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Examining Grade 9 Students' Conceptions of The Nature Of Science

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Abstract

The aim of this research was to examine Grade 9 students' understanding of the nature of science (NoS). There were 37 female and 34 male students participating in this research, all of which were from an education-extended school in the Chaiyaphum Primary Educational Service Area Office 3, Thailand. The students' conception of the nature of science was examined using an open-ended questionnaire about the nature of science adapted from the one used in Lederman et al. (2002) VNOS-C, and an interview record form. Twenty percent of the students were randomly selected for an interview to probe deeper into their understanding. The data from the questionnaires and interviews were analyzed base on an interpretive paradigm. Research findings indicated that the majority of the students had little awareness, and held naïve views, of all aspects of the nature of science. These findings indicated that the students' understanding of the nature of science was inadequate and fragmented. An improvement of the students' understanding of the nature of science is thus necessary.

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*Keywords:*Grade 9 student, Nature of Science (NoS)

1. Introduction

Teaching and learning about the Nature of Science (NoS) has long been a major goal of science educator. The understanding of the NoS is a significant and primary component of scientific literacy (Lederman, 1992; Abd-El-Khalick&BouJaoud, 1997; IPST, 2002; 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). Understanding of the nature of science enables any person to find out knowledge for themselves and then apply such knowledge to become an informed citizen. At the same time, understanding of the nature of science can help people realize values of science, limitations of science, and impacts of science and technology on society (Lederman, 1992).

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Teaching and learning about NoS in Thailand has been emphasized since 1975 by presenting in high school curriculum, specified objectives including the notion that students have an understanding of importance of theory as a fundamental idea in science, the use of scientific methodology for troubleshooting, and have a positive attitude towards science. In the present basic educational curriculum B.E. 2551 (A.D.2008), the study of the NoS is more emphasized and appears in the science study objective as "science instructional management in educational institutes shall aim to understand natural boundary and science limitation". Based on the background described in the previous section, it was decided that the purpose of this study would be to examine Grade 9 students' current understandings of the nature of science.

The research question of this study was what is Grade 9 students' current understandings of the NoS?

2. The significance of the Nature of Science

Understanding the NoS supports the development of scientific literacy and this has been discussed earlier. The main reform efforts in science education have included much discourse about the importance of enhancing students' conceptions of NoS.

Clough and Olson (2012) asserted that effective NoS instruction helped students to understand science content. They argued that firstly, understanding the NoS helped students to understand and work from the assumptions that underlie scientific knowledge; Secondly, that understanding the NoS raised students' interest in science and science classes thus improving motivation to learn the science content. Thirdly, by teachers explicitly addressing the NoS the construction and reconstruction of science ideas was made clear, and helped students understand that some of the ideas they held were once held by scientists.

Emphasizing the investigative nature of science and science as a way of knowing suggests that curriculum is giving some influence to helping students understand the NoS. To elicit students' understanding of the NoS, many researchers used different methods and instruments for evaluating students' understanding of the NoS. Nevertheless, they have persistently shown that students hold inadequate understanding of the NoS.

3.Methodology

The study involved examining Grade 9 students' understanding of the NoS.This study was designed for collecting and analyzing data in order to answer what is Grade 9 students' current understanding of the NoS? Quantitative research was used to investigate the students' understanding of NoS.

3.1 Participants

Participants were 71 Thai Grade 9 students who enrolled in the first semester of the academic year 2012. Grade 9 students were seeking in Ban Wangtakhe school of the Chaiyaphum Primary Educational Service Area Office 3, under the Office of the Basic Commission, in the Northeast region of Thailand.

3.2 Data Collection and Instruments

Questionnaires and interviews were chosen to be the appropriate data collecting techniques. Questionnaires were used to examine the students' 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 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 students' understanding of NoS aspects (Lederman et al., 2002). These methods were selected because the nature of open-ended question allows students to answer in their own words. The questionnaire was adapted and sent to three Thai science educator experts for validation.

The second instrument was an interview. In this study, in order to investigate students' 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). 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. Twenty 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.

3.3 Data Analysis

The questionnaires and accordingly interview transcripts of the 14 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.

4. Results

The results of this study are presented in three sections. First, the characteristics of participants are reported and discussed. Second, the level of students' 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.

4.1 Participant Characteristics

The participants in this study included 71 Thai Grade 9 students in Ban Wangtakhe school of the Chaiyaphum Primary Educational Service Area Office 3, under the Office of the Basic Commission, Thailand.
The participants were thirty seven female (52.11%) and thirty four male (47.89 %). Twelve students (seven female and five male) were classified according to achievement history in science as high achievers, thirty five students (nineteen female and sixteen male) as mid-level achievers, and twenty four students (eleven female and thirteen male) as a low achievers. All of participants are Buddhist. And fourteen (20 %) of participants was randomly selected for interview to probe their understanding.

4.2 Participants' understanding of NoS from VNOS-C questionnaire

The following table (Table 1) summarizes the grade 9 students' 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 1 Level of grade 9 students' understandings of NoS

Item	VNOS-C Questionnaire statement	Aspect of NoS	Level of understanding		
			Naïve	Intermediate	Informed
1	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)?	Empirical	46 64.78 %	25 35.22 %	-
2	What is an experiment?	Empirical	51 71.83 %	20 28.1 %	-
Item	**VNOS-C Questionnaire statement**	**Aspect of NoS**	**Level of understanding**		
			Naïve	Intermediate	Informed
3	Does the development of scientific knowledge require experiments?	Empirical	43	28	-

	a) If yes, explain why. Give an example to defend your position. b) If no, explain why. Give an example to defend your position.		60.56 %	39.44 %	
4	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?	Tentative Inferential Creative and Imaginative Distinction between scientific theory and law	46 64.78 %	25 35.22 %	-
5	Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.	Distinction between scientific theory and law	71 100 %	-	-
6	After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? a) If you believe that scientific theories do not change, explain why. Defend your answer with examples. 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.	Tentative Distinction between scientific theory and law	71 100 %	-	-
7	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?	Observation and Inferential	71 100 %	-	-
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? 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. b) If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.	Creative and Imaginative	34 47.89 %	37 52.11 %	-
9	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?	Theory-laden	71 100	-	-
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. a) If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. b) If you believe that science is universal, explain why. Defend your answer with examples	Social & Cultural	40 56.33 %	31 43.67 %	-

4.3 students' understanding of NoS from semi- structured interviews.

This section presents the profiles of the participants initial views of the NoS from the follow-up semi-structured interviews. The participants' views for each item 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.

Table 2 Example of student conceptions about the Nature of Science

The item of VNOS-C Questionnaire	Aspect of NoS	Example of student conceptions about the Nature of Science		
		Naïve	Intermediate	Informed
1	Empirical	Science uses a scientific method in order to investigate the answers and different from other types of knowledge such as philosophy and religion.	Science was the study of the natural phenomena and all of scientific knowledge can be tested.	-
2	Empirical	The experiment was the best way to test the hypotheses and the experiment required the scientific method.	The experiment was a process in order to draw a conclusion by testing a hypothesis and an experiment involves the variables such as dependent variables, independent variables and a controlled variables.	-
3	Empirical	Scientist have to design an experiment to get scientific data, scientific knowledge and to test hypotheses.	All of scientific knowledge cannot testable.	-
4	Tentative Inferential Creative and Imaginative Distinction between scientific theory and law	Scientists can see atomic structure from high-powered microscopes. I believe they are very certain.	Scientists cannot see atomic structure directly. They drawn a conclusion by the result of experimental and use creative and imaginative for construct models of atoms that demonstrate understanding of atomic structure.	-
5	Distinction between scientific theory and law	Theories are potentially developed to become laws.	-	-
6	Tentative Distinction between scientific theory and law	Scientific theories and scientific law do not change because scientists take long time to discover the various theories and tested to ensure that is true before published	-	-
7	Observation and Inferential	The scientific knowledge in textbooks is reliable and scientists can test what a species is because they can see DNA from high-powered microscopes.	-	-
8	Creative and Imaginative	Scientist did not use creativity and imagination during their investigations because may be the result of an experiment was incorrect.	Scientist may be used creativity and imagination only in limited areas, for instance developing experiments.	-
9	Theory-laden	Both of conclusions were not difference because nobody can not seen the dinosaurs.	-	-
10	Social & Cultural	I think scientific knowledge is universal and has the same meaning in everywhere and is not influenced by cultures and society	Science is influenced by cultures and society because science is human endeavour. So, many factors such as religion, politics, and the economy influence the creation and development of scientific knowledge.	-

5. Discussion and Implications

These research findings indicated that grade 9 students' understanding of NoS were inadequate.

The majority of participant held naïve views and intermediate but nobody held informed views in all items of the questionnaire.

A high inadequate of understanding the NoS in this study were distinction between a scientific law and theory, Observation and inferential, and Theory-laden. The majority of participants understood scientific theories are less stable than law. (Bell, Lederman, & Abd-El-Khalick, 2000; Buaraphan, 2009; Chamrat, 2009). 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). In terms of observation and inferential, 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).In addition, they thought technology in nowadays is very modern and scientists develop an accurately scientific knowledge. In theory-laden aspect, they misunderstood the questions because the answers of the participants were irrelevant of the question in the questionnaire. Many research of NoS shown students 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).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 and did experiments. (Lederman, Lederman, Kim & Ko, 2012). 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 grade 9 students' understanding of NoS inadequate. In addition, the results of this study shown evidence that implicit NoS instruction was ineffective. From this study, I recommend the teacher use explicit and reflective NoS instruction to improve students' understanding of NoS. Furthermore, teachers have to know their students' ideas about NoS because they can plan instruction to improve their students' understanding of NoS. (Abd-El-Khalick, 2002).

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