Examining Junior High School Science Teachers’ Understanding of the Nature of Science in Chaiyaphum Province, Thailand

Rungnapa Sangsa-ard\textsuperscript{a} and Kongsak Thathong\textsuperscript{b}

\textsuperscript{a}PhD candidate, Science Education Program, Faculty of Education, Khon Kaen University, Thailand
\textsuperscript{b}Associate Professor Dr. Science Education Program, Faculty of Education, Khon Kaen University, Thailand.

Abstract

This research aims to examine junior high school science teachers’ understanding of the nature of science (NOS). The participants include 116 junior high school science teachers in education extended schools from the Chaiyaphum Primary Educational Service Area Office 1 - 3, Thailand. Research instruments consisted of an open-ended questionnaire of NOS that was adapted from Lederman et al. (2002) VNOS-C, and an interview record form. Ten percent of the participants were randomly selected for an interview to probe deeper into their understanding. The data from the questionnaire and interviews were analysed base on an interpretive paradigm. The results revealed that about sixty three percentage (63.3\%) of the junior high school science teachers held intermediate views of NOS in each of the surveyed aspects. There was about thirty three percentage (32.7\%) that hold the naïve views in all surveyed aspects of NOS. However there was about seven percentage (6.6\%) of the participants hold the informed views in only five aspects of NOS. These aspects were the empirical, tentative, observation & inferential, creative & imaginative, and social & cultural understandings. These results indicated that the teachers’ understanding of NOS inadequate to teach NOS to their students. Therefore, teachers’ understanding of NOS is neccessary.

Keywords: Junior High School Science Teachers, Nature of Science (NoS)

1. Introduction

Science plays an important role in present and future society. It can be said that science is a modern culture in a knowledge society. Scientific literacy needs to be developed for all citizens (The Institute for the Promotion of Teaching Science and Technology [IPST], 2003). Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. (National Research Council [NRC], 1996). The understanding of the NoS is a significant and primary component of scientific literacy (Lederman, 1992; Abd-El-Khalick & BouJaoud, 1997; IPST, 2003; NRC, 1996; Bybee, 1997). An understanding of the NoS is important if individuals are going to make responsible personal decisions and become effective local and global citizens. To understand the characteristics of scientific knowledge and how it is obtained, citizens need to be able to appraise claims and apply scientific knowledge that may affect their everyday decisions about things such as health, diet, choosing energy resources and to reach informed views on matters of public policy regarding these areas (Bell & Lederman, 2003). Research also indicates that the knowledge of the NoS, understanding of the structure of scientific knowledge and the forms of argumentation used by scientists assists students in learning science content (Songer & Linn, 1991; McComas & Olson, 1998).

* Corresponding Author name. Tel.: +66-86-136-1991
E-mail address: rungnapa90@gmail.com
Science teachers play an essential role in the success or failure of students’ development of NoS understanding. Major reform efforts in science education have included much discourse about the importance of enhancing students’ conceptions of the NoS. For instructional management planning of the NoS, Schwartz and Lederman (2001) suggested that in instruction of the NoS, teachers need to firstly understand concepts of the NoS before any learning intervention related to the NoS can take place. They suggested that students need to discuss and exchange ideas about science and related scientific fields to develop their understanding.

In Thailand, the IPST in 2003 realized the importance of providing professional development for science teachers so it situated science and technology teachers' standards by developing and adjusting from American standards. The IPST initiated standards for science and technology teachers. Ten standards were developed and the nature of science and technology was stated in the first and the second standard:

Standard 1: the nature of science and technology is understanding that the nature of science and technology comprises curriculum content structure and science and technology content knowledge, knowledge of inquiry, and processes, and applying knowledge and understanding of NoS to initiate learning experiences in meaningful way for students.

Standard 2: Applying science and technology based on integrity and interest in self-professional development by using science and technology to benefit society. Both science curriculum and science and technology teachers' standards in Thailand, clearly express the importance of the NoS in science education.

Based on the background described in the previous section, it was decided that the purpose of this project would be to examine junior high school science teachers’ current understandings of the nature of science in Chaiyaphum Province, Thailand. The research question of this study was what is the junior high school science teachers’ current understanding of the NoS?

2. The Nature of Science

The NoS typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge or the development of scientific knowledge (Lederman, 1992; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Nevertheless, there is no one complete definition of this term. NSTA noted that philosophers, historians, scientists, and science educators have not yet agreed on a single definition (NSTA, 1998). The conceptions of the NoS itself are also considered by science educators as tentative and dynamic as having “changed throughout the development of science and systematic thinking about its nature and workings” (Dawkins & Glatthon, 1998; Lederman, 1998; Akerson, Abd-El-Khalick, & Lederman, 2000).

In this study the NoS is defined as the values and assumptions inherent in science, scientific knowledge, and the development of scientific knowledge. It represents the unique characteristics of science by describing and explaining what the science is, how it works and how it is different from other disciplines, what scientists have done throughout history, and how science and scientists interact with the society.

Seven aspects of the NoS were selected to emphasize in this study because they are generally agreed upon, accessible to K-12 students, and important for all citizens to know (Lederman & Lederman, 2004; McComas, 2008; Matthews, 2012). The seven elements of the NOS include: (1) Empirical; (2) Observation and Inferential; (3) Tentative; (4) Theory-laden; (5) Social and Cultural; (6) Creative and Imaginative; (7) Distinction between a scientific law and theory.

3. Teachers’ view of the Nature of Science

In order to improve students’ understanding of the NoS, research by Akerson, Abd-El-khalick, and Lederman (2000) focused on equipping pre-service and in-service teachers with an adequate understanding of the NoS. If teachers do not have an adequate understanding of NoS, they cannot conduct NoS views to student even if NoS views are suitably addressed in the science textbooks and curriculum. Consequently, teachers’ conception of NoS plays a critical role in the implementation of science curricula, and teachers will implement science curricula in a way that reflects their own view of the NoS (Travis, 1994). Lederman (2007) supported the notion that science teachers do not possess adequate or informed views of NoS that teachers’ understanding of the NoS is reflected in planning for instruction and/or classroom practice. In addition, teachers’ understanding of NoS appears to be
essential, but not sufficient, for effectively translating their understanding into science teaching. (Lederman, Lederman, Kim & Ko, 2012)

4. Methodology

The study involved examining junior high school science teachers’ understanding of the NoS. This study was designed for collecting and analyzing data in order to answer what is the junior high school science teachers’ current understanding of the NoS? Quantitative research was used to investigate the teachers’ understanding of NoS.

4.1 Participants

Participants were 116 Thai junior high school science teachers who enrolled in the first semester of the academic year 2012. Junior high school science teachers were seeking in the Chaiyaphum Primary Educational Service Area Office 1 - 3, under the Office of the Basic Commission, in the Northeast region of Thailand. All of participants in this study were grade 9 junior high school science teachers.

4.2 Data Collection and Instruments

Questionnaires and interviews were chosen to be the appropriate data collecting techniques. Questionnaires were used to examine the teachers’ understanding of seven NoS aspects. The first instrument was in this study was the Views of the Nature of Science questionnaire (VNOS-C) (Lederman et al., 2002). It was administered to assess the participants’ understanding of NoS. The VNOS-C (see Appendix A) consists of ten open-ended questions that help identify understandings of the tentative, empirical, creative, subjective, theoretical, cultural, and social nature of science. The VNOS-C has been reported as a reliable and valid measure of teachers’ understanding of NoS aspects (Lederman et al., 2002). These methods were selected because the nature of open-ended question allows science teachers to answer in their own words. The questionnaire was adapted and sent to experts for validation.

The second instrument was an interview. In this study, in order to investigate teachers understanding of the NoS, the researcher applied question items from open-ended questionnaire instruments developed by the View of Nature of Science Questionnaire (VNOS) developed by Lederman et al. (2002) (see Appendix B). The interview question items from this source were applied and translated into Thai. The interview schedule was reviewed and suggestions for improvement of the content validity were made by three Thai science educator experts. Ten percent of the participants were randomly selected for interviews to further probe their understandings by the researcher in the first semester of academic year 2012.

4.3 Data Analysis

The questionnaires and accordingly interview transcripts of the 12 interviewed participants were analyzed and compared for the purpose of establishing the validity of the open-ended NoS questionnaire. This analysis revealed that the profiles of participants’ NoS views as obtained from the NoS questionnaires were trustworthy to participants’ views as revealed and detailed during individual indebt interviews.

The researcher was coding the VNOS-C surveys and classify coded the responses and compared analyses. The researcher read each response carefully and interpreted it into three groups. Terms used to describe participant understanding of the NoS were informed, intermediate, and naïve. Descriptions of the terms are:

1) Informed understanding of aspects of the NoS is defined as aligning with descriptions of specific aspects contained within Science for All Americans(AAAS, 1990) and the National Science Education Standards (NRC, 1996).

2) Intermediate is used by the researcher to describe an understanding of a specific aspect of the NoS which has elements of both informed and naïve understanding. It is used to represent understanding aspects of the NoS which are neither naïve nor informed. The term is often used in reference to religious or philosophical belief systems which are a combination of different, and at times contradictory, beliefs or practices. Intermediate describes the participant holding to both informed and naïve beliefs, views, and understandings of a specific aspect of the NoS simultaneously.

3) Naïve understanding is defined as not aligning with these descriptions.
5. Results

The results of this study are presented in three sections. First, the characteristics of participants are reported and discussed. Second, the level of junior high school science teachers’ understanding of NoS from VNOS-C questionnaire are reported in Table 1. Finally, the outcomes in NoS understanding that resulted from the VNOS-C questionnaire and semi-structured interviews are reported.

5.1 Participant Characteristics

The participants in this study included 116 junior high school science teachers in education extended schools from the Chaiyaphum Primary Educational Service Area Office 1-3, Thailand. The participants were sixty eight female (58.6%) and forty eight male (41.4%). Forty three of the participants (37.1%) had teaching experience of 6-10 years, and twenty one (18.1%) had teaching experience of 0-5 years. The level of education, seventy three of the participants held a Bachelor’s degree (63.8%) and thirty (25.9%) held a graduate diploma program in teaching. Twelve participants (10.4%) held a Master’s degree. Seventy three participants had science majors (62.9%) such as general science, biology, chemistry, physics, science education, and food science and thirty three participants had non-science (37.1%) which consisted of educational research and evaluation, curriculum and instruction mathematics, administration, education technology, and primary education. As thirty six of junior high school science teachers were assistant teachers (31.1 %), and academic standing of teachers were thirty one (26.7%). The participants from the Primary Education Service Area Office 1 were forty six (39.7 %). The junior high school science teachers from Primary Education Service Area Office 3 were forty (34.4 %) and thirty (25.9 %) of participants from Primary Education Service Area Office 2. And twelve (10 %) of participants was randomly selected for interview to probe their understanding.

5.2 Participants’ understanding of NoS from VNOS-C questionnaire

The following table (Table 1) summarizes the participant teachers’ understandings of NoS from the VNOS –C questionnaire by classifying the target aspects of the NoS in to one of three levels. These three levels were naïve, intermediate, and informed.

<table>
<thead>
<tr>
<th>Item</th>
<th>VNOS-C Questionnaire statement</th>
<th>Aspect of NOS</th>
<th>Level of understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?</td>
<td>Empirical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>16.4 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95</td>
<td>81.9 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>1.7 %</td>
</tr>
<tr>
<td>2</td>
<td>What is an experiment?</td>
<td>Empirical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>1.7 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>108</td>
<td>93.1 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>5.2 %</td>
</tr>
<tr>
<td>3</td>
<td>Does the development of scientific knowledge require experiments? a) If yes, explain why. Give an example to defend your position. b) If no, explain why. Give an example to defend your position.</td>
<td>Empirical</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>108</td>
<td>93.1 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>6.9 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>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 the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?</td>
<td>Tentative</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>21.5 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>91</td>
<td>78.5 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.</td>
<td>Distinction between scientific theory and law</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>30</td>
<td>25.8 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86</td>
<td>74.2 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Item</td>
<td>VNOS-C Questionnaire statement</td>
<td>Aspect of NOS</td>
<td>Level of understanding</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------</td>
<td>--------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td></td>
<td>After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?</td>
<td>Tentative Distinction between scientific theory and law</td>
<td>Naïve</td>
</tr>
<tr>
<td></td>
<td>a) If you believe that scientific theories do not change, explain why. Defend your answer with examples.</td>
<td>26</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>b) If you believe that scientific theories do change: Explain why theories change. Explain why we bother to learn scientific theories. Defend your answer with examples.</td>
<td>84.5 %</td>
<td>75.0 %</td>
</tr>
<tr>
<td>7</td>
<td>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 specific evidence do you think scientists used to determine what a species is?</td>
<td>Observation and Inferential</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>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?</td>
<td>Creative and Imaginative</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>a) If yes, then at which stages of the investigations do you believe 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.</td>
<td>84.5 %</td>
<td>75.0 %</td>
</tr>
<tr>
<td></td>
<td>b) If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.</td>
<td>84.5 %</td>
<td>75.0 %</td>
</tr>
<tr>
<td>9</td>
<td>It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis 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?</td>
<td>Theory-laden</td>
<td>98</td>
</tr>
<tr>
<td>10</td>
<td>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.</td>
<td>Social &amp; Cultural</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>a) If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.</td>
<td>14.7 %</td>
<td>68.1 %</td>
</tr>
<tr>
<td></td>
<td>b) If you believe that science is universal, explain why. Defend your answer with examples</td>
<td>14.7 %</td>
<td>68.1 %</td>
</tr>
</tbody>
</table>
5.3 Teachers’ understanding of NoS from VNOS-C questionnaire and semi-structured interviews.

This section presents the profiles of the participants initial views of the NoS from both the VNOS-C questionnaire and the follow-up semi-structured interviews. The participants’ views for each aspect of the NoS are presented separately. These aspects include empirical, tentative, distinction between a scientific law and theory, observation and inferential, creative and imaginative, theory-laden, and social and cultural.

5.3.1 Empirical

From the first item from VNOS-C About ninety five (81.9 %) of the junior high school science teachers held the intermediate views. They indicated that science is the concerted human effort to understand, or to understand better, the history of the natural world and how the natural world works, with observable physical evidence as the basis of that understanding. However, from the semi-structured interviews, it was clear that they cannot compare the difference between scientific knowledge and philosophy and religion or other types of knowledge. From the semi-structured interviews, one participant explained:

Science is knowledge of natural world or space. Science is a study of a scientific discipline that involves research (collecting data), analyzing, and forming a collective result or summation of that data. Scientific knowledge is durable, and science cannot provide complete answers to all questions. Scientific knowledge differs from the other knowledge. Scientists seek for the knowledge by the scientific method or another way (P #49).

But nineteen (16.4 %) of the junior high school science teachers held the naïve views. They still believed that “evidence” made science different from other disciplines. In a follow up interview, one teacher explained:

Science is everything which can verify, or appears in the world. Science is not only testable but also had evidence. And different from other disciplines of inquiry (e.g., religion, philosophy) because religion is man's respect since newborn (P #80).

Only two (1.7%) of the junior high school science teachers held informed views. They argued scientific knowledge is based upon observation and emphasizes the repeatability of those observations. They could clearly delineate scientific knowledge from religious or other types of knowledge. They believed scientific knowledge was based on repeatable, verifiable observation or experience rather than pure logic or reasoning to create scientific knowledge. One interviewee indicated:

Scientists studied of natural phenomena using repeatable methods, empirical data and logical reasoning for explaining phenomena. Scientific knowledge is the facts which can be proven. Normally what’s held as good science is- is what is generally accepted by the majority of the scientific community and has been tested and experimented on and there have been repeatable evidences supporting the truthfulness of the held claims. Scientists always interpret their observations to draw inferences and construct explanations, which are infused with assumptions and based on theoretical consideration, observational, personal, social, and cultural influences. Science is different from other disciplines in that it deals with processes that can be quantitatively analyzed and uses a specific scientific method in order to determine the answer (P #8).

The second item from the VNOS-C questionnaire asked “What is an experiment?” This item was held with an intermediate view by one hundred and eight (93.1 %) of the junior high school science teachers. They believed that an experiment is a way to test and manipulate the objects of interest while keeping all other factors the same. Furthermore, they acknowledged the role of observation in the scientific process and often mentioned the idea of repeatability with experiments. One teacher commented in the semi-structured interview:

The experiment is very important for investigating scientific knowledge. The process of experiments searches for answers to his/her questions. Scientists do experiments for verifiability and confirmation the hypothesis. And they use many methods for investigation (P #96).

In contrast, there were six (5.2%) of the junior high school science teachers holding an informed view. These junior high school science teachers’ views were different from those holding the intermediate views. They believed that an experiment cannot prove a theory or a hypothesis. Experiments are not always important in investigating scientific knowledge and they believed that an experimental process is based upon observation and stressed the repeatability of those observations. On interviewing, one teacher explained:
Scientist is this the word used or is it the word “science”? That has been tested and experimented on and in which there have been repeatable evidences supporting the truthfulness of the held claims. An experiment cannot prove a theory or a hypothesis. It just disreputes or adds validity to them. An experiment is a controlled way to test and manipulate the objects of interest while keeping all other factors the same (P #15).

From VNOS-C item 3, one hundred and eight (93.1 %) of the junior high school science teachers held naïve views for this item. They believed progress in understanding scientific knowledge depended on experimental science for verifying hypotheses and establishing scientific facts, theories as absolute truth. The development of scientific knowledge can only be attained through precise experiments. Moreover, they were not able to provide an example in support their responses. From semi-structured interviews, one teacher said:

I think scientific knowledge would not exist without experiments. Science would not exist without scientific process which is only based on experiments. The development of scientific knowledge can only be achieved through an experiments (P #96).

However, eight (6.9%) of junior high school science held intermediate views because they believed scientific knowledge progress did not require only experiment and an experiment does not always involve the act of manipulation of equipment and collecting data. Many considered that the development of scientific knowledge depended on observation. In a follow up interview, one teacher described:

I think experiments are not important for development scientific knowledge because some phenomena are not able to be tested. Theories cannot be directly tested experimentally. Formulating and testing explanations of nature using observation, experiments, and theoretical models are important for the development scientific knowledge (P #112).

5.3.2 The tentative

From VNOS-C item 4, ninety one (78.5 %) of the junior high school science teachers held intermediate views. Their major argument was that scientists used experimental work for investigation and they used a model for representation to explain the theory or their new discovery. But the participants were not able to give an example to support their responses. Some ideas of participants from semi-structured interviews indicated:

The atomic model is designed by scientist’s imagination from the experimental results. The model can be changed if they have new information. It seems that new data is the only thing that would have someone change their theory (P #62).

However, there were twenty five (21.5 %) of the junior high school science teachers that held the naïve view and believed that scientists can see atoms with high-powered microscopes. They were very confident of the structure of atoms because the data was based on experimental result. One of the participants said:

Atoms have a definite shape which is evidenced from an experimental results. Many scientists have done many experiments to validate their findings and nowadays there are high powered microscopes so they can see the structure of an atom. The image of an atom is a construct that can be seen with electron microscopes. The scientific knowledge in science textbooks is reliable and correct (P #77).

From VNOS-C item 6, eighty seven (75.0 %) of the junior high school science teachers held the intermediate view. They revealed theories can be changed if scientists discover enough supporting evidence, and laws cannot be changed because they have been already proved without any disagreement. Contradictory statements are found in their responses in that they do not refer to what can cause scientific ideas, principles, and laws to change. From the semi-structured interviews, one participant indicated:

Scientific theories can change when scientist discover new data. New information and technological advances allow increased accuracy in experimentation. A law has been tested and cannot be changed (P #26).
About twenty six (22.4 %) of the junior high school science teachers held naïve views in that their responses showed that the theories can be changed, but laws are fixed. They stated that scientific laws started as theories and ultimately became laws after repeated and proven demonstration. In a follow up interview, one teacher described:

*Scientific theories do not change because it was verified by science community. Scientists take long time to discover the various theories and tested to ensure that it is true before published. Theories are constantly under going change and can be proven false at anytime but laws will not (P #77).*

However, three (2.6 %) of the junior high school science teachers held an informed view because they believed theories and laws are evenly believable. Because of new information and modern technology theories can change so that the current theories don’t fit. The interviewee said:

*Scientific knowledge can change over time including theories and laws. Science cannot give absolute truth, it is only reality. New data, new perspectives on the data, cultural influences are listed as agents of change. For example, in atomic theory no one has seen an atom directly. Scientists know of its existence only by indirect evidence. In the past, scientists believed that atom was the smallest possible particle.*

*Then they discovered that the atom was made of even tinier parts. Nowadays, scientists are aware of dozens of subatomic particles, and they continue to find ever smaller bits of matter (P #32).*

5.3.3 Distinction between a scientific law and theory

The fifth item from VNOS-C questionnaire asked “Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example”. Eighty six (74.2 %) of the junior high school science teachers held the intermediate view about NoS understanding. They expressed a difference between a scientific laws and scientific theory but some responses were contradictory. They described that scientific theories were made of concepts that were in accordance with normal observation or that they might go further and proposed new explanatory models for the world. However they held misconceptions in that there was a hierarchical relationship between the two and they considered that scientific theories were less stable than laws. In addition, their examples illustrated the difference between scientific theories or scientific laws were not clearly understood. From the semi-structured interviews, one participant explained:

*Scientific theories differ from scientific laws, and are just explanations, and new evidence may be discovered which can alter the theory to fit the new information. Scientific laws are something that can be directly observed and proven. Scientific theories are an explanation of how something happened but it can never be proven. Scientific laws are made up of observations and supported hypotheses to the degree where it can called truth (P #74).*

Furthermore, thirty (25.8 %) of the junior high school science teachers held naïve views. They argued that scientific theories and scientific laws are different and they believed the hypotheses are potentially developed to become theories and theories are potentially developed to become laws. When the researcher interviewed the participant explained that:

*Scientific theories can change all the time if scientists discovered new data but scientific laws cannot change because it's proven by science community. Laws start as theories and can become laws only when they are repeated and proven (P #112).*

5.3.4 Observation and inferential

From VNOS-C item, they were seventy six (65.5 %) of the junior high school science teachers that held the intermediate view for this question. They believed in the role of interpretation, there was inference in several responses and a scientist’s worldview or religious background is limited primarily to use (?). Scientists do not apply in context of constructs, proper use of terms such as species or atoms. However, they still believe facts speak for themselves in that atoms can be seen and can scientists can test what a species is. On interviewing, one teacher explained:
Scientists investigate phenomena in which science process involves data collection, and testing hypotheses. They studied species after they had analyzed and summarized data. This scientific knowledge was verified by the scientific community for validation and reliability. Thus, their declaration to society was that this knowledge was published in textbooks (P #56).

About thirty four (29.3 %) of the junior high school science teachers held naïve views as they believed scientists can see atoms with high-powered microscopes and they are very certain of the structure of atoms. They still believe do not distinguish between observations and inference-making. One teacher expressed in the semi-structured interviews:

*In the past it was not certain about the meaning of species, but now it is possible to know what animals belong to what species. The scientific knowledge in textbooks is validated and tested. So, we can trust.* (P #112)

Nevertheless, there were six (5.2 %) of the junior high school science teachers that held informed views. The participants in this group believed an evidence is indirect and relates to things that we don’t see directly. In addition, they articulated the distinction and relationship between observations and inferences consistently throughout their responses and in appropriate contexts. One of teacher explained:

*Species is not a theory. It is a term created by humans. The scientists observe how organisms interact and then define that a species is a group of organisms that share similar characteristics and can interbreed. In addition, the way scientists’ define a species is influenced by the different theories that each scientist has studied and they therefore come from a different background* (P #32)

5.3.5 Creative and Imaginative

From VNOS-C item 8, eighty seven (75.0 %) of the junior high school science teachers held an intermediate view. They argued that creativity and imagination may be used but only in limited areas such as hypothesis forming, planning, and developing experiments or data collection and investigation techniques. Creativity and imagination are to be abstained from in the other areas such as data analysis and conclusions. However, the participants did not provide any examples or they provided inadequate examples to support their views concerning the use of imagination and creativity in science. From the semi-structured interviews, one teacher explained:

*Scientists use creativity and imagination in their investigations in order to achieve their objectives and aims of experiments. Most scientists’ use of creativity and imagination is limited to planning and design stages of their investigation. Creativity and imagination should not be used in the data collection or analysis stage* (P #62).

In contrast, twenty (17.2 %) of the junior high school science teachers held the naïve view. They believed scientists do not use of creativity or imagination in science because the scientist has to be objective and consider bias. In a follow up interview, one teacher explained:

*Scientists do not use their creativity and imagination to investigate because an experiments' result will be biased. Sometime I am not sure because I think creativity and imagination depend on the individual. Virtually no creativity is involved in analyzing data or developing models and theories* (P #96).

About nine (7.8 %) of the junior high school science teachers held informed views. They believed that scientists used creativity and imagination throughout scientific endeavors including data analysis, research design, hypothesis forming and theory development. On interviewing, one participant explained:

*I believe creativity and imagination permeates all stages of scientific investigation in terms of the invention of explanations. Creativity and imagination are thought of as inventiveness and is useful for making new things. For example, the invention of airplanes, a telescope, and a computer program* (P #8).
5.3.6 Theory-laden

From VNOS-C item 9, almost of the junior high school science teachers were ninety four (84.5 %) held the naïve views about this item. They still believed that scientists did not recognize the role of prior knowledge, past experiences, beliefs and values and how that affected how scientists viewed the world, interpreted ideas or how they developed of scientific knowledge. Participants believed scientists were objective so that they gave the best and fairest results in every condition and experiment. When the researcher follow-uped this idea in a semi-structured interview, one teacher explained:

Scientists must be objective and non-selective in the manner in which data is acquired, or in the way the results are presented. Further discoveries or study will lead to one correct view or explanation of the phenomenon. Scientists will never know what happened as they had no written notes or witnessed evidence of what caused the extinction. If they get the same results moreover, then they become sure that their theory is a proven law, and a fact (P #80).

However, about eighteen (15.5 %) of the junior high school science teachers held the intermediate view. They believed that different viewpoints of scientists, such as religious and cultural viewpoints, may influence their interpretations or views. From the semi-structured interview, one teacher explained:

I think the data is limited. Some scientist use the evidence to support their theory while others use that evidence to support another theory. While neither can prove the other wrong, neither can provide enough evidence to prove themselves. Almost all scientists are bringing their own background knowledge and personal understanding of the world to their findings. Their personal beliefs will influence how they interpret the data (P #49).

5.3.7 Social and Cultural

The final statement of VNOS-C, there were seventy nine (68.1%) of the junior high school science teachers that held the intermediate view about this statement because they believed social and cultural values norms affect science without contradictions but do not provide examples or elaboration. On the other hand, they believed that social, cultural, and political aspects influenced the development of scientific and technological knowledge. One of the participants said:

I think science and scientific knowledge reflect the social and cultural values of society. Many factors such as religion, politics, and the economy influence the creation and development of scientific knowledge. Partially of scientific knowledge are according with the principles of Buddhism (P #74).

However, the junior high school science teachers holding the informed views were twenty (17.2%). They believed all aspects of society and the culture influence the acceptance of scientific concepts. They could elaborate on the relationship with examples or explain the relationship between science, society and political values in detail.

Scientists are human. Therefore, scientific research has aimed to improve the lives of individuals and society in areas such as satellites, communications and transportation. In addition, culture are related to societal values. For example, people in each area have different values and culture. Some cultures believe only humans have a spirit or soul, others believe all living things have them, and still others believe even non living things do. So, theoretical perspectives of scientists are imbedded in the different aspects of their culture, society, economics, politics, philosophy, and religion (P #15).

At least, seventeen of the participants (14.7 %) held naïve views in that they did not believe science that science influenced culture or culture influenced science. They still believed science processes are seen as standing apart from culture, and transcending culture. In addition, science is about facts and is not influenced by cultures and society. On interviewing, one participant explained:
I think scientific knowledge is universal and has the same meaning in every country. Scientific knowledge is concrete facts that have been proven, observed, can be repeated, and seen by someone else to get a right or wrong answer. In addition, scientific knowledge in textbooks is universal (P #26).

6. Discussion and Implications

These research findings indicated that junior high school science teachers’ understandings of NoS were inadequate, and shallow. The majority of participant held naïve views and intermediate view or demonstrated incorrect in all surveyed aspects of NoS. They held scientific method was important to teach, science operating was very logical scientific, scientific knowledge require an experiment, scientific method as an universal and method is step-by-step (Abd-El-Khalick & BouJaoude, 1997; Akerson, Hanson & Cullen, 2007; Buaraphan, 2009; Craven, Hand, & Prain, 2002; Dogan & Abd-El-Khalick, 2008; Haidar, 1999; Mellado, 1997; Murcia & Schibeci, 1999; Palmquist & Finley, 1997). They indicated that scientific knowledge could be proven through testing and experimental and believed scientific idea as the truth (Mathins & Bell, 2007). In term of tentative most of them not clearly saw theories as inferential in nature and scientific law as generalizations. They also decribed scientific theories change as a result of new evidence and advances in technology. (Mathins & Bell, 2007; McComas, 1996).

The participants often presented that they believed scientific knowledge in science textbooks and still believed in scientist’s answer or scientist’s idea because they thought when scientists developed knowledge the use both observation and inference (Abd-El-Khalick, 2004; Lederman, Lederman, Kim & Ko, 2012). But they didn’t express how the data were gathered and they always use laboratory activities in textbook is most likely “cook book” (Abd-El-Khalick, 2004; Akerson et al, 2007). For the role of creative and imaginative, this finding shown the majority of participants held intermediate views they explain scientists used imaginative in some of step when they developed scientific knowledge such as in planning step and used creative in observation and analyzing data (Lederman, Lederman, Kim & Ko, 2012). Nevertheless, some of participants understood scientist used both creative and imaginative in all step of development scientific knowledge such as design of an experiments and in the interpretation of data (Mathins & Bell, 2007; Yuenyong, 2010). A high inadequate of understanding the Nos in this study is distinction between a scientific law and theory. The majority of participants understood scientific theories are less stable than law and scientific theories (Bell, Lederman, & Abd-El-Khalick, 2000; Buaraphan, 2009; Chamrat, 2009). Many research of NoS shown science teacher believed that scientist reach different conclusions because they have different data and evidence. The participants not understood about scientists’ backgrounds, personal views, and biases toward the data potentially played important role in their interpretation of the data (Abd-El-Khalick & BouJaoude, 1997; Brickhouse, 1990; Dogan & Abd-El-Khalick, 2008; Gallagher, 1991; Haidar, 1999; Mathins & Bell, 2007; Murcia & Schibeci, 1999; Promkatkeaw, Sungong, & Kaewviyudh, 2007; Rampal, 1992; Thye & Kwen, 2003; Buaraphan, 2009; Buaraphan, 2011). None of participants held informed views. The last aspect of NoS, most of participant not mentioned social and cultural influences on science. They believed the scientific enterprise unrelated public. However, some of participants revealed the scientific enterprise and scientific knowledge can be affected by social and cultural. (Buaraphan, 2009; Mathins & Bell, 2007)

These results indicated that the teachers’ understanding of NoS inadequate to teach NoS to their students. Therefore, teachers’ understanding of NoS is necessary for science teachers to promote students’ understanding of the NoS. This finding will be benefits to science educators in professional development that emphasizes junior high school science teachers’ understanding of the NoS.

Acknowledgements

A special thanks to Dr. Kathy Saunders my supervisor at The University of Waikato, New Zealand for her guidance, insight, and encouragement.
Reference


