High School Students' Understanding of the Nature of Science

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Abstract
The purpose of this study was to investigate students' understanding of the Nature of Science (NOS). One hundred and eight high school students at a secondary school in the Secondary Educational Service Area Office 36 participated in this preliminary study. An open-ended questionnaire adapted from the *View of Nature of Science - Form C* questionnaire (VNOS-Form C) of Lederman et al. (2002) was applied to collect data. By using content analysis, students' responses were categorized into 4 groups including; informed, transitional, naive, and no understanding. The research findings showed that most of the students had transitional understanding about NOS mostly in the aspects of; science, technology and social are effect of each other, science demands on evidence, scientific knowledge is tentative, creativity and imagination in science, science is a social activity, the human subjectivity in science. They could identify these characteristics but they could not give more reason to support their answers. However students held highest percentage of naive understanding and no understanding in some aspects. In particular 86.11% of the students held a naive understanding about diversity of science process; they understood that inquiry is a step by step scientific method and the only way to explore scientific knowledge is through experiment. Furthermore 75.93 % of students had no understanding in the aspect of science is based on both observation and inference. They could not explain or answer the questions of this aspect. The research finding suggests that science teachers should focus and find proper teaching and learning approach for enhance students' understanding of the nature of science and using the students' prior understanding as a basic to develop effective science teaching and learning.

Keywords: Nature of Science, NOS Understanding

Introduction

The goal of science education is to promote scientific literacy (The Institute for the Promotion of Teaching Science and Technology (IPST.) 2003; Crowther; Lederman and Lederman. 2005; Flick; and Lederman. 2006; Lederman. 1992). One characteristic of the scientifically literate persons is understanding of the nature of science. An understanding of the nature of science can help students to understand the process of science and make informed decisions on socio-scientific issues (IPST. 2003; American Association for the Advancement of Science (AAAS.). 2013; Lederman. 1992) and to appreciate science as a part of culture and society (Driver et al. 1996; McComas; Clough; & Almazroa. 2000).

These are the key aspects of the NOS that high school students must know; 1) scientific knowledge is tentative, 2) Science is based on both observation and inference, 3) science demand on evidence, 4) the diversity of scientific process, 5) the subjectivity in science, 6) creativity and imagination in science, 7) science is a social activity, and 8) science, technology and social are effects of each other (IPST. 2002; AAAS. 2013; Abd-El-Khalick; & Lederman. 2000; Lederman et al. 2002; McComas; Clough; & Almazroa. 2000; Sandoval. 2005; Schwartz; Lederman; & Crawford. 2004).

The previous studies have shown that in the difference contexts students understand the NOS differently. For example in some context students understand that scientific knowledge can be changed when there is new evidence to rebut the evidence or interpretation of the original conclusion. Scientists do new experiments to prove or disprove the new evidence (Ladachart; & Suttakun. 2012; Chamrat; Yutakom; & Chaiso. 2009) but other students perceived that scientific knowledge cannot be changed. It is the truth and proved already (Kijkuakul; Yutakom; & Engkagul. 2005; Khishfe. 2008; Schwartz; Lederman; & Crawford. 2004). In particular researches have reported misunderstanding about the nature of science in many aspects as follow. Scientific knowledge is the truth, because there is empirical evidence to support it and is not related to the use of creativity and imagination. Creativity and imagination of scientists cannot be taken as scientific evidence (Mahalee; & Faikhamta. 2010; Khishfe. 2008; Schwartz; Lederman; & Crawford. 2004). Scientific laws are more reliable than scientific theory. Scientific laws cannot be changed, but the scientific theory can be changed (Chamrat; Yutakom; & Chaiso. 2009; Schwartz; Lederman; & Crawford. 2004). The quest for knowledge is a scientific method of experimentation and requires definite stages (MahaLee; & Faikhamta. 2010; Chamrat; Yutakom; & Chaiso. 2009). Society and culture have not impacted on science because scientific knowledge is universal and constructed of experiments that follow a certain step by step formula. (Kijkuakul; Yutakom; & Engkagul. 2005; Chamrat; Yutakom; & Chaiso. 2009). The belief and the values of a scientist should not affect their work. (Chamrat; Yutakom; & Chaiso. 2009; Khishfe. 2008; Khishfe; & Abd El-Khalick. 2002) In addition, most of the students were unable to distinguish the observation and interpretation of the scientific evidence (Khishfe. 2008; Khishfe. 2012; Khishfe; & Abd El-Khalick. 2002; Limpanontt. 2011). Students still show no understanding about scientific knowledge is a result of the interpretation. (Ladachart; & Suttakun. 2012). Students still lack awareness about the importance and

complexity of the scientific enterprise and the collaboration between scientists and society. (Kijkuakul; Yutakom; & Engkagul. 2005; Bell et al. 2003).

Research Objective

This study is the first phase of the NOS learning model projects. Because of a variety of understandings of the nature of science in different contexts, so the authors would like to know high school students' understanding of the nature of science in the northern Thailand context where the authors will develop a learning model for enhancing students' understanding of the nature of science**.**

Significance of the research

1. The data from this study can be use as a guide to create a learning model that encourages students to understand the NOS.

2. The science teacher can use the results of this research as a guide to develop learning activities that are based on students' prior understanding of the NOS.

Scope of the research

The participants

The participants were high school students who study in Science - Mathematics program of 2nd Semester of 2015 academic year, at a school in The Secondary Educational Service Area Office 36, Thailand. The researcher chose the participants by purposive sampling with cooperative students or volunteers. The total of participants was 108 students consisting of; 7 students from Grade 12, 29 students from Grade 11 and 72 students from Grade 10.

The scope of the nature of science in research

This research explored the NOS in the aspects which should be teaching and learning to high school students consisted of; 1) Scientific knowledge is tentative, 2) Science is based on both observation and inference, 3) Science demand on evidence, 4) The diversity of scientific process, 5) The subjectivity in science, 6) Creativity and imagination in science, 7) Science is a social activity, 8) Science, technology and social are effects of each other

Definition

Understanding of the nature of science refers to the ability to describe the comparative examples about the nature of science: 1) Scientific knowledge is tentative, 2) Science is based on both observation and inference, 3) Science demand on evidence,
4) The diversity of scientific process, 5) The subjectivity in science, 6) Creativity and imagination in science, 7) Science is a social activity, 8) Science, technology and society

are effects each other. Students express themselves and one can analyze students' understanding of the nature of science from the questionnaires adapted from VNOS-Form C (Lederman et al. 2002.)

Research Design

The study utilized a survey research design to permit the authors to understand the participants' understanding of the nature of science. Qualitative and quantitative approaches have been used to analyze data.

Research Methodology

Data collection tools

The data was collected by the open-ended questionnaire adapted from VNOS-Form C of Lederman et al. (2002) and the Index of Item-Objective Congruence (IOC) value of each questionnaire item is between 0.67 – 1.00. It was separated into two parts. The first part, general information section, aimed to examine initial data of students such as gender and grade. The second part identified students' understanding of the nature of science. This part has 12 question covering 8 aspects of the nature of science. The questionnaire was taken pilot study with 31 high school students that were non-participants in this study.

Data collection

The data was collected during November – December, 2015. The time allotted for students to complete an open-ended questionnaire was about 45 minutes.

Data analysis and statistics

The data were analyze by using content analysis to classify students' answers into four groups including; informed, transitional, naive and no understanding or no answer (Khishfe; & Lederman. 2006) by using criterion as follows;

1. Informed (I) group was defined as the group of students who gave their description of the nature of science which relate to the scientific community.
2. Transitional (T) group was defined as the group of students who gave their description of the nature of science which relate to the scientific community but not completely or didn't cover all the issues.
3. Naive (N) group was defined as the group of students who gave their description of the nature of science which did not relate to the scientific community.
4. NO understanding or NO answer (NU) group was defined as the group of students who did not answer questions or who gave the answer "I do not understand the question" or repeated the question.

Furthermore the frequency and the percentage of students in each group were investigated and the examples of students' answers of each group were selected to clarify the findings.

Findings

The high school students' understanding of the nature of science at a secondary school in The Secondary Educational Service Area Office 36, Thailand was surveyed. The total of participants was 108 students consisting of; 7 students from Grade 12, 29 students from Grade 11 and 72 students from Grade 10. Of the participating students forty three were male and sixty five were female. The results of the survey are shown in Table 1.

Table 1: The frequency and the percentage of students in each understanding of the nature of science group

Aspect of Nature of Science	**The frequency and the percentage of students in each group understanding**			
	I	**T**	**N**	**NU**
Scientific knowledge is tentative	0 (0.00)	90 (83.34)	18 (16.66)	0 (0.00)
Science is based on both observation and inference	0 (0.00)	26 (24.07)	0 (0.00)	82 (75.93)
Science demand on evidence	0 (0.00)	93 (86.11)	0 (0.00)	15 (13.89)
Diversity of science process	0 (0.00)	15 (13.89)	93 (86.11)	0 (0.00)
The subjectivity in science	0 (0.00)	68 (62.96)	0 (0.00)	40 (37.04)
Creativity and imagination in science	2 (1.85)	90 (83.34)	14 (12.96)	2 (1.85)
Science is a social activity	0 (0.00)	88 (81.48)	20 (18.52)	0 (0.00)
Science, technology and social are effects of each other	2 (1.85)	102 (94.45)	0 (0.00)	4 (3.70)
Total	0.5 (0.47)	71.5 (66.20)	18.13 (16.8)	17.9 (16.55)

Note : I : Informed**, T :** Transitional**, N :** Naive**, NU:** No answer or No Understanding

Table 1 showed that most of the students had transitional understanding about NOS mostly in the aspects of; science, technology and social are effect of each other, science demands on evidence, scientific knowledge is tentative, creativity and imagination in science, science is a social activity, the human subjectivity in science. They can identify these characteristics but they cannot give more reason to support their answers. However students held highest percentage of naïve understanding in the aspect of diversity of science process (86.11%) and no understanding in the aspect of observation and inference (75.93%). The details of students' understanding of the nature of science in each aspect are as follows.

Scientific knowledge is tentative

Most of the students (83.34%) had transitional understanding; they accepted scientific knowledge can be changed but they cannot complete explain why scientific knowledge can be changed. For example:

"Scientific knowledge can be changed because scientists discover new evidence, then make scientists accept it. It is a new theory" (S454)

"Can be changed if a scientist creates new principles" (S431)

"Scientific knowledge can be changed. If a scientist tested the theory with new idea then the theory should be consider new" (S510)

The other students (16.66%) held naïve understanding; they believed that scientific knowledge cannot be changed because the knowledge has been recognized and has been tested. For example:

"Scientific knowledge cannot be changed because it was tested and accepted already" (S517)

Science is based on both observation and inference

Most of the students (75.93%) held no understanding; they did not answer the question or did not reflect their understanding on this aspect. However some students (24.07%) had transitional understanding; they can explain that the scientists create a conclusion from the evidence of research and observation or scientists get their scientific knowledge from their observation. But they cannot explain that scientist make inference of those observations. For example:

"The scientists conducted the principles and concepts from the direct observation of organisms" (S430)

Science demands on evidence

Most of the students (86.11%) had transitional understanding; they were aware that science demands evidence but they cannot explain that scientific evidence may be conducted by experimentations, investigation, or observations. For example:

"The scientists do the experiments on animals because they try to prove their ideas" (S453)

"They may get information or evidence from experiments" (S405)

However, some students (13.89 %) held no understanding; they could not answer the question or reflect their understanding of this aspect.

The diversity of scientific process

Most of the students (86.11%) held naïve understanding; they that the scientific process is only the step – by – step scientific method and the construction of scientific knowledge require the experimentation. For example:

"The scientific process is step-by-step. The results of the study are reliable and have been explicitly recognized by the scientific community" (S603)

"If the scientists do not use the step – by – step scientific method. The results of their researches are not accepted" (S413)

However, some students (13.89 %) had transitional understanding; they understood that the scientific process does not necessarily have exactly the same sequence of steps. Scientists do a variety of processes but students cannot explain about the diversity of the scientific process.

The subjectivity in science

More than half of students (62.96 %) had transitional understanding; they can explain that scientists construct scientific knowledge in different ways because scientists have different ideas but the students cannot explain or gave more reason to support their understanding such as scientists' prior knowledge, scientists' values, race and nationality of scientists or the social context of scientists' work. For example:

"Because scientists have the different ideas and point of views" (S428)

"Because people have different views and each person imagine something in a different way" (S463)

A smaller percentage (37.04%) held no understanding; they could not answer the question or reflect their understanding of this aspect.

Creativity and imagination in science

Most of the students (83.34%) had transitional understanding; they believed that scientists use creativity and imagination in science but they explained that the scientist use their creativity and imagination only to plan and design scientific inquiry. For example:

"Scientists only use creativity and imagination in the planning and design process" (S468)

"Scientists use creativity and imagination in the process of planning and design (experiment)" (S512)

"Creativity and imagination are used in the planning and design inquiry. It requires planning and design. Using the imagination is important in science" (S506)

Only 12.96% of the students had naïve understanding; they understood that creativity and imagination cannot be used to create scientific knowledge because scientists have tried to find the truth. For example:

"Scientists cannot use creativity or imagination in their work because they discovered scientific knowledge from experiments" (S501)

However, 1.85 % of students held no understanding; they did not answer the questions and only two students (1.85%) had informed understanding; they could explain that scientists use their creativity and imagination in all of scientific process or in all processes of created scientific knowledge.

Science is a social activity

Most of the students (81.48 %) had transitional understanding; they accepted social is supporting of the development of scientific knowledge but they cannot explain scientists working together as a social group or as a science community. Scientists need to support or to promote scientific enterprise. The scientific works will affect the quality of life in society. For example:

"Scientists cannot do their works if the society does not accept their works and that mean their work would be meaningless or bad" (S418)

"If the society does not accept scientists' work the scientist cannot do their work because they have no money or no resource for do their experimentation" (S508)

However, there is some students (18.52%) had naïve understanding; they understood that scientists working without social relationships. The successfulness of scientific work only depends on the scientists. For example:

"Because scientists have conducted researches by themselves without support from society in the process of scientific knowledge development" (S423)

Science, technology and social are effects of each other

Most of the students (94.45 %) had transitional understanding; they can explained that technological developments have resulted in the construction of scientific knowledge or the developed of technologies effects on the quality of human life. The advancement of technology has meant the development of science and quality of human life but they cannot explain the coherence in all aspects. For example:

"The advancement of technology can help to develop scientific knowledge" (S505)

"The advances in technology affect the quality of human life. If society lacks advances in technology, society might be obsolete and underdeveloped" S454

Some 3.70 % of the students held no understanding; they could not answer the question. Furthermore, some of the students (1.85 %) had informed understanding; they could explain that technological developments resulted in the development of scientific knowledge and it can improve the quality of human life. The development of scientific knowledge influences the development of society and technology. When people have a better quality of life they would have the ability to develop scientific knowledge and technology as well.

Conclusions and Discussions

Firstly, most of the students had transitional understanding about NOS mostly in the aspects of; science, technology and social are effect of each other, science demands on evidence, scientific knowledge is tentative, creativity and imagination in science, science is a social activity, the human subjectivity in science. They can identify these characteristics but they cannot give more reason to support their answers. For example they accept scientific knowledge is tentative but they cannot complete explain why scientific knowledge can be change. Maybe it is because The NOS is taught by implicit approach (Mahalee;& Faikhamta. 2010) so they did not reflect on their thinking or learning about the NOS.

Secondly, most of the students had naïve understanding that the scientific inquiry is a step-by-step process: that scientific inquiry is only experimental, consistent with the research of Chamrat; Yutakom; & Chaiso (2009) and Mahalee; & Faikhamta. (2010). Maybe it is because in the science classroom students do the experiment repeated step-by-step from textbook. Teachers believe that doing experiments is enough to promote students' understanding of the scientific process. (Abd-El-Khalick; & Lederman. 2000)

Thirdly, most of the students lack an understanding that science is based on both observation and inference. It is consistent with the research of Ladachart; & Suttakun (2012) Khishfe (2008) and Limpanontt (2011). This could be a consequence of implicit learning; students have never had experiences on the NOS explicit learning (Mahalee;& Faikhamta. 2010). In learning activities from textbooks, students know and use observation and inference as a basic process skill but they could not connect between what they did in science classroom and the scientists' work.

Finally most of the students lack an awareness of the importance and complexity of the scientific enterprise. This is consistent with the research of Kijkuakul; Yutakom; & Engkagul (2005) and Bell et al. (2003). Maybe it is because students are not given the opportunity to reflect on the scientific enterprise explicit during learning. They read and memorize science content in textbooks for the purpose of examination. They show a lack of interest about how scientific knowledge is used in the real world.

The study suggests that science teacher must encourage students to explicit and reflective about the nature of science found from the scientific inquiry activity and the history of science in science lessons and using the students' prior understanding as a basic to develop effective teaching and learning.

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