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Korean Pre-service Teachers' Understanding about the Nature of Science (NOS)

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Abstract: The purpose of this study was to examine Korean preservice science teachers' understanding of the nature of science (NOS). Thirty-one Korean preservice teachers were given an open-ended questionnaire about their understanding of NOS. The Korean preservice teachers' responses were categorized according to pattern and theme. These findings will provide information to aid in the development of curriculum and instruction to improve preservice teachers' understanding of NOS. Compared to in previous studies, Korean preservice teachers demonstrated various philosophical stances that have been suggested by philosophers of science. In addition, they were more likely to connect science to human endeavors and social needs. These results were interpreted in relation to the influence of the science methods course, secondary science curriculum, and the traditional cultural view.

Key words: the nature of science; preservice science teachers; philosophical stances; cultural differences in the views about NOS social/cultural influences

I. Introduction

The current science education literature advocates scientific literacy for all students as an ongoing goal of science education. Also, an understanding of NOS is identified as an important element to have in accomplishing the goal of scientific literacy (AAAS, 1989; Lederman, 1992). Despite the longevity of this goal, studies have found that students do not possess adequate conceptions about NOS (Duschl, 1990; Lederman, 1992; Lederman & O'Malley, 1990). One explanation for students' lack of understanding of current conceptions about NOS is that the majority of elementary and secondary teachers rarely address this topic explicitly in their science classes. In addition, many studies have consistently shown that preservice science teachers and experienced science teachers do not possess adequate conceptions about NOS themselves (Gallagher, 1991; King, 1991; Lederman, 1992; Liu & Lederman, 2003).

Preservice and experienced science teachers' poor understanding of NOS may be in large part due to the lack of emphasis on NOS in the science courses in most teacher preparation programs (Matkins, Bell, Irving & McNall, 2002). As the need to include NOS in preservice teacher education programs has been recognized in science education, many studies have reported the effectiveness of preservice teacher education programs that include NOS instruction (Lin, 1998; Matkins *et al.*, 2002; Palmquist & Finley, 1997). However, some studies have reported limited success in facilitating preservice teachers' conceptions about NOS (Abd-El-Khalick, Bell, & Lederman, 1998; Matkins *et al.*, 2002). Based on these mixed results, science teacher educators have come to focus on how to include NOS in preservice teacher education programs. In order to successfully introduce NOS in teacher education programs, we need to examine preservice teachers' understanding of NOS more explicitly.

To date, previous studies investigating preservice teachers' understanding of NOS have limitations due to problems inherent in the questionnaire methods (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The traditional way of ascertaining preservice teachers'

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understanding of NOS has been through questionnaires and survey instruments that use multiple choice items or Likert scales. However, participants do not always perceive and interpret test statements in the way that test designers intend (Hodson, 1993). To avoid the problem of the traditional questionnaire method, research on students' and teachers' conceptions about NOS has moved primarily from quantitative to qualitative assessment approaches (Blanco & Niaz, 1998; Lederman *et al.*, 2002).

In addition, there have been a few studies in Korea that have investigated students' views about NOS (Kang, Scharmann, & Noh, 2004). These studies have focused on secondary school students and have used quantitative methods with multiple choice questionnaires or Likert scales. Even though there has been agreement about the importance of NOS in science teacher education in Korea, few studies have been conducted with preservice science teachers. In order to provide Korean preservice teachers with opportunities to develop new knowledge about NOS, their current knowledge about NOS should first be investigated. Thus, the main objective of this study was to examine, through use of an open-ended questionnaire, Korean preservice science teachers' understanding of NOS.

Another goal of this study was to identify the tendency in the views about NOS possessed by non-Western preservice teachers. Even though Western science isconsidered the prototype of modern science, the tendency to define science strictly from a Western viewpoint could lead to serious and detrimental consequences for students from non-Western cultures and languages (Kawagley, Norris-Tull, & Norris-Tull, 1998). Some studies have reported differences in the NOS views of secondary school students from non-Western countries (Allen & Crawley, 1998). However, few studies have been conducted with preservice teachers from non-Western countries. Thus, in this study, Korean preservice teachers' conceptions about NOS were characterized to reveal the possibility of cultural influence on preservice teachers' views about NOS.

Ⅱ. Theoretical background

NOS

There are various definitions of the "Nature of Science." NOS has typically been defined as the epistemology of science, i.e. an individual's values, beliefs, and assumptions inherent in the development of scientific knowledge (Hammrich, 1997; Lederman 1992; Lederman & Zeidler, 1987). More broadly, Osborne and his colleagues (2003) defined NOS as "ideas-about-science." In this study, we refer to the nature of science as the epistemology of science in relation to the nature of scientific knowledge and the development of scientific knowledge.

There have been efforts to identify NOS components that are applicable to K-12 students (Lederman, 1992; Lederman & Abd-El-Khalick, 1998; Smith, Lederman, Bell, McComas, & Clough, 1997). The components included are that scientific knowledge is empirically based (derived from observations of the natural world), that it is tentative, and that it includes subjective perspectives. In addition, scientific knowledge is the product of human inferences, imagination, and creativity and is socially and culturally embedded. The distinctions between observation and inference, and between theories and laws, have also been added to these characteristics.

Osborne and his colleagues (2003) suggested the need to establish a consensus about which components of NOS should be included in the school science curriculum. These nine themes were considered as essential components of school science curriculum by scientists, science communicators, philosophers and sociologists of science, and science educators. The themes were science and certainty, analysis and interpretation data, scientific method and critical testing, hypothesis and prediction, creativity, collaboration in the development of scientific knowledge, science and technology, historical development of scientific knowledge, and diversity of scientific thinking.

Moss and his colleagues (2001) divided the components of NOS into two areas: the nature of scientific knowledge and the nature of scientific enterprise. McComas and Olson (1998) also suggested several features of NOS that should be considered for inclusion in school science curriculum. Even though these different studies suggested different components of NOS, they commonly accepted the idea that these components overlap each other and cannot be taught independently (Osborne *et al.*, 2003).

While the importance of an understanding of NOS has been accepted in the science education community, many studies that investigated K-12 students' conceptions about NOS have shown that students typically have not acquired an adequate understanding of NOS (Duschl, 1990; Lederman, 1992; Lederman & O'Malley, 1990; Lederman *et al.*, 2002). This overwhelming conclusion about the lack of student understanding of NOS has led the researchers to focus on the teacher as a critical variable.

Teachers' conceptions about NOS

Many NOS researchers turned their attention to teachers to assess their understanding of NOS (Bright & Yore, 2002; Gallagher, 1991; King, 1991; Lederman, 1992; Lederman, Schwartz, Abd-El-Khalick & Bell, 2001; Liu & Lederman, 2003). This body of research is based on the assumption that science teachers need to understand NOS in order to improve the scientific literacy of their students. Furthermore, teachers' understanding of NOS can influence their approach to science teaching and teaching behaviors (Eichinger, Abell & Dagher, 1997). Many studies were consistent in showing that neither preservice science teachers nor inservice science teachers possessed adequate conceptions about NOS (Gallagher, 1991; King, 1991; Lederman, 1992; Liu & Lederman, 2003).

According to research results that investigated inservice teachers' conceptions about NOS, a significant proportion of teachers held a positivistic view of science, believing that scientific knowledge is not tentative (Lederman, 1992). Most inservice teachers were unable to articulate a deep, consistent understandingof NOS, and could not connect NOS with their science classes (Gallagher, 1991). Similarly, studies assessing preservice teachers' knowledge showed that they did not recognize the meaning or role of scientific knowledge (Bright & Yore, 2002; King, 1991; Lederman *et al.*, 2001 Liu & Lederman, 2003). They did not have the notion that scientific theories are related to beliefs in one's thoughts apart from empirical observation (Bloom, 1989). They also believed that scientific knowledge is a collection of observations and explanations that have been proven to be correct (Aguirre, Haggerty, & Linder, 1990). In research to reveal Taiwanese participants' conceptions about NOS with regard to focused components, Liu & Lederman (2003) indicated that most preservice teachers retained inadequateviews of the empirical nature of scientific knowledge, of the tentativeness of scientific knowledge, and of the creativity and imagination necessary for scientific investigation. In addition, most participants showed a hierarchical view of the relationship between scientific theories and laws.

Ⅲ. Methods

Thirty-one Korean preservice teachers were given an open-ended questionnaire on their understanding of NOS. The participants were all juniors in the Department of Chemistry Education at a large national university in southeast Korea. Their ages ranged from 20 to 23 years old. Most students' science and science education backgrounds were similar. They had completed 35-40 science credit hours and 6 credit hours of science education courses. None of the participants had taken a formal course related to NOS. Data were collected at the end of the semester in a science methods course for preservice teachers taught by the third author. In the science methods course, there were four hours of classes related to the topic of philosophy of science. In these classes, the participants learned about various philosophical stances, including positivism, Popper's falsification, Kuhn's scientific revolution, and Lakatos' research program.

An open-ended questionnaire about NOS was administered at the end of the course. The questionnaire used in this study consisted of eight questions. Six items were taken from and validated by Lederman et al. (2002). The items were designed to elucidate respondents' views regarding the target componentsof NOS and the reasons that underlie their views (Lederman *et al.*, 2002). Components that were included were the empirical nature of scientific knowledge, inferential nature, tentativeness, subjective nature, the role of creativity/imagination, and social/ cultural influences. We added two items to investigate the preservice teachers' views about the development of scientific knowledge.

The data analysis and interpretation were discussed until a consensus was reached among the authors. First, we coded each segment of the participants' responses from the questionnaires. By comparing and combining the initial codes, some patterns that revealed the participants' understanding of NOS were identified (Glaser & Strauss, 1967; Strauss & Corbin, 1990). These patterns were grouped into seven target components of NOS in terms of their properties and dimensions. Within each target component, we organized the patterns of the participants' responses into categories. To ensure the credibility and trustworthiness of the findings, several rounds of analysis were conducted.

Ⅳ. Results and Discussion

The Korean preservice teachers' responses were grouped into seven target components of NOS: empirical nature, inferential nature, tentativeness, development of scientific knowledge, subjective nature, creativity/ imagination, and social/cultural influences. In each target component, identified categories and patterns of responses are describedalong with the number of respondents. The excerpts that represent each category are also presented along with the pseudonym of each participant (i.e., P1, P2,…P31). In some cases, a participant's responses were included in more than one category or pattern. The categories that were identified in each target component are presented in Table 1 with the number of respondents.

Empirical nature

The participants' views about the empirical nature of science were organized into three categories: positivistic view, emphasis on process, and connection with human life and endeavor. Among the three categories, the positivistic view was most frequently mentioned by the participants (22 responses). In this category, the preservice teachers believed that scientific knowledge is based on observable or objectivefacts (12) science is objective, while religion and other disciplines are subjective (8) scientific knowledge can be proven (7) science is a collection of theories and laws (4) and science has its own step-by-step method (4). The following two descriptions represent the participants' positivistic views.

> Religion is subjective in that it is based on beliefs. However, science is objective because its subject, method, and result isgrounded in objective facts. (P21)
>
> Scientific knowledge consists of proven facts. (P17)

While most participants showed positivistic views about scientific knowledge, some participants (14) placed more emphasis on the process of science than the outcomes or results of science. In the category, "emphasis on process," the preservice teachers focused more on science as the process of observing, exploring, and predicting matter and phenomena in nature (9) and the process of inquiry for problem solving, revealing cause-and-effect relationships, and discovering new theories or rules (5).

> Science is a discipline that observes and explores the matter and principles of nature. (P4)

Table 1
Categories that reveal the participants' view of NOS (N=31)

Target NOS components		Categories	#
Empirical nature		Positivistic view	22
		Emphasis on process	14
		Connection with human life and endeavor	11
Inferential nature		Do not recognize uncertainty of scientific knowledge	19
		Recognize uncertainty of scientific knowledge	12
Tentativeness		Do not recognize tentativeness	1
		Recognize tentativeness within a positivistic stance	11
		Recognize tentativeness supported by the current philosophical stances	19
Development of scientific knowledge	Philosophical stance	Positivistic view	9
		Popper' s falsification	4
		Kuhn' s scientific revolution	3
		Lakatosian view	5
	Factors	Human desires and efforts	14
		Social need to pursue the advancement of human life	4
		Social cultural factors	8
Subjectivity		Inadequate understanding of subjectivity	16
		Adequate understanding of subjectivity	15
Creativity/Imagination		Only in the planning stage	20
		Only after data collection	5
		Planning/after data collection or during data collection	4
		Throughout the whole process	2
Social/cultural influence		Scientific knowledge is universal	8
		Science reflects social cultural values	23

: Number of respondents

> Science is a series of processes that includes generating the problem, inquiring to solve the problem, and drawing a conclusion. (P5).

This finding seems to relate to the science methods course that the participants were taking at the time of the study. The course emphasized inquiry as the main topic. By discussing and implementing inquiry throughout the semester, the participants came to value the process of science rather than the outcomes of science when they defined science. This result seems to be consistent with the results of previous studies suggesting that an understanding of NOS can be improved through science process skills instruction and through doing science (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000 Haukoos & Penick, 1983).

Finally, many participants emphasized that science is a discipline for improving the quality of human life (11). According to the responses in this category, scientific knowledge should be applied to everyday life and should pursue the advancement of human life (9). In addition, science is a discipline for satisfying humans' intellectual desires (2).

> Science is to find the cause of phenomena and to apply this finding to everyday life. (P10)
>
> Science should contribute to improving the quality of human life. (P11)

> Science is a discipline to satisfy humans'desire to know everything around them. (P19)

These responses can be interpreted as more informed in that the Korean preservice teachers viewed science as a human endeavor (Liu & Lederman, 2003) and scientific claims as based on a mix of observational, personal, and social influences (Lederman *et al.*, 2002). This result shows a different tendency in Korean preservice teachers from that of previous studies, which reported that preservice teachers did not recognize science as a human endeavor (Seung & Bryan, 2009; Liu & Lederman, 2003). However, to some extent, these responses are likely related to the tendency to view science and technology as identical. By identifying science with technology, participants in this category indicated that science needs to be applied to everyday life and should contribute to improving human life. For example, P2 mentioned, "Science has invented many things such as the automobile, train, and medicine to satisfy human and social needs."

Inferential nature

Korean preservice teachers' views about the inferential nature of scientific knowledge were investigated by asking them, "How certain are scientists about the structure of the atom?" Nineteen participants believed that scientists were certain or very certain about atomic structure. They responded that scientists can be very certain about atomic structure because it is supported by scientific facts and evidence from many experiments and technology (9). As P19 described, participants mentioned that scientists could see an atom using technology.

> They [scientists] are very sure because they can see the atom with a microscope and they have observable evidence. (P19)

Two participants mentioned that the current atomic structure is an irrefutable fact because there is no contrary evidence. For example, P16 said:

> The atomic structure is an irrefutable fact because it can explain well natural phenomena and it is supported by many experiments. (P16)

Some participants just described some theories (e.g. Bohr's atomic model, electron cloud models, etc.) that have been developed to describe the atomic structure instead of explaining the reasons why scientists can be certain of their theories (8).

On the other hand, 12 participants believed that scientists cannot be very certain about the atomic structure because, to some extent, their theories include inference. They indicated that the atomic structure would be modified and developed continuously (3). For example, P8 said:

> As various atomic models have been suggested, scientists accept the possibility that new modes can be developed. (P8)

Only three participants considered the atomic structure as a potential model that, so far, scientists have established based on indirect evidence. For example, P22 said:

> They (scientists) consider the atomic structure as a potential model that they can believe based on evidence so far. (P22)

Six participants presented unclear explanations or only mentioned theories related to the atomic structure.

In conclusion, many Korean preservice teachers did not have an adequate understanding of the inferential nature of scientific knowledge. In other words, they did not recognize the distinction between observation and inference. Some of them showed strong beliefs about experiments and technology and believed that atomic structure was established through direct observation. Even the participants who believed that scientists cannot be certain about atomic structure did not provide a suitable rationale for their choice that atomic structure is a potential model that has been established based on scientists' inferences. On the other hand, many participants' lack of understanding about the inferential nature of scientific knowledge might be due to the specific context of the question (i.e. how certain are scientists about the structure of the atom?). If the question had included a different context or if it were a general type of question not in a specific context, the participants' responses might have been different. This implies that in order to correctly assess preservice teachers' understanding of NOS, we need to use various methods together (e.g., questions in various contexts, interviews, etc.).

Tentativeness

Only one participant mentioned that scientific theories do not change after scientists develop them. All the other participants recognized the tentativeness of scientific knowledge, even though the participants' views related to the tentativeness were varied. Some participants (11) showed a positivistic stance that indicated a belief in absolute truth. They believed that scientific knowledge changes and scientists could attain absolute truth by new discoveries due to the development of science and technology (6). The following two descriptions represent this belief well.

> Due to undeveloped science and technology, a scientist might not reveal facts. (P4)
>
> Even though there is absolute truth, scientists may fail to arrive at the truth. (P20)

Some mentioned the lack of observable data and evidence as the main reason why scientific theories change (3). These responses show that the participants recognized the tentativeness of scientific knowledge within a positivistic stance.

On the other hand, many participants (19) supported the current philosophical stance about the tentativeness of scientific knowledge. They believed that scientific knowledge is potential truth since it can be falsified or modified by future scientists (11). It can be truth only in certain contexts (5). In addition, human ability has limits in knowing everything in the natural world (5). Some participants mentioned that scientific knowledge is limited by the paradigm of the time or subjective factors of scientists such as theoretical background and personal characteristics (4).

> Scientific knowledge is potential truth that always has the possibility of being falsified. It's only an outcome of human endeavor. (P17)
>
> Scientific knowledge cannot be proven. It is a theory that can be explained in current contexts. (P11)

Four participants cited historical cases (e.g. Dolton's atomic theory, Newton's theory etc.) as evidence to support the tentativeness of scientific knowledge.

In conclusion, many participants (19) had a more informed view that was not restricted to a positivistic view in that they did not believe in absolute truth. They recognized that scientific knowledge has a contextual and subjective nature. On the other hand, 11 participants' responses did not go beyond the positivistic view even though these participants believed in the tentativeness of scientific knowledge. They believed that scientific knowledge is tentative only until scientists can reach absolute truth through having sufficient evidence. This implies that even when preservice teachers accept the tentativeness of scientific knowledge, they may have different philosophical stances. This needs to be considered in NOS teaching.

Development of scientific knowledge

The participants' views can be categorized into four philosophical stances that have been suggested by philosophers of science to describe how scientific knowledge develops: positivistic view (Casti, 1989), Popper's falsification (Popper, 1963), Kuhn's scientific revolution (Kuhn, 1970), and the Lakatosian view (Lakatos, 1970). Nine participants' responses were identified as the positivistic view. In this category, the participants demonstrated that scientific knowledge develops from the accumulation of facts, evidence, and experiences in human society (5). They also believed that scientific knowledge develops gradually through correcting and complementing current theories (5). Some participants indicated that scientific knowledge develops along with the development of technology (6). P13's response can be included in this category.

> I think scientific knowledge develops by

> gradual modification and complementing current theories. For example, the octet rule was modified to the 18 rule, and through the gradual process, current orbital theory was also generated. (P13)

Four participants' ideas were close to Popper's falsification. They indicated that if contrary evidence appears, the current theory can be falsified. For example, P26 responded as follows:

> Scientific knowledge is generated inductively through experimentation and this knowledge is applied to many cases. If the fact is proven, it can be a theory or law. If a current theory cannot explain a new case, it is falsified. Scientific knowledge develops through this falsification. (P26)

Three participants demonstrated Kuhn's notion of scientific revolution. According to this category, scientific knowledge develops in a revolutionary way through the emergence of a new paradigm (3). If many anomalies that can not be explained by a current paradigm accumulate, a new theory emerges as a new paradigm. P7 described this as follows:

> A new theory is established based on current scientific knowledge, and it is accepted as a new theory through proof. Otherwise, a current theory is replaced by an evolutionary theory. These processes are repeated, and scientific knowledgeis developed and expanded. If new phenomena or anomalies that cannot be explained by current theories are accumulated, scientific knowledge should be generated in a new way. (P7)

Five participants held views that reflected Lakatos' theory of research programs. Scientific knowledge develops dialectically (2), and the process of development includes competition between two theories (1). If a theory cannot explain some phenomena, scientists modify or extend the theory as a protective belt (1), or a new theory that has more explanatory power emerges (1). P11's response shows an example of this category.

> Science develops through the competition of two theories that interpret the same phenomena differently. As one theory develops, another theory degenerates. Through this process, science develops. (P11)

Concerning factors that influence the development of scientific knowledge, participants chose factors that focused on human endeavor and emphasized social perspectives. Some participants (14) believed that scientific knowledge develops as a result of human (or scientists') desires and efforts (e.g. curiosity, asking questions and giving alternative views, open-mindedness). Others indicated that scientific knowledge develops to satisfy a social need to pursue the advancement of human life (4), and social/cultural factors (e.g. funding, manpower, education, scientists' cooperation, social values) influence the development of science (8).

In summary, the participants showed various patterns of responses concerning how scientific knowledge develops. Even though the participants' responses were not elaborate, the basic ideas in their responses were close to the positivistic view, Popper's falsification, Kuhn's scientific revolution, or the Lakatosian view. This result seems to be due to the participants' learning experiences in the science methods course. During the course, the participants studied various theories of philosophy of science for four hours. In addition, as an assignment, they analyzed scientific theories found in secondary science textbooks in terms of the Lakatosian view. The finding that participants indicated various current philosophical stances such as Kuhn's and Lakatos' views implies that thepartial introduction of NOS in the science methods course might be effective in broadening participants' philosophical stances.

Another characteristic of the participants' responses was that they emphasized human endeavor and social need as factors that influence the development of scientific knowledge. This result seems to be consistent with the response that science is a discipline for improving the quality of human life (which is related to the empirical nature of scientific knowledge). These responses, to some extent, seem to be influenced by the secondary science curriculum in Korea, which emphasizes the interrelatedness of science, technology, and society. In addition, this trend seems to be related to the traditional Korean cultural view which encourages each member to contribute to society. This Korean cultural view values social need over individual need.

Subjectivity

The participants' views about the subjective nature of scientific knowledge was investigated by asking a question about how different conclusions were possible if the scientists were all looking at the same experiments and data. Sixteen participants did not recognize that scientists' subjectivity influencesthe construction of scientific knowledge. They indicated that, due to a lack of evidence, different conclusions are possible (4). That is, they thought that if science developed to a higher level, scientists would reach the same conclusion. For example, P_1 explained that different interpretations are due to the low level of the current science.

> Different interpretations are due to the level of current science. If science develops more and scientists can get information that is closer to the truth, they can draw a correct conclusion. (P_1)

They also indicated that different experimental methods and different abilities in finding data lead scientists to different conclusions (5).

Fifteen participants recognized the subjectivity of scientific knowledge. Some of them responded that scientists' beliefs, values, and theoretical background influence the scientific knowledge they generate (8). Along the same line, other participants mentioned that scientists may reach different conclusions using the same data because of their own subjective interpretations (8).

> Due to the scientists' scientific opinions or personal beliefs, they may draw different conclusions using the same experiment and data. Otherwise, they are likely to explain a certain phenomena using their previous knowledge. (P_7)

In conclusion, many participants (16) showed an inadequate understanding of the subjectivity of scientific knowledge. This finding seems to be consistent with the previous finding in which many participants showed an inadequate understanding of the inferential nature of scientific knowledge. Rather than accepting the subjective and inferential nature of science, many participants believed that because of the lack of evidence and the low level of science and technology, scientists draw different conclusions even from the same data.

Creativity/Imagination

All participants believed that scientists use creativity/imagination in the research process. However, most participants (20) indicatedthat scientists use creativity/imagination only in the planning and design stage. That is, in the planning stage, scientists use creativity/imagination to generate questions and hypotheses (6). The participants also mentioned that, in the planning stage, scientists use creativity/imagination to decide on research methods (4) and to predict results (3).

> In general, scientists generate hypotheses first and conduct research to confirm the hypotheses through experiment or investigation. After making hypotheses, they conduct experiments and collect data. Scientists creatively plan experiments to investigate their hypotheses in the most reasonable way. If they use creativity or imagination during the collecting of data or after data collection, they may not attain objective results. (P_{21})

As shown in her response, P_{21} believed that scientists use creativity/imagination to plan experiments. However, she believed that scientists do not use creativity/imagination during or after the data collection due to the necessity to sustain the objectivity.

On the other hand, five participants responded that scientists use creativity/imagination only after data collection. They thought that scientists use creativity/imagination when they interpret data and generate a new theory based on the interpretation. For example, P28 said:

> Scientific theory cannot be directly drawn from data. Through the interpretation of data, scientific theory can be generated. In this process, scientists' creativity plays an important role. For example, Kepler established his laws by creatively interpreting thedata that his advisor had collected for several decades. (P28)

Three participants selected the planning/design stage and the stage after data collection, and one participant selected the planning/design stage and the stage during data collection. Only two participants believed that scientists use creativity/imagination throughout the whole process. P16, one of the two, mentioned that since scientists do not follow fixed steps, the whole process of investigation requires creativity.

> Scientists use creativity or imagination in the whole research process. For example, when Newtongenerated the theory of gravity, he did not follow fixed steps. When he saw a certain phenomenon, he imagined something. He also used his creativityand imagination when he planned an experiment, generated a hypothesis, corrected the hypothesis, collected data, and conducted a new experiment. I think this whole process is the result of scientists' creativity. (P16)

Most participants' responses saying that scientists do not use creativity during the data collection seem to relate to the responses that participants made about the empirical nature of scientific knowledge. Specifically, many participants believed that scientific knowledge is objective in that it is based on objective facts and that scientific knowledge is established through an objective method. Thus, many participants seemed to think that scientists do not use creativity and imagination during the data collection because they must follow an objective method.

Social/cultural influence

Most participants (23) recognized that science reflects social and cultural values. According to them, science and technology are strongly related to social issues (i.e. political, economic, and religious issues) (10). In addition, science is part of culture (5), and cultural differences can cause different interpretations in the generation of scientific knowledge (2). Since scientists cannot be independent of society, scientific knowledge is inseparable from social and cultural values (3). The participants also accepted that science is related to the need forsociety to improve people's lives (2). P31's response shows her belief that social/cultural values influence the process of accepting scientific theory.

> A scientific hypothesis has to follow many verification steps in order to be accepted as a scientific theory. In this process, besides scientists, the people in the areas of politics and religion and general citizens influence the decision. For example, Copernicus' heliocentric theory could not be accepted because it did not represent the sociocultural values at that time. (P31)

Eight participants did not accept the concept of social/cultural influences on science. They believed that scientific knowledge is universal in that it does not change in a different society and culture (2). They also mentioned that science is a discipline for finding the truth that already exists in nature, and scientific knowledge cannot be influenced by external factors (2). In addition, they indicated that science does not accept social/cultural influences on science because scientific knowledge is based on facts and is established by objective methods (2). These responses seem to relate to the positivistic view about the empirical nature of scientific knowledge. The participants who believed that scientific knowledge is based on facts and observational evidence were likely to believe that scientific knowledge is universal regardless of social/ cultural influences.

> Scientific knowledgeis identical in all

> countries. Science is a discipline that emphasizes objectivity. Social or cultural values cannot influence the objective process of experimentation and observation. (P24)
>
> Scientific knowledge is based on facts and established by objective methods. Thus, it is not related to social cultural values. (P21)

P24's and P21's responses show their beliefs in the objectivity of science, which led them to believe that scientific knowledge is independent of social/cultural values.

The finding that most participants (23) showed an adequate understanding of the social/cultural influences in science seems to be consistent with the participants' responses about the development of scientific knowledge. Many participants mentioned social factors in explaining the development of scientific knowledge.

V. Implications

The results of this study provide information that will help in the development of curriculum and instruction to improve preservice teachers' understanding of NOS. In order to successfully teach NOS, students' current knowledge about NOS needs to be taken into account. This study indicated that the degree of Korean preservice teachers' understanding was different according to the NOS components. They held more naive views of some components (e.g., inferential nature, creativity/imagination, subjectivity) compared to other components (e.g. development of scientific knowledge, tentativeness, social/cultural influences). That is, the results of this study give information about which components should be emphasized in the curriculum and instruction of NOS. In addition, the results of this study show that a certain component of NOS was related to another component of NOS. For example, an understanding of the role of creativity/imagination was related to an understanding of the empirical nature of scientific knowledge. There was also a connection between the development of scientific knowledge and the social/cultural influences on science. This finding agrees with the assertion that components of NOS are interrelated and overlap, and thus, should not be taught independently (Osborne *et al.*, 2003; Seung & Bryan, 2009). So, in the process of developing curriculum and instruction in NOS, more concerted effort needs to be made in helping preservice teachers give their attention to the connections among the components of NOS.

In this study, Korean preservice teachers' views of NOS were categorized according to pattern and theme. This categorization will be helpful when teacher educators develop instructional strategies for NOS. For example, even though most participants believed that scientific knowledge is tentative, the rationale that they provided to explain this tentativeness was varied and included different philosophical stances. Some participants showed a positivistic stance whereby scientific knowledge changes and scientists can attain absolute truth. Other participants believed that scientific knowledge is potential truth which can always be falsified or replaced by a new theory. Related to creativity/imagination, most participants indicated that scientists use their creativity and imagination in their investigation. However, the participants demonstrated various views about the stage in the process when scientists use creativity and imagination. Some participants indicated that scientists use creativity or imagination only in the planning and design stage. Others recognized that scientists use creativity or imagination when they interpret data to generate a new theory. These various patterns among the participant responses need to be considered in the design of more effective NOS classes.

Compared to previous studies indicating that preservice teachers held a positivistic, idealistic view of science (Seung & Bryan, 2009; Aguirre *et al.*, 1990; Lederman, 1992; Liu & Lederman, 2003), this study of Korean preservice teachers demonstrated the various philosophical stances that have been suggested by philosophers of science. For example, concerning the tentativenessof science, many participants indicated that scientific knowledge can never be absolutely proven irrespective of the amount of empirical evidence (Popper, 1963). In addition, the participants used various theories from the philosophy of science when they were asked to explain how scientific knowledge develops. To some extent, the reason why Korean preservice teachers showed more informed views in this NOS aspect may be connected to their previous learning experience. In the same semester, the participants attended a philosophy of science class for four hours. The classes were a part of the science methods course. At that time, they learned about the positivistic view, Popper's falsification, Kuhn's scientific revolution, and Lakatos' theory. They also did an assignment that analyzed various scientific theories in secondary science textbooks in terms of the Lakatosian view. This learning experience seemed to influence the participants in giving informed responses. Considering the lack of explicit NOS courses in Korean teacher education programs, partial introduction of NOS in the science methods course seems to be helpful for improving preservice teachers' understanding of NOS.

The Korean preservice teachers were more likely to connect science to human endeavor and social needs compared to in previous studies (Akerson *et al.*, 2000; Bell, Lederman, & Abd-El-Khalick, 2000; Liu & Lederman, 2003). They recognized science to be an outcome of human endeavor and believed that science develops to satisfy social needs. This result seems to be influenced by the traditional Korean cultural view which emphasizes social commitment, and the Korean secondary science curriculum, which includes the STS (science, technology, and society) curriculum. This finding implies that there is a need to characterize potential notable similarities and differences between the views on NOS possessed by Korean preservice teachers and the views possessed by preservice teachers in other countries. The research that has been conducted in Western cultures should not be simply applied to non-Western countries, which could lead to unfavorable consequences. The research to investigate students' and teachers' views of NOS needs to consider their cultural background including educational background. Thus, in future studies, Korean preservice teachers' conceptions about NOS need to be compared to those of preservice teachers in other cultures. In addition, there is also a need to investigate in depth how social and cultural differences impact the differences in preservice teachers' understanding of NOS.

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Appendix A

Nature of Science Questionnaire

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)?
2. Do you think scientific knowledge is always true? Yes or No? Why do think so?
3. How do you think scientific knowledge develops? What factors influence the development of scientific knowledge?
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 that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists use to determine what an atom looks like?
5. After scientists develop a scientific theory, does the theory ever change?
   - If you believe that scientific theories do not change, explain why with examples.
   - If you believe that scientific theories do change:
     Explain why theories change.
     Explain why we bother to learn scientific theories.
6. In the recent past, astronomers differed greatly in their predictions of the ultimate fate of the universe. Some astronomers believed that the universe is expanding while others believed that it is shrinking; still others believed that the universe is in a static state without any expansion or shrinkage. How were these different conclusions possible if the astronomers were all looking at the same experiments and data?
7. Scientists perform experiments/ investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
   - If yes, then at which stages of the investigation do you believe scientists use their imagination and creativity: planningand design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
   - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.
8. Some people 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 or by the intellectual norms of the culture in which it is practiced.
   - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
   - If you believe that science is universal, explain why. Defend your answer with examples.