Changes of Students' Understanding of the Nature of Science After Two and Half Years of Public Science Education in Ontario Canada

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Abstract : A longitudinal study traced changes in students' understanding of Nature Of science (NOS) through the public secondary science education in Ontario Canada. Although the concepts of NOS are complicated, and students' understandings are not easy to change, not many longitudinal studies have been done across the world. The current study tried to identify the changes of participating students' understandings of NOS for two and half years of public secondary science education in Ontario Canada. Pretest was administered using Views of Nature of Science (VNOS-C) when six participants graduated from a middle school of Toronto. Two and half years of secondary education, the posttest was carried out using the same instrument. After pre and posttest, probing interviews were performed. The analysis of the data was founded on the Standards and the conceptual framework for this study. The findings were that the initial views have little changed. Most examples and explanations the participants provided were from their science classes. Lab activities for confirming the existing laws and theories and observable photos in science textbooks made students regard the knowledge as a truth. Naturally, their knowledge has been expanded for 2 and 1/2 years, but this expansion of scientific knowledge led students toward Universalist views on science. On the other hand, when science was presented with a historical approach or was networked with other concepts, students acknowledged science and scientific knowledge had been induced from inferences as well as observations and experimental results. Based on the findings the authors of this research suggest that educating the knowledge of science should be historical and networked approaches rather than teaching the knowledge as concise and true statements of the nature.

keywords : understanding of NOS, public science education, a longitudinal study

I. Introduction

Understanding the Nature of Science (NOS) has been emphasized in recent science education since it is regarded as a bridge to reach general scientific literacy across many countries (AAAS, 1993; Council of Ministries of Education Canada, 1997; National Research Council, 1996). Scientific literacy has become a requisite element for citizens to participate in democratic decision-making on societal issues as well as to address day-to-day matters (Driver, Leach, Millar & Scott, 1996; Saddler, 2004). For decades now, considerable efforts have been made to enhance both student and teacher understanding of NOS. Many studies on NOS, however, report that teachers and students stubbornly hold naïve realistic views of science, and of experimental inductive scientific methods in spite of all effort to shift their outlook toward more comprehensive and informed views (Lederman, 2007; Schwartz & Lederman, 2004).

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This lack of understanding can be inherent in NOS education and studies. Clough (2006) and Clough, Clark and Berg (2000) stress that changes of deeply embedded conceptions require time and effort. However, very rarely have longitudinal studies on NOS been conducted (Bell et al, 2001; Lederman, 2007). Clough et al's study revealed that misconceptions of NOS have proven difficult to correct even with long-term educational efforts. Some studies have hastened to conclude that student understanding of NOS either does not change at all or partially improves based upon imposing a short-term special NOS curriculum (Liu & Lederman, 2002; Miller et al., 2010). Consequently, a longitudinal approach is crucial to understand how everyday science class settings affect students' understanding of NOS (Miller et al., 2010).

Another issue is that many NOS studies were carried out in a decontextualized learning environment, isolated from the setting of an everyday science class, which did not reflect an actual science curriculum (Arkerson et al., 2006; Lucas & Roth, 1996; Meichtry, 1992). Lucas and Roth's study, one of the very few longitudinal studies on NOS, traced two students' views of science in a secondary physics class for one year using the active involvement of the instructor together with a book, Inventing Reality: Physics as Language. The study is not about the effect of an everyday science class setting and science curriculum. In consequence, the research findings cannot provide proper guidance for the everyday setting science classes.

The present study aimed to examine longitudinal changes of students' NOS concepts through two and a half years of public secondary science education in Ontario Canada. It sought to ascertain students' initial understanding of NOS and, if there were changes over time, explore how that understanding changed, and what experiences and components of their education contributed to the changes. No special intervention was made between the preliminary and final tests to achieve the research context as a public science classes. The findings are based on the responses to the survey questions and students' interviews. This study is expected to shed light on the effects of secondary science education on students' understanding of NOS, as it is actually practiced in secondary public schools in Ontario Canada.

In addition, the findings of this study could be a reference to Korea's public science education in terms of the effect that how lab activities and interdisciplinary approaches of Ontario's science curriculum (Science, Technology, Society and Environment: STSE) for Korea's Science, Technology, Engineering, Arts and Mathematics (STEAM) education.

II. NOS in Ontario Secondary Science Curriculum and Conceptual Framework

1. NOS in Ontario Secondary Science Curriculum

The Council of Ministries of Education Canada (1997) stipulated that all students have to learn scientific literacy through K-12 science education. The Pan-Canadian Protocol for Collaboration on School Curriculum defines scientific literacy as the "possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world of the twenty-first century" (Ontario Science Curriculum [OSC], 2008, p.4). In conjunction with this goal, science courses aim to equip students "to understand the basic concepts of science [knowledge of science], to develop skills strategies and habits of mind required for scientific inquiry [doing science] and to relate science to technology, society, and the environment [knowledge about science]"(p.6). These aims are to enable students to "understand and consider critically the role of science in their daily lives, and the impact of scientific development on society and the environment" (p.16). Specifically, OSC emphasizes the inter-relationships between Science, Technology, Society and the Environment (STSE). STSE encourages students to understand that science is not isolated from societal and cultural values; rather it actively interacts with human life. Through STSE education, students can learn the complex combinations of fact and value to which developments in science and technology have given rise in modern society. This brief overview of OSC perspectives shows science education emphasizes the enhancement of investigating skills, and the relationship of science to society and to other discipline as well as the knowledge of science.

2. Conceptual Framework for the Current Study

The conceptual framework for this study needs to identify the relationships among the OSC perspectives, NOS concepts, and the questions of the corresponding NOS concepts collected data. Figure 1 illustrates these relationships. Previous studies on NOS and learning science guide the relationships between classroom practice and NOS concepts (Bell et al., 2003; Duschl, 1990; Roth & Roychoudbury, 1994). Also, the authors of VNOS-C (Lederman et al., 2002) provided the standards in interpretations of the responses to questions and the acknowledged NOS concepts.

The connections among OSC goals, science class activities and NOS concepts were identified by the previous studies such as Lederman et al. (2002) and Park (2012). For instance, OSC stipulates that the development of the skills, strategies, and habits of mind required for scientific inquiry should connect to the practice of classroom such as lab activities. Student-directed experiments that resemble the authentic scientific studies with full of messy and trial-and-errors could enhance their understanding of the underdetermination scientific theories (Bencze & Bowen, 2009). In contrast, recipe-style experiments should tend to reinforce deterministic, or naïve realistic views (Wu & Hsieh, 2006). Roth and Roychoudbury (1994) and Duschl (1990) argue that how scientific knowledge is presented to students determines their views of science; if scientific knowledge is presented as a body of established facts, students tend to regard it as an accumulation of knowledge that approaches to truth – a naïve realistic view (Lederman et al., 2002; Liang et al., 2009). If, on the other hand, scientific knowledge is presented as a continuous process of concept development and an interpretive effort to determine the meaning of data, students will acquire more informed views.

The goal of STSE education of OSC can

affect students' understanding of science as a culturally and socially embedded enterprise. If class presentations stressing the cultural and political influences on science will help students recognize this, whereas presentations emphasizing the cross-cultural and trans-historical nature of scientific knowledge will nurture a Universalist perspective (Matthews, 1994). Conceding the distinction between the context of discovery and the context of judgment (Herschel, 1830, cited in Losee, 1972, Hickey, 2005), students' views

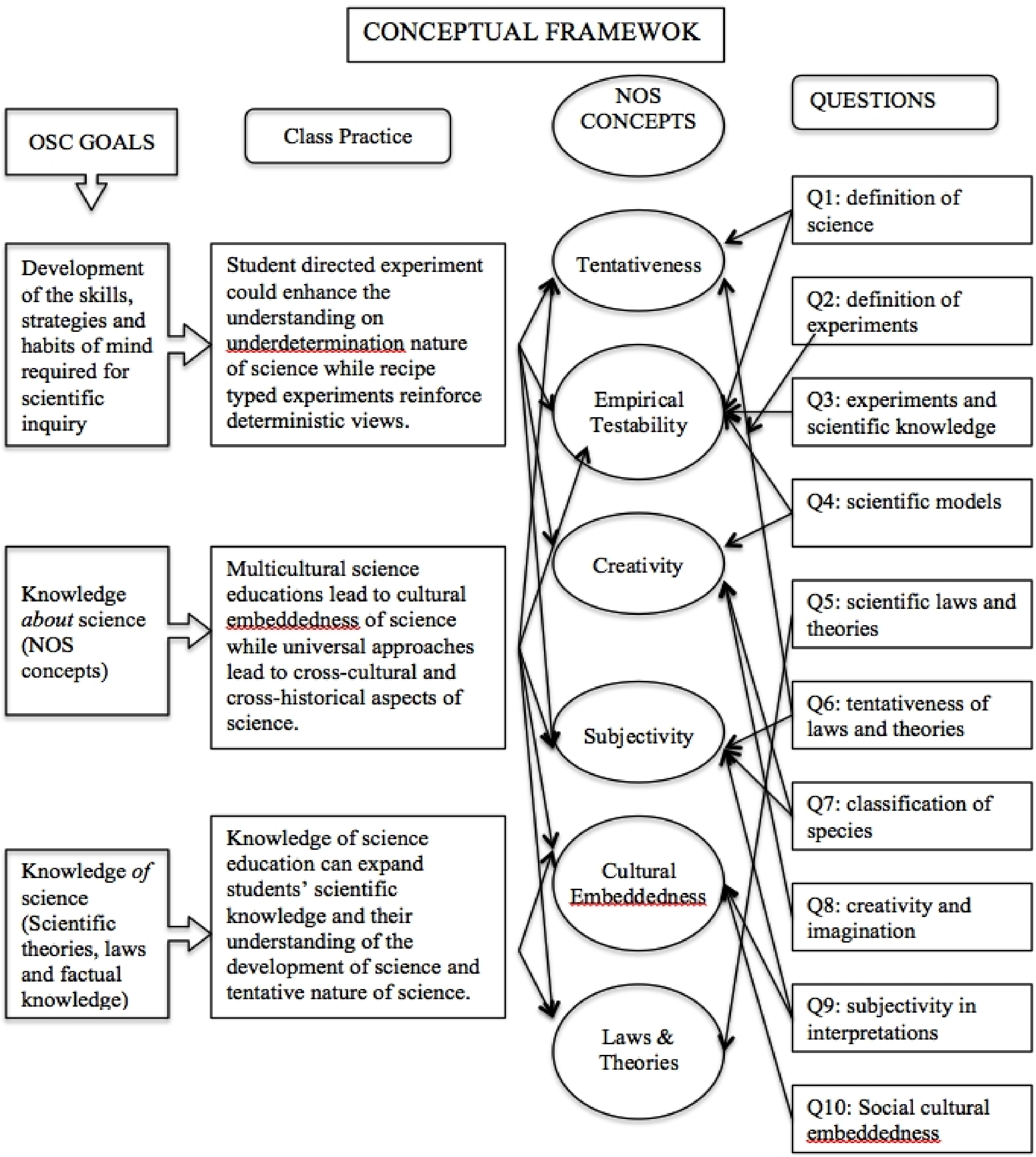

Figure 1. Conceptual Framework for the Present Study

would be interpreted from the perspective of both these contexts.

The conceptual framework was proposed to facilitate the interpretations of this research. Its usage could limit to this study since the concepts of NOS have not reached an agreement among the philosophers of science and science educators and the questions from VNOS-C (Ledermant et al., 2002) cover different concepts of NOS. Thus, other classifications and connections are also possible.

III. Methods

1. Participants

Since this research pursued chronological concept changes of students' understanding of NOS, tracing and accessing the initial participants were a concern until this study concluded; therefore, convenience sampling (Warner, 2008) was used. Initially, 8 students in Grade 8 participated in the pretest. They graduated from the same public middle school in a big city of Ontario, but their high schools were different due to the school zone or moving. In the posttest, re-inviting email and 6 responded ; thus, two students were excluded in this research. All names used in this paper are pseudonyms.

DASL took Grade 9 and 10 Academic Science courses. She said that she enjoyed Biology classes, especially learning about reproduction and ecosystems. She was taking Grade 11 Academic Biology when the posttest was conducted. YFZ wanted to major in Engineering, so she took both Grade 9 and 10 Academic Science, and in Grade 11 she was taking Biology and Chemistry. JHAQ received his elementary education in Korea and moved to Canada when he was in the Sixth Grade. He took all academic science courses offered up to Grade 11. When he participated in this study, he was taking Physics and Chemistry. JSL graduated from a gifted program and entered a gifted program in the same high school with other participants. His pretest answers were not restricted to the questions; indeed, his ideas freely flowed from topic to topic. By contrast, in the posttest, all his answers were as concise and simple as possible. SUNJS graduated from the same public middle school as other participants of this study, but he entered a Roman Catholic high school. He has been focusing on mathematics and science because he wants to be an architect. After graduating from the same middle school, SKHJ's family moved to a different city when he started Grade 10. He worried that his knowledge might not be sufficient to answer the questions because he would major in a business area and had not focused on science subjects. However, since he liked science classes and wanted to learn science more, he took Grade 9 and 10 Academic Science courses.

2. The Measuring Instrument

As this research pursues how students' concepts of NOS have changed through their school science education, the questionnaire should cover the broad concepts of NOS and provide enough room for participants to express their ideas. Due to such reasons, this study employed VNOS-C. Individual students' writing skills could hinder them in expressing their ideas, but probing questions using interviews in person, the Internet chatting tools and emails compensated for this weakness.

Views of Nature of Science, Form C (VNOS-C) (Lederman et al., 2002) consist of 10 open-ended questions covering various concepts of the nature of science: tentativeness, theory-laden observation, social and cultural embeddedness, dependence on creativity and imagination, different characteristics of scientific laws and theories and the outcomes of both inference and observation. It was attempted to ameliorate the weakness of paper-and-pencil-based and forced-answer assessments of NOS. The validity of the instrument was established through the wide range of participants (from secondary students to science teachers) across countries (Bell et al., 2003; Schwartz & Lederman, 2002). Lederman et al. (2002) advised that researchers should not judge a respondent's answer as correct or wrong. Rather it classifies the answer as a naïve realistic or an informed view. They provided the Standards (Lederman et al., 2002, pp.514-516) to help researchers interpret responses.

3. Data collection

Figure 2 shows the order of data collections. The pretest using VNOS-C was administered using a paper-and-pencil format and the posttest utilized emails. The follow-up probing interview questions also employed interviews in person, emails or the Internet chatting tool for the participants' convenience. The pretest was conducted when participants graduated from middle school in July 2009. Eight sets of printed questionnaire were distributed, but 6 sets were re-collected. Because of the complex content of the questions, time to complete the answers fully was given, so that re-collection took about one week. In late December 2011, when the participants in the posttest were in Grade 11, six sets of questionnaires were re-collected. After a preliminary analysis of both pretest and posttest answers, emails for follow-up questions were sent. An Internet chat was arranged in two cases as the participants preferred while the rest were done in person. Figure 2 shows the order of data collections.

4. Data analysis

Figure 2 depicts the data collections as well as data analysis and the role of each author. The authors of this study independently identified and classified students' answers. After that, member checking had been carried out. Disagreements were discussed and re-identification and re-classification were performed. OSC (2008) was triangulated with the probing questions asked during the third step analysis. The conceptual framework also guided the data analysis.

VI. Results

The overviews of students' understanding of NOS were arranged by the concepts of NOS. Comparisons of individual cases were made within a subject, not between subjects.

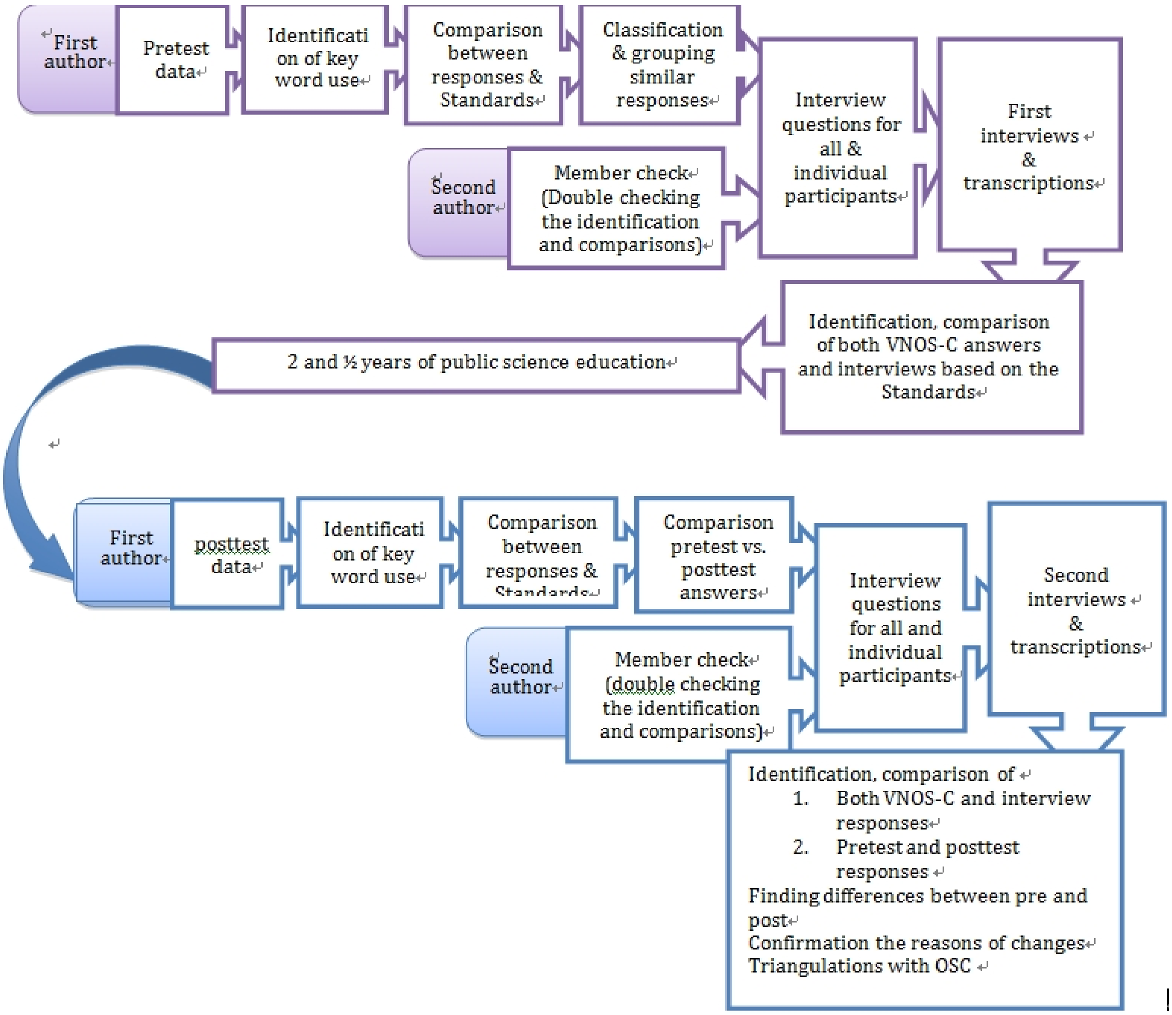

Figure 2. Order of Data Collection and Data Analysis

1. Tentative Nature of Science

The National Science Education Standards (National Research Council [NRC], 1996) and McComas and Olson (1998) maintain that scientific knowledge is durable and reliable, but it can be changed and replaced over time by new theories, reinterpretations of the previous data or new evidence. As Figure 1 shows, the participants' views of tentativeness could be revealed in the answers of the demarcation question, changeability of scientific theories, scientific models and classification of species. Thus, using the responses to the definition of science (VNOS-C question No. 1), changeability of scientific theories (question No.6) and classification of species (question No. 7), their views on tentativeness were described.

All participants agreed that scientific knowledge is durable but is changing because of discoveries and accumulation of knowledge. According to the participants, science deals with facts and truths that should be supported by evidence. The evidence that ancient people thought truth has been revealed wrong with the help of technology. DASL explained the tentative nature of science using the germ theory of modern times and devil spirits of ancient science. That is, ancient people did not have microscopes, so they could not see small living things. This lack of technology made ancient people have misconceptions. Likewise, the contemporary scientists can be wrong since their tools are less developed than the tools that the future scientists have:

> DASL: In ancient times people thought that diseases were caused by misfortune, gods or curses. Now we know why we get diseases that caused a lot of people to get sick and eventually die.....In Grade 9 Biology, I learned cells. Bacteria are basically cells and they transfer disease, and our body cells fight against them.
>
> R: Du you think the current germ thory can change in the future? Please explain the reasons.
>
> DASL: Yes, but we can see bacteria using a microscope. Maybe doctors discover different kinds of bacteria.(bold added)

SUNJI's excerpt also shows discoveries in science led changes of scientific knowledge:

> Scientific theories do change as scientists discover something totally new that is different than the previous observation that took place before. For example, during the middle of the 18th century, there was this person named Antoine Lavoisier, who came up with this idea/theory that states that the heat was a substance. However, when the time passed and the scientists started to gain more knowledge of the heat, they figured ou that the heat was not a substance, but only a motion.(bold added)

Another reason of changing scientific knowledge is accumulation fo knowledge. According to the participants' interviews, that many scientists have devoted their lives to know the natural world, so new knowledge has developed; Science is developing as humans continue to find new ways or methods to figure out something that they could not in the past (SUNJS). In the pre-interview, JHAQ said,

> JHAQ : If you study hard, you could know a lot. I read many biographies of scientists and all of them discovered things, laws and theories.
>
> R: Do you think new knowledge accumulates on the old one?
>
> JHAQ : I don't think scientists starts studies from the very first level. They start on the basis of other studies. Newton said that his works were possible since he could see further from the shoulder of a giant [Galileo Galilei].

Figure 3 illustrates how students' views had changed on the classification of species. Three students moved to discoveries with the help of new technology and one reasoned as accumulation of knowledge.

Through pre and posttest and interviews, the participants provided diverse and concrete examples to support their views of science. Their knowledge of science has been growing for 2 and ½ years; however, no one described reinterpretation from the existed data and resources of the natural phenomena can also make changes of scientific knowledge. Even in the follow-up interviews, the participants were not aware of the possibility. The authors of VNOS classified these groups as naïve views.

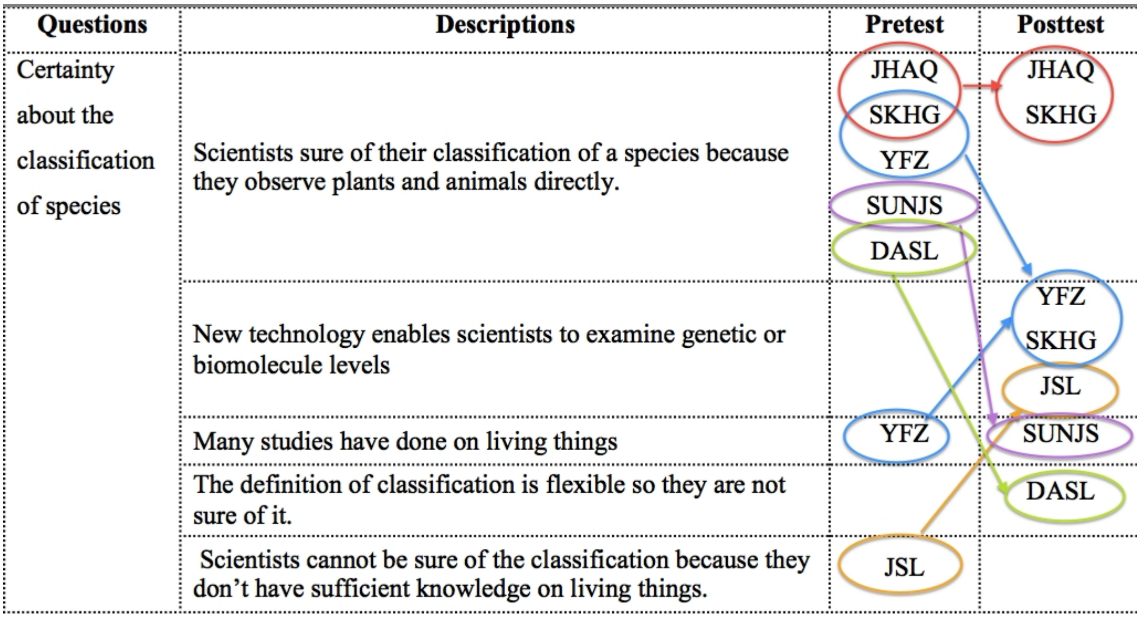

Figure 3. Summary of Pretest and Posttest Responses to the Question of Species' Classification

2. Empirical Evidence Based Scientific Knowledge

The concepts of empirical evidence-based scientific knowledge mean that scientific knowledge should be testable and supported by empirical evidence (AAAS, 1993; Lederman, 1992; McComas & Olson, 1998; Popper, 1963). This concetp is a major criterion, which determines whether a statement is scientific or pseudoscientific (Popper, 1963). As the conceptual framework (Figure 1) shows the concepts can be found through several questions of VNOS-C like the definition of an experiment (Question No.2) and the role of experiments (Question No.3).

The participants viewed scientific experiments as the ways to prove or disprove an idea, and the idea proved and supported by experiments is true, if not, it is false. In the pretest, JSL said, "An experiment is a method to investigate what a certain substance or organism is" and in the posttest, "An experiment is a set of tests performed by scientists to observe. It tests the scientist's theory or law"; and "A theory itself is nothing." YFZ provided examples that a theory or an idea can/cannot be scientific. In the pretest, she exemplified that Aristotle's idea, the heavier falls faster, was not scientific knowledge because it had not been verified by an experiment while the concepts of acid, base and neutralization are real scientific since she could see the color changes in the posttest. Throughout the pre and posttest, SKHJ viewed "An experiment is a method of proving or disproving hypotheses that have been proposed, but are lacking evidence for or against it." This means that the science should be founded on the experimental results or observations.

All emphasized the empirical evidence in science as the demarcation of science and other subject areas so that science deals with physical worlds. For YFZ, scientific inquiries bring things from "inside the box" to "outside the box." She explained the inside and outside boxes as the abstract, unlimited worlds and concrete and limited worlds. Her concept has not changed through 2 and ½ years. When this inside-and outside box metaphor brought up in the post interview, the outside box could be judged as "right or wrong by the empirical evidence" (quotations from her gestures). In her pre and posttest responses show that how she considers empirical evidence;

> Scientists' classification of species should be based solely on observations and experimental evidence, with no room for creative imagination or human inference; Scientists are extremely certain, as classification of animals has been around for a long time (pretest) and,
> Scientists are fairly certain about the characterization of what a species is, because they are able to study the genetic makeup and behavior of certain species (posttest).

SUNJI cited his physics lab activities on the principles of wave to explain how a mere hypothesis became a scientific knowledge:

> I recently have had a lab in my physics class about how a transverse wave and a longitudinal wave travels in a slinky. However, when me and my friends gathered together to perform the lab, we did not know what to do and what will happen if we do something. Instead, we... began doing the lab by following the procedures that were on the sheet and observed what happened as we experimented. Therefore, I could have come up with the information that I figured out from the experiment. Because of this reason, I believe that without experiments, scientists will not going to figure out something and develop anything even if they have a basic sense of knowledge in that particular thing.

As this excerpt shows, the experience of laboratory experiments led him to the idea that scientific experiments are a way to find knowledge. In the beginning, he and his friends did not have ideas about the experiment, but after conducting the experiment he understood the principle. Also in the posttest, he said that experiments enabled scientists to create correct models: "Because scientists go through numerous experiments and observations, they are able to create a representation that looks similar or exact as the particular thing that they studied over a long time."

Most participants regarded scientific experiments as ways of finding evidence for a hypothesis to be scientific, which means scientific knowledge needs objective evidence and is replicable when other scientists follow the same procedures, they can have the same results. However, no reflections on the theory-laden experiments and observations have been found from students' responses and interviews. In other words, if an idea or hypothesis students have not been taught that the evidence or results of an experiment is theory-laden.

3. Subjectivity

Most scholars concede that there are no absolutely pure objective observations such as logical positivists' argument (Chalmers, 1998; Hickey, 2005). Even if they exist, they are useless for the development of scientific knowledge (Popper, 1959). Actually, all observations are governed by observers' prior knowledge, backgrounds, values and research goals (Chalmers, 1998; Hodson, 1998; Popper, 1963). Several questions such as Q4 (scientific models), Q6 (scientific laws and theories) and Q7 (classification of species) are closely related to the concept. In this section, subjectivity is discussed using the responses to the atomic models.

Figure 4 illustrates students' distributions in the pre and posttest. Most students answered that the atomic models were the results of direct observations using electron microscopes. DASL's excerpt represents this idea:

> I think scientists are pretty sure about the atom as a central nucleus composed of protons and neutrons with electrons orbiting the nucleus. Scientists would probably use a microscope to determine what an atom would look like.

Two students trusted the authority of the textbook and also; whatever is in the textbook should be truth, otherwise it cannot belong in the textbook. SKHJ mentioned, "They are sure enough to put this knowledge they believe they have acquired into textbook to teach generations to exactly what extent is unsure since scientists have their own ideas."

In these excerpts, no rooms are left for the possibility that scientists' prior knowledge could have affected the model, which is consistent with the answers of dinosaur extinction. That is, lack of data forced science to use imagination; otherwise, all scientists would have the same interpretation.

However, at the posttests, students were well aware that the models were the results of other related studies and inferences. They knew how several different atomic models have developed such as Thomson's plum pudding model, Rutherford's and Bohr's models. Students explained how chemical reactions can be explained using the atomic models and how inferences were involved in scientific knowledge. SUNJI has changed from "They probably saw how [an] atom looks like and the structure of [an] atom in the pretest. However, in the post interview, he said that scientists created the structures through other studies;

> [S]cientists are able to **create** structures of something, for example: an atom that contains protons, neutrons, and electrons, that cannot be seen, because of the fact that they go through numerous experiment[s] and observe the particular object, atom in this case. (bold added)

The responses to the question contrasted to the responses to the classification of the species. Aforementioned, the participants credited the observations of genetic codes and bio-molecular structures of living things. However, responses to the atomic models students described the history of atomic model developments. They provided reasons of their stance that the diverse models were based on the inferences of experiments.

4. Creativity

The pivotal role of imagination and creativity in the context of discovering scientific knowledge has generally been admitted while its place in the context of judging scientific theories is still controversial (Hickey,2005; Godfrey-Smith,2002). Popper (1959) did not consider the discovery context a scientific

Questions	Description	Pretest	Posttest
Atomic model	Scientists are sure because they observed using an electronic microscope	DASL SUNJS JHAQ SKHG YFZ	DASL YFZ
	Many different studies and experiments provide scientists to make atomic models and structures	YFZ JSL	SUNJS SKHG JSL YFZ JHAQ
	The models in science textbooks are correct otherwise they cannot be in the textbook	JHAQ JKHG	

Figure 4. Summary of Pretest and Posttest Responses to the Atomic Models

process; however, Kuhn (1962) says distinguishing these two contexts is meaningless since observations are not objective and the standards of judgment are not absolute.

The participants reasoned why scientists use creativity and imagination: lack of knowledge and no available knowledge. DASL and JSL placed themselves in logical empiricism (Ladyman, 2002; Psillos, 1995), which emphasizes objective observations and empirical evidence, and had skeptical on the idea that scientists use imagination. This view did not change through pretest and posttest across the answers.

In DASL's response to the question No.9, the reason of different interpretations from the same data of the same evidence, was consistent in the pre and posttest; if there had been enough evidence, then scientists would have reached the same results. Due to the lack of evidence made scientists use guess and imagination;

> If you cut a piece of cake out with a knife or a butter knife, both will cut and leave similar marking behind, so the person trying to figure out what cut the cake would probably leave two conclusions with the evidence provided (the regular knife or the butter knife) (parenthesis original) (pretest).

JSL expressed skeptical views of imaginative interpretations of the natural phenomena since science deals with truth or false. Imagination and creativity do not belong to the realm of truth; "Scientists do not use imagination and creativity because they are scientists. …. I am very stereotypical, but it is a shadow of truth" (in the pretest).

Regarding scientific methods, most participants agreed that scientists should use imagination and creativity because their jobs involve discovering things. In the definition of science, the participants thought that science is an area of discovering things, laws and theories about our nature, so that scientists are pioneers who devote themselves to know unknown worlds. The job requires imaginations.

Rather than classifying JSL and DASL's view as a naïve, and other students' views as informed (Lederman et al., 2002), the participants need to know the concepts that objectivity implies shared subjectivity, shared imagination and creativity in the community.

5. Scientific Laws and Theories

In distinguishing between scientific laws and theories, no difference was found at either stage (Figure 4). Only one student (one was excluded copying the answer from the Internet) in both tests distanced different roles for scientific theories and laws, but the rest expressed a hierarchical view. The participants maintained that theories are not truth and lack evidence to be laws, while laws are factual results of observations. So then, laws are true although they may be revised to some degree in their precision. This hierarchical relationship was found frequently in many other studies (Lederman, 2007; McComas, Clough, & Almazroa, 1998; Park, 2012).

For instance, JHAQ answered that theories are "assumptions, and reliable explanations" while laws are "the descriptions of facts and absolute truth (?)" (the question mark is original). He distinguished different roles for theories and laws, but ontologically he believed laws are true while theories are not.

> JHAQ: Laws are Newton's three laws of motion, gravitation laws and Mendel's law ... I don't think I learned many laws because there are not many laws. I learned a lot about theories such as atomic theories.
> R: Why do you think there are not many laws?
> JHAQ: Because they are absolute truths. Although science has developed a lot, not many absolute truths were discovered.... I learned laws and many theories in science classes, but laws were always the same with which I learned until now, not changed. ....They were discovered by scientists, once they were discovered, they have not changed. Maybe some minor changes.

His memory of learning laws and theories gave the impression that laws were always the same so they were absolute truth while theories had changed because they were not absolute truths.

Another example of the unchanged view is from YFZ. In the pretest she said,

> Theories change because although it seems logical and correct at one point, additional knowledge after time, may be applied to the theory and prove it wrong; if there is enough information, a change in the theory is possible, resulting in a brand-new theory

At the same continuum, her posttest responses were,

> Scientific theories are not law for a reason, and that reason is that the theory doesn't have enough evidence to back it up to make it "written in stone". As more information becomes discovered (usually thanks to our modern technology and equipment), scientists are able to better mold the theory to become more accurate and specific. Theories change because new information is constantly being discovered that could affect the theory.

With respect to such hierarchical relationships, some scholars in NOS studies (Lederman et al., 2002; Lederman, 2007; McComas, Clough, & Almazroa, 1998) strictly distinguish scientific laws and theories

Question	Descriptions	Pretest	Posttest
Theories and laws	theories are guess/assumption, while laws are facts.	SUNJS	
	Theories lack evidence, but laws are proven as facts and truths.	SKHG JHAQ YFZ JSL	SUNJS SKHG JHAQ YFZ
	Theories are explanations why a phenomenon happens and laws are descriptions of observations	JSL	JSL DASL

Figure 5. Summary of Pretet and Posttest Responses to the Questiona of Theoreis and Laws

depending on their roles; however, some do not. For instance, Hickey (2005) asserts that scientific theories can be promoted when they have enough evidence: "Science achieves explanations by developing theories that satisfy the most critically empirical tests that can be applied at the current time. Such satisfactory theories may be called scientific laws" (p.32). Duhem (1906 cited in Losee, 1972) argued successful theories become scientific laws. He contrasted with these successful theories, the use of scientific theories as explanatory concepts.

Here, even scientists, philosophers of science and science educators are confused in distinguishing these two concepts. It might be difficult for the participants to distinguish the concepts.

6. Cultural Embeddedness

Considering the societal, cultural and political embeddedness of science, in the pretest, students focused on discovery context, so they agreed that science influences and is influenced by people's needs; however, in the posttest their focus was scientific knowledge itself. They held Universalist views (Matthews, 1994) on science because scientists from different countries can communicate with each other using the communication and transportation technology. Students claimed that scientific knowledge is the same around the world, citing such examples as the periodic table and equations. If it were not the same, international tests of science Olympiad would not be possible.

JSL began by saying in his pretest that while science is ideally universal, in reality it is not. A society or political outlook that accepts cultural influence in science is less developed than one, which holds science is universal. People who think science is culturally embedded are less developed, thus "they should suffer for us, for instance, sweat-shops, in poverty and very unclean conditions." Follow-up questions asked him to clarify his early views on the moral responsibilities of science, and his attitude towards culturally embedded views of science. He answered that

> Science itself does not have any good or bad values. The way we think about science should not be empathetic and reflect on social and political values,... because having that kind of opinion is thinking that they are less than us, therefore, we should have access to education. We need to use science wisely.

This excerpt shows that JSL now thinks science is amoral. Culture and society determine who practices science and how. "Science should be developed in such a way that can help free people from ignorance." This pretest answer is notable in voicing moral values and goals in science and experiments; that is, the responsibility of science-enlightened people to remove ignorance and counter the effects of excess consumerism on natural resources:

> [W]hy should we not develop something that could come to our advantage if used carefully? Many think of environmentalism, tradition and all those other values that should matter. ..... [W]e believe in those values but fail to take action. Because you can't change the world, because already we are running out of resources and we don't have the power to stop people from wanting more, needing more, buying more and building more. ... [I]t was science which created us all these luxuries, our industrialization.

However, in the posttest, JSL did not mention any moral values or goals in science and scientific development at all. He said,

> Science is an essential knowledge of the structure of our world. It is human effort to understand the nature of our world better.

In answer to a probing question, JSL reflected on how his negative views on science have changed:

> I thought all issues [global warming, consumerism, pollutions] were tangled. Still I think so. But the responsibility is not just for science, but it is more on media. ...we should treat our problems right now, with science, to get more of those hybrid cars to reduce our waste and more effectively and some people need to be reminded science is only the way out.

Figure 6 illustrates students' views on social and cultural embeddedness of scientific knowledge. The participants had moved to the Universialist view (Matthews, 1994) in the posttest. YFZ's stance well explained this figure. In the pretest, cultural influences were natural due to the economical reasons: "What a society needs decides what scientists should study, and the needs decide where the money goes." In the posttest, however, she insisted that scientific knowledge be universal: "Scientific formulas don't vary from continent to continent, and neither does the Periodic Table." She clearly held that while society might affect the motives or causes for research, the scientific knowledge gained was itself universal.

The participants admitted the social and cultural values could affect what scientists work on and how they approach to the matter. On the contrary, they thought that the outcomes of their works are universal. That is, the participants regarded science as the approved knowledge while the process and motives are not. For 2 and 1/2 years, they learned the knowledge of science widely and deeply. In accordance with the growth of the knowledge, the participants probably got the impressions that it is universal.

Questions	Description	Pretest	Posttest
Science in social, cultural, religious and political embeddedness	Scientists are humans and humans are affected by society and politics.	DASL	DASL
	Science tries to meet societal and people's needs	SUNJS JHAQ YFZ	JHAQ
	Science is the same around the world (ICT development)		SUNJS SKHG
	Science, itself, is not biased, but scientific research can be affected depending on the interests of a society, culture.	SKHG	Universalist view
	Science is universal (mathematical equation, periodic table)	JSL YFZ	JSL YFZ

Figure 6. Summary of Pretest and Posttest Responses to the Question of Societal, Cultural Embeddedness of Science

V. Conclusion and Discussion

This study examined how students' views on science have changed in two and half years of secondary science education and how science classes have affected their views. As previous studies advocate class activities could promote students' understanding of NOS (Akerson & Abd-El-Khalick, 2003; Lederman et al., 2001), we attempted to interpret both pre and posttest results of survey and follow-up interviews within OSC perspectives.

Although there was no radical change in the student views over these two and half years, we could identify a few changes arising from effective ways of presenting scientific knowledge. We also concluded that in the higher grades, as their knowledge of science grows deeper and broader, students tended toward Universalist views of science (Matthews, 1994). In other words, from the examples they provided revealed that the photos of microscopic world, and confirmatory lab activities made students place themselves in the Universalist perspectives.

Addressing the goal of OSC, "to relate science to technology, society, and the environment" (p.6), class activities that emphasize multicultural science education explained the cultural embeddedness of science. OSC indirectly suggests that a social, cultural or political situation affects the development of scientific knowledge by illuminating how the use of science can affect human activity and environments. In the discovery context, all students in both pretest and posttest agreed that societal, cultural and political values affect scientists' work. As to knowledge judgment, OSC does not provide sufficient sources to show how a society or culture accepts different scientific knowledge. A question directly asked about interrelationships between science and society and culture. Also, answers on the definition of science and on different interpretations from the same data could include this aspect of science. The participants in this study saw scientific knowledge as universal, while the motives to gain it might be culturally embedded. JSL especially mentioned that scientific experiments needed to consider carefully the ethical issues surrounding natural resources and less developed countries. In the pretest, students accepted the assertions that different cultures and societies regard science differently, and that political and cultural entities affect what and how scientists should study. Although they admitted these influences, the posttest answers still inclined to universal views. As they gained scientific knowledge, they seemed to focus on the results more than the motives or use of science. They mentioned equations, periodic tables and chemical reactions, the internationally active interactions among scientists and international students' science contents to support their universal views. This trend was found in Wong and Hodson's (2009) study; they interpreted participants' realistic views on science comparing scientists' realistic views. Scholars in the area of NOS study and science educators (Bell & Lederman, 2003) have agreed that universal views are more acceptable than relativistic views on scientific knowledge. Bell and Lederman argue that for young students relativistic views of science do more harm than good because students are not yet developed intellectually enough to deal with them. Philosophers of science admit culturally, politically and socially embedded science in the discovery context while maintaining universal views of science in the context of judgment.

Addressing the goal of OSC, "developing skills of scientific investigation and communication", the first chapter of Grade 9 and 10 describes this matter with such issues as formulating scientific questions, making predictions and hypotheses, performing, recording and analyzing skills. Most of the detailed explanations describe student-directed experiments; for instance, "plan and conduct and investigation, involving both inquiry and research, into how a human activity affects " (OSC, p. 51). The survey questions involved scientific experiments and the results of experiments and scientific knowledge. Almost all students in the both tests said that experiments are essential to confirm scientific theories. SUNJS and DASL described their lab activities as pre-determined by science teachers or textbooks; students simply followed prescribed procedures. Their lab experiences gave the idea that if they followed instructions, they could get the correct answers. So, they had a strong trust in experimental results. Since students' lab activities rarely involved their own ideas, they could not recognize that related theories were involved in the experiments. Such confirmatory use of scientific experiments can give students the perception that scientific experiments are objective and a theory supported by experimental results should be accepted as truth until and unless new discoveries falsify it.

Nevertheless confirmatory lab activities yield positive effects on learning; participating students stated that they could understand how scientists could reach a theory, and gained self-confidence by confirming that they could also obtain the same results that great scientists achieved. Students saw apprenticeship opportunities for future careers solidified their convictions that scientific knowledge is based on empirical evidence. In SUNJS's case, he could not connect the wave principles with his lab activities. Following the step-by-step instruction, and obtaining the predicted results, he and his group members figured out the relationship between what they did and what they learned during class. JSL and YFZ valued experiment as an apprenticeship or scaffold for further scientific developments. Researchers (Bell & Lederman, 2003) criticize recipe-type experiments because they cannot stimulate students to formulate scientific inquiries, or to develop problem-solving skills. Such critiques may be true; these experiments may not achieve the maximum benefits compared to student-directed experiments. However, considering students' ability and the complexity of scientific theories, student-oriented experiments without detailed instructions can class time. DASL said that when they experimented following the hand-outs her teacher provided the experiments were good, otherwise, their lab experiments would be messy. She got the impressions from the lab activities that scientists are genius, what they got from the experiments is true or at least approximately true. If the science teacher provided further information about the controlled variables, theory-laden observations (lab settings vs. natural environments), students could have learned the nature of lab experiments. In short, Balance is needed between student-directed and recipe-type experiments to promote both the knowledge and the practice of science.

OSC required students to understand scientific concepts as one of its major goals. Setting this goal in a NOS context, Roth and Roychoudbury (1994) and Duschl (1990) argue that the way scientific knowledge is taught decides students' views of science. If science is presented as a body of knowledge, students tend to view science as an accumulation of knowledge that approaches to truth – these are naïve realistic views. When instead science is presented as a continuous process of concept development and human endeavor to understand nature, students will gain informed views. A few survey questions (atomic theory, evolution theory, classification of species) directly and others indirectly could reveal how participants understood knowledge of science in OSC. Examining students' responses to the atomic structure, it was found that when learning scientific knowledge involved chronological development of knowledge and networked with other concepts, students acknowledged scientific knowledge is tentative and is induced from related concepts as well as direct observations. At the pretest students placed weight on direct observations using electron microscopes or authority of textbook, but all students in the posttest showed more informed views of NOS, explaining the historical development of atomic models and discussing how the model can be used to explain chemical reactions.

Despite the small number of participants and the representativeness of the samples, the study suggests that students' NOS concepts may be formed during the elementary school years. Scientific literacy is becoming more and more vital for the public's participation in democratic decisions on science, and for the individual's skill in problem solving. Because NOS is a significant and fruitful way to enhance the public's scientific literacy, it needs to be implemented in the early school years.

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