiments and data collection	7	5.60
• Use in setting hypotheses, designing experiments, data collection, and concluding theories	7	5.60
• Use in making conclusions	4	3.20
• Scientists are observant and imaginative	2	1.60
• Use in designing experiments, data collection, and making conclusions	2	1.60
• Use in designing inventions	2	1.60
• Use in designing reports	1	0.80
• Use in setting hypotheses, designing experiments, and data collection	1	0.80
• Use in designing models	1	0.80
Scientists do not use their creativity and imagination during their investigations	9	7.20
• Science demands only realities	3	2.40
• Science uses logics to prove realities	2	1.60
• Scientific method is consisted of systematic steps	2	1.60
• Science has fixed theories	1	0.80
• Results from experiments are exactly as they are found	1	0.80
Total	**125**	**100.00**

Almost all participants (92.80%) stated that scientists use their creativity and imagination during their investigations, especially in designing experiments (39.20%). One science teacher, as an example, stated that "Scientists use creativity and imagination in designing steps of doing experiment especially setting related hypotheses. In designing experiments, scientists must use their ideas or imagination regarding how to conduct their experiments to test their hypotheses. Scientists use imagination in setting hypotheses and use creativity in designing experiments" (P32-4). However, there were 7.20% of the participants who reflected that scientists do not use their creativity and imagination during their investigations. One participant firmly stated "Creativity and imagination have no room in science because scientists cannot use imagination in their investigations to find out the answers of the problems. They must use the results from experiments only. When the results come, they must analyze and make conclusions as the results said" (P54-2).

Subjectivity in science

When responded to Item 9: It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions? The results are as follows.

Table 11: In-service science teachers' understanding of NOS: VNOS-C+ Item 9

Conception	Frequency (f)	Percentage (%)
Two groups of scientists have different conclusions because…		
• They have different ideas, beliefs, or imagination	75	57.25
• They make conclusions based on existing evidence	16	12.21
• Both conclusions can be correct	13	9.92
• There is no clear evidence	11	8.40
• They use different proves	4	3.05
• They use different reasons	4	3.05
• They conclude differently	3	2.29
• They analyze differently	2	1.53
• They use different technologies	1	0.76
• They discovered differently	1	0.76
• They observed differently	1	0.76
Total	**131**	**100.00**

More than half of the participants (57.25%) believed that two groups of scientists can reach different conclusions with the same set of data because they possess different ideas, beliefs, or imagination. As one science teacher stated "The difference of ideas between two groups of scientists makes them reach different conclusions. The reasons of different ideas may include different backgrounds of scientists that lead them to different understanding" (P19-1).

Social and cultural embeddedness in science

When responded to Item 10: Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. Which one you believe, explain why and how. The results are as follows.

Table 12: In-service science teachers' understanding of NOS: VNOS-C+ Item 10

Conception	Frequency (f)	Percentage (%)
Society and culture influence science	78	62.40
• Science responds to needs of society	14	11.20
• When science progresses; society and culture change	13	10.40
• When society and culture change; science changes accordingly	11	8.80
• Science is one part of human beings and society	10	8.00
• Society, religion, and culture relate to science	8	6.40
• Science is the principles of logic that make society not credulous	4	3.20
• Scientists cannot do some experiments that are illegal or not accepted by people in society	4	3.20
• The development of each country is different	2	1.60
• Science is proven beliefs	2	1.60
• The root of science is beliefs, society, and cultures	2	1.60
• Budget affects scientific enterprise	1	0.80
• Culture make us understand nature	1	0.80
• People with some values do not accept scientific experiments	1	0.80
• Science relates to everything	1	0.80
• Scientific enterprise is reasonable and provable; it can create some specific values	1	0.80
• Science is learning all the time	1	0.80

• Science reflects values and thinking	1	0.80
• The world is changing all the time	1	0.80
Society and culture do not influence science	47	37.60
• Science is provable; prove demands value-free	26	20.80
• Science is reasonable	5	4.00
• Science is systematic	5	4.00
• The interpretations in science are the same everywhere	4	3.20
• Science is accepted from society	2	1.60
• Science involves human beings with all cultures	2	1.60
• Science is freedom	1	0.80
• Science comes from continuous investigations	1	0.80
• Science demands experiments	1	0.80
Total	**125**	**100.00**

More than half of the participants (62.48%) believed in the social and cultural influences on science. The main reason was that science responds to needs of society (11.20%). As one science teachers stated "Scientific enterprise reflects social, political, and philosophical values, and patterns of traditions. For example, many scientific works are created to respond to needs of people in society or to solve problems in the world community" (P09-1). In contrast, there were 37.60% of the participants who believed that society and culture do not influence science. The main reason (20.80%) was that science is provable and such prove demands value-free. As one participant stated, for example, "Social, political, philosophical, and cultural values do not affect scientific enterprise because doing science follows specific guidelines and patterns that are the same for any society or values" (S01-3).

DISCUSSION

Cultivating NOS in science education may appear as a difficult and challenging task for science educators in many countries. In Thailand, NOS had been cultivated in science education since 2001 in the Basic Education Curriculum B.E. 2544. NOS was explicitly mentioned in the Sub-strand 8: Nature of Science and Technology of the Science learning area. More than a decade ago, at present, NOS is generally believed to take a strong root in science education in Thailand. In-service science in Thailand are normally expected to possess adequate understanding of NOS. However, this study reveals that many Thai in-service secondary science teachers still possess misunderstanding of NOS, especially scientific theories and laws, and subjectivity in science.

Anyway, the common understanding of NOS shared by Thai in-service science teachers in this study are as follows. Science is defined as a subject (35.51%), knowledge (27.54%), and process (10.14%). Science differs from other disciplines (99.32%) because it proves realities by experiments (28.77%), is a process for seeking knowledge (23.29%), and can be proven (22.60%). Scientific experiments are a process for proving realities (40.65%), testing hypotheses (37.42%), and seeking new knowledge (12.90%). Science needs experiments because experiments are a process for proving realities (40.65%), confirming knowledge (37.42%), and providing students direct experiences and deep memorization (11.72%). Scientific theories are tentative (89.60%) because of new evidences (16.80%), advancement of tools, methods, or technologies (15.20%), and the changing world (14.40%). Scientific theories differ from laws because scientific theories can be changed (25.60%) and they come from scientists' thinking (6.40%). Scientists are confident in atomic models (66.95%) because the models come from experiments. Scientists use creativity and imagination (92.80%) during the designing experiments (39.20%), all steps (12.80%), and data collection (12.00%). Scientists provide different explanations within the same evidence because they have different ideas, beliefs, or imagination (57.25%). Science is culturally and socially influenced (62.48%) because science responds to social needs (11.20%), the advancement of science changes society and culture (10.40%), and the change of society and culture forces science to change accordingly (8.80%). The details of discussion related to those common understanding of NOS are presented below.

Meaning of science

About one-third of the science teachers in this study view science as a subject or a discipline. The others view science as either knowledge or process. Only a few teachers regard science as both process and product (knowledge). The science teachers' view of science as a discipline about nature show their understanding of NOS. However, they should add the role of science in providing explanations for natural phenomena.

Difference between science and other disciplines

Almost all science teachers believe that science differs from other disciplines. The main reason because science employs experiments to prove realities. They give emphasis on a scientific experiment as a specific way for seeking knowledge that makes science differ from other disciplines. However, the science teachers pay less attention to the role of empirical evidence in science that separates science from other disciplines or "ways of knowing"

Scientific experiment

Nearly all science teachers gives emphasis on scientific experiments as essential for developing scientific knowledge as the atomic models. The common misunderstanding of NOS that scientific models are copies of reality is not popular in this study as found in other studies (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008), though a few teachers state that scientists are certain about the structure of the atom because they see it from electromicroscope. In this case, they view scientific models as copies of reality rather than human inventions (Abd-El-Khalick & BouJaoude, 1997) because scientists say they are true or because much scientific observations and/or research have shown them to be true (Dogan & Abd-El-Khalick, 2008). In addition, there is a few teachers in this study who state about a universal step-wise scientific method. This finding is also contradict to other studies (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999).

Tentativeness in science

Most of the science teachers reflect that scientific theories can be changed. The main reason for change was the discovery of new emerging data or evidence (16.80%). Only few of the science teachers believe that scientific theories cannot be changed. This finding is similar to Dogan and Abd-El-Khalick (2008) and Lunn (2002) who found that science teachers generally believed in the tentativeness of scientific knowledge. Scientific theories, for example, can be renewed and changed both in the light of new knowledge and new facts.

Scientific theories and laws

Almost all science teachers believe that there are difference between scientific theories and laws. Interestingly, there are a variety of reasons to support such differences. However, there is no science teacher who can 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." Moreover, some teachers express misunderstanding to support the difference between scientific theories and laws that: Scientific theories can be changed; but laws cannot be changed. Another common misunderstanding is related to a hierarchical relationship between hypotheses, theories, and laws (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Rubba & Harkness, 1993). This finding confirms that the conception that scientific theories and laws are different types of ideas is not easily grasped by most science teachers (Abd-El-Khalick & BouJaoude, 1997).

Creativity and imagination in science

Almost all science teachers in this study believe that scientists use their creativity and imagination during their investigations, especially in designing experiments. This finding is contradict to the studies revealed that 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).

Subjectivity in science

More than half of the science teachers reflect subjectivity in science. They state two groups of scientists can reach different conclusions on the same set of data because they possess different ideas, beliefs, or imagination. The science teachers in this study can be divided into two groups by using common bipolar views of NOS as found in the literature: a) subjectivity, theory-laden, and b) objectivity, theory-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 can affect their scientific thinking and decision-making (Lunn, 2002). However, many science teachers strongly believed in objectivity in science, which is firmly based upon theory-free observation. For example, some 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).

Social and cultural embeddedness in science

More than half of the science teachers believe in the social and cultural influences on science. The main reason was that science responds to needs of society. In contrast, there were some science teachers believe that society and culture do not influence science because science is provable and such prove demands value-free. This finding is similar to Brush (1989), Haidar (1999), and Rubba and Harkness (1993) who found that the social and cultural influences on the scientific enterprise are explicitly recognized by most science teachers.

In summary, the findings of this study suggest that although NOS is officially included in the basic education curriculum, it is not guarantee that in-service science teachers must possess well-informed understanding of NOS. Many in-service science teachers in this study like others around the world possess mixed, and incoherent understanding of NOS (Abd-El-Khalick & BouJaoude, 1997; Dogan & Abd-El-Khalick, 2008; Haidar, 1999).

IMPLICATIONS

NOS understanding is widely accepted as one important attribute for science students. Therefore, at present, NOS is included in many curricula worldwide. Teaching NOS in classrooms is not an easy task; science teachers themselves must possess well informed understanding of NOS. As we have known, teachers cannot effectively teach what they do not know.

This study suggests that explicit inclusion of NOS in the basic education curriculum yields some benefits as partly reflected by more informed conceptions of NOS held by the Thai in-service science teachers science teachers. It also presents some common understanding as well as misunderstanding of NOS possessed by these science teachers that can be utilized as a basis for designing more appropriate teacher professional development programs to help in-service science teachers develop more informed understanding of NOS.

Helping science teachers attain adequate understanding of NOS is, therefore, an essential task for science educators. To do that, at first, we needs some information about their prior understanding of NOS. Consequently, the VNOS-C+ used in this study can be employed to explore in-service science teachers’ understanding of NOS.

Subsequently, there are many activities that can be used to help improve science teachers’ NOS conceptions. The effective approach, which is widely supported by many studies, is the explicit-reflective approach. The examples of explicit-reflective NOS activities are writing assignments defining science and pseudo-science (Craven et al., 2002), explicit discussion of NOS and its roles within conceptual change and cooperative learning environment (Palmquist & Finley, 1997), and growing awareness of, and commitment to, constructivism (Pomeroy, 1993). However, to be reminded, explicitly teaching NOS outside a science context has only a limited effect on 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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REFERENCES

[1] Abd-El-Khalick, Fouad, & BouJaoude, Saouma. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*(7), 673-699.

[2] Abd-El-Khalick, Fouad, & Lederman, Norman G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22*, 665-701.

[3] American Association for the Advancement of Science. (1990). *Science for all Americans* New York: Oxford University Press.

[4] Behnke, F. L. (1961). Reactions of scientists and science teachers to statements bearing on certain aspects of science and science teaching. *School Science and Mathematics, 61*, 193-207.

[5] Boonmuangsaen, Sarash. (1997). *A study of senior high school science teachers' understanding of the nature of science in the Educational Region 9.* (Master), Mahasarakham University.

[6] Brickhouse, Nancy W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53-62.

[7] Brush, S. G. (1989). History of science and science education. *Interchange, 20,* 60-71.

[8] Buaraphan, Khajornsak. (2009a). Pre-service and in-service science teachers’ responses and reasoning about the nature of science. *Educational Research and Review, 4*(11), 561-581.

[9] Buaraphan, Khajornsak. (2009b). Thai inservice science teachers’ conceptions of the nature of science. *Journal of Science and Mathematics Education in Southeast Asia, 32*(2), 188-217.

[10] Buaraphan, Khajornsak, & Sung-ong, Sunun. (2009). Thai pre-service science teachers' conceptions of the nature of science. *Asia-Pacific Forum on Science Learning and Teaching, 10*(1), 1-22.

[11] Carey, L. R., & Stauss, N. G. (1970). An analysis of experienced science teachers' understanding of the nature of science. *School Science and Mathematics, 70*, 366-376.

[12] Craven, John A, Hand, Brian, & Prain, Vaughan. (2002). Assessing explicit and tacit conceptions of the nature of science among preservice

elementary teachers. *International Journal of Science Education, 24*(8), 785-802.
[13] Dogan, Nihal, & Abd-El-Khalick, Fouad. (2008). Turkish grade 10 students' and science teachers' conceptions of the nature of science: A national study. *Journal of Research in Science Teaching, 45*(10), 1083–1112.
[14] Driver, R., Leach, J., Miller, A., & Scott, P. (1996). *Young people images of science*. Pennsylvania: Open University Press.
[15] Haidar, Abdullateef H. (1999). Emirates pre-service and in-service teachers' views about the nature of science. *International Journal of Science Education, 21*(8), 807-822.
[16] Institute for the Promotion of Teaching Science and Technology. (2002). *National Science Curriculum Standards*. Bangkok: Institute for the Promotion of Teaching Science and Technolgy.
[17] Lederman, Norm G, Abd-El-Khalick, Fouad, Bell, Randy L, & Schwartz, Renee S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.
[18] Lederman, Norman G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.
[19] Lunn, Stephen. (2002). 'What we think we can safely say...': Primary teachers' views of the nature of science. *British Educational Research Journal, 28*(5), 649-672.
[20] McComas, William F., Clough, Michael P., & Almazroa, Hiya. (1998). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies*. Netherlands: Kluwer Academic Publishers.
[21] Mellado, Vicente. (1997). Preservice teachers' classroom practice and their conceptions of the nature of science. *Science & Education, 6*, 331-354.
[22] Ministry of Education. (2001a). *Basic Education Curriculum B.E. 2544*. Bangkok: The Printing House of Express Transportation Organization of Thailand.
[23] Ministry of Education. (2001b). *Basic Education Curriculum B.E. 2544 (2001)*. Bangkok: The Printing House of Express Transportation Organization of Thailand.
[24] Office of the Education Council. (2002). *National Education Act B.E. 2542 (1999) and Amendments (Second National Education Act B.E. 2545 (2002))*. Bangkok: Office of the Education Council.
[25] Palmquist, Bruce C, & Finley, Fred N. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching, 34*(6), 595-615.
[26] Pomeroy, Deborah. (1993). Implications of teachers' beliefs about the nature of science: Comparison of the beliefs of scientists, secondary teachers, and elementary teachers. *Science Education, 77*(3), 261-278.
[27] Popper, K. R. (1963). *Conjectures and refutations: The growth of scientific knowledge*. London: Routledge.
[28] Popper, K. R. (1992). *The logic of scientific discovery*. London: Routledge.
[29] Rampal, Anita. (1992). Images of science and scientists: A study of school teachers' views of characteristics of scientists. *Science Education, 76*(4), 415-436.
[30] Rubba, Peter A., & Harkness, William L. (1993). Examination of preservice and in-service secondary science teachers' beliefs about science-teachnology-society interactions. *Science Education, 77*(4), 407-431.
[31] Tairab, Hassan H. (2001). How do pre-service and in-service science teachers view the nature of science and technology? *Research in Science and Technological Education, 19*(2), 235-250.

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