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Identification and Interpretation: A Framework of Naturalistic Epistemology Perceived by Korean Pre-Service Science Teachers

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Abstract

The epistemology of science and teachers' perspectives on it have been major lines of investigation in science education research. The role that epistemology should play in science education has become increasingly relevant because of its incorporation within some important curriculum reform movements around the world. Improving teachers' perspectives and designing advanced teaching-learning sequences along them have been substantial parts of the science education reform. Such efforts are having been active when a new epistemological position emerged. The present inquiry has been conducted at the interface of these two lines of research. The main focus of the study is analyzing the way Korean pre-service teachers interpret epistemological aspects of scientific knowledge. A questionnaire to explore pre-service teachers' epistemological beliefs was developed for developing frameworks of naturalized epistemology. The questionnaire is composed of items using Likert scale and open-ended items. Two groups of pre-service teachers participated in this exploration: in an elementary teacher education universities and a secondary science teacher education university. Epistemological beliefs of prospective elementary teachers were identified through qualitative analysis of the answers to the open ended questions as well. Suggestions for curricula change and teaching-learning strategies being involved in the incorporation of scientific epistemology are considered.

Keywords: naturalized epistemology, science teacher, teacher perception

1. Introduction

Epistemological issue of science is not new in science education, As Matthews said: "science cannot be taught without philosophy because science itself throughout its history has been philosophical" (Matthews, 1990). Epistemologists are concerned with the following questions: What counts as knowledge? What is the justification of belief? What are the intellectual virtues? What are the limits of knowledge? What is inquiry? What are the social processes and interactions that are involved in search for knowledge and attempts at systematizing and communicating it?

These aspects of epistemology are relevant to both of students and teachers. Students should develop a reasonable view of science. Schwab (1962) criticized the frequently taught versions of scientific method which belies science as a creative enterprise of human imagination and promoted erroneous view of the epistemology of science. Students have prior beliefs of epistemological aspects of science and scientists (Hodson, 2009, p. 23). These beliefs may be different from the views that form the intended learning about science components of the curriculum. Teachers in all levels from elementary to tertiary, must take students' prior beliefs and teach them accordingly.

Teachers also have dual relevance in epistemology. It affects what and how to teach (Hodson, 2009). It seems self-evident that teachers' own epistemological beliefs will impact on their pedagogical practice, including decisions about the design of teaching-learning sequence. Many research findings ascertain this claim (Tsai, 2002; Hashweh, 1996; Kichawen et al., 2004; Duschl, 1983; Lantz & Kass, 1987; Wolfe, 1989; Brickhouse, 1990; Waterman, 1983; Gallagher, 1991; King, 1991). Furthermore, teachers' views on epistemology might be passed onto students via education (De Medeiros, 1993). Trumbull and Kerr (1989) concluded that the development of teachers' view came from the manner in which they themselves been taught. Indeed, scientific literacy is an important goal of science education (Hurd et al., 1980; Hodson, 2009). One component of scientific literacy is an understanding of the substantive and syntactical structure of science (Hodson, 2009).

With these epistemological aspects of science education in mind, it is noted that there is a distinction between two perspectives from which this study may approach the epistemological aspects of science. The first perspective which many epistemologists, including Alston (2005), call traditional is one that attempts to respond to Cartesian skeptical doubts by showing, without presupposing that we already know various things, that we have genuine knowledge or well-grounded belief. One attempt is trying to formulate and justify a form of inference from data to hypothesis that requires no input of other hypotheses that must themselves be justified by other data. Traditional empiricism and rationalism that insist on a solution to the problem of induction stands in line with this perspective in that they seek to find the channel to absolute truth. Certainly, a moment's reflection should be sufficient to reveal the futility of trying to show that we have knowledge without presupposing some knowledge (Alston, 2005, p. 7; Giere, 2001, pp. 28-29). What drives this traditional point of view is strong sense of realism understood in terms of the truth of beliefs or hypotheses (Giere, 2001, p. 28). Positive evidence is understood as a firm ground of a hypothesis' being true absolutely. However, a scientific community could be seriously mistaken about the hypotheses it regard possibly true

With the other perspective which is called recently naturalized epistemology, we can determine whether one belief is, for example, grounded on adequate evidence or reasons, by using whatever we take ourselves to know or believe on adequate grounds. The epistemic evaluation will proceed on the assumption that we already have reliable background knowledge that is relevant to it. If we didn't presuppose a background of relevant knowledge, we would be in no position to determine the epistemic status of beliefs.

But beliefs, whether scientific or not, are not assigned probabilities on the framework of Bayesian statistics (Giere, 1988). In case of scientific reasoning, non-Bayesian statistics presents statistical thinking in terms of methods with various (probabilistic) design characteristics (p. 22). The emphasis is on experimental situation. Hypotheses are not assigned probabilities at all, but evaluated by the well groundedness of the results of relevant experimentations. It is not just the data itself, but also the fact that it was generated in a particular way, that makes a hypothesis sufficiently reliable belief. Reaching an epistemic reasoning is not so much a process of logical inference as a process of decision making of an agent with normal epistemic virtues (Giere, 1988). Thus, even if a judgement has positive ground for a particular belief depends on what other hypotheses related are regarded as possibly true, the community could easily end up judging there to be positive evidence for hypotheses that are false. But basing the judgement solely on these two elements reduces the number of sources of mistaken judgements to a minimum. This study assumes that a non-bayesian account of agent with normal virtues in context of naturalized epistemology provides a key element of sound understanding of authentic science and its epistemology for science education.

Furthermore, with reference to science education, there is an even deeper aspect at which the naturalized epistemological framework departs from traditional one. On traditional accounts, it is taken for granted that the basic object of evaluation is a linguistically formulated statement which may be true or false. This viewpoint coincides with everyday reasoning about everyday matters which could cause the commonsense naive realism with regard to scientific knowledge. Within the philosophy of science, however, the nature of structure of theory has been analyzed for more adequate understanding of scientific enterprises, including epistemic evaluation, ontology of theory and scientific inquiry (Giere, 1988; Thagard, 1988).

The traditional account of structure of scientific theories is based on law-statement deductive systems which are, in part, composed of universal generalizations. The major sources of dissatisfaction with the law-statement view not only overlook actual practices of scientists as cognitive agents for constructing knowledge, but also make it difficult to understand the conceptual changes in history of science, and the ontological natures of theories with regard to real world, particularly in modern science of complex systems.

On the other hand, the naturalized account of structure of scientific theories which is based on scientific model has a number of variations. Advocates of these variations all understand statements about predicates such as harmonic oscillators as not being directly about the world at all, but as definition of models, abstract objects whose behavior perfectly satisfies the definitions (Giere, 2001, p. 23). Thus, on model-based understanding of theories, the relationship between statements and the real world is mediated through a model.

On Non-bayesian model-based understanding of science in line with naturalized epistemology of science (Alston, 2005; Giere, 1988), the concept of truth is pragmatic in context-dependence. It represents a picture of science in which progress consists not in falsifications or verifications of theories for absolute truths, but in the construction of models which better fit the real world with greater generality in relevant context.

Rough sketches of two kinds of epistemology of scientific knowledge which guided this study are given in Table 1.

Table 1. A brief comparison between traditional and naturalized epistemology of scientific knowledge

Traditional	Naturalized
Origin of knowledge	
• Scientific knowledge is originated directly from observation and logic. • Theoretical meaning is derived from correspondence rule. • Scientific explanation is given in logico-deductive argument.	• Sense-making of phenomena is not only embodied, but also embedded in a society and historically developed culture • The process of discovery is on model-based abduction in problem solving context.
Ontology of scientific theory	
• Truth value is determined by direct correspondence between theoretical statements and real world events.	• Agents intended to use model to represent a part of real world
Scientific law	
• Scientific law is universal statement. • Theories tested over and over finally attain law status.	• Scientific law is generalization in limited scope. • Scientific law is a kind of model
Aim of science	
• The aim of scientific knowledge is truth.	•The aim of scientific knowledge is problem solving in certain context.
Progress of science	
• Scientific knowledge advances through logical reductive process	• Scientific change can be explained by dialectical process of interaction between human spirits and world in context of STS.
Tentativeness	
• Scientific knowledge is cumulative and unchanging	• The origin and evaluation of theory are dependent on historical context.
Epistemological status of observation	
• Observations are pure direct sensing of reality. • Verification or confirmation is the foundation of meaning.	• Observation is made within the context of modeling on a certain perspective. • Instruments are laden by theoretical perspectives.
Epistemological status of theory	
• Scientific knowledge should be established on doubt-free firm foundation. •Verification and falsification are criteria of demarcation.	• The objectivity and rationality of science should be understood in socio-historical context. • The choice among the alternative theories by scientific community should be explained by non-bayesian decision-making theory.

Based on these epistemological frameworks, this study is concerned with prospective teachers' beliefs about the 8 epistemological aspects of scientific knowledge. It was from the perspective of the pre-service teachers involved in learning epistemological aspects of science on the one hand, and teaching school science as in-service teachers in the future on the other hand, that the central question of this study was developed:

-What are pre-service teachers' beliefs about the epistemology of science?

-On what warrants these beliefs are supported?

2. Methodology of Naturalized Epistemology Framework Development

To investigate pre-service teachers' epistemological understandings, two kinds of surveys, closed and open-ended questions, were developed. In the pilot study, survey questionnaire was developed, administered, reviewed and revised. The final survey questionnaires were administered to pre-service teachers in three different colleges in Korea during main study and analyzed quantitatively and qualitatively. In this section, participants, research instruments, data analysis, and validity and reliability would be described.

2.1 Participants

All the participants of the study were pre-service teachers in three different colleges in Korea. In pilot study, 27 sophomores participated from T university of education which is educating pre-service elementary teachers. Among them eight students volunteered to take part in the interview followed.

In main study, three groups of pre-service teachers participated: 33 freshmen from A university of education, and 20 juniors and seniors from C national university. The students from C national university were pre-service secondary teachers majoring in the area of science or Earth science education. About 20-30% of three colleges were male (Table 2).

Table 2. Participants of the study

Group (Number of participants)	Colleges	method
Pilot study for developing items of frameworks		
Pilot(27)	Sophomores in A University elementary pre-service teacher program	● survey ● interview
	Main study	
A(33)	Freshmen in A University elementary pre-service teacher program	● survey ● open-ended question
C(20)	Juniors or seniors in C University secondary pre-service science teacher program	● survey

Generally, participants of the study were very high achieving students. Because of the high popularity of the teacher education colleges in Korea, most of them had high scores in Scholastic Aptitude Test for College Entrance, a nationwide examination, and high GPA during high school. Participants have taken courses related to science in college. Participants of A university of education were freshmen, and completed few college science courses. Participants of C national university were juniors or seniors. Six of them were physics education majors, five chemistry education, seven biology education, and eleven Earth science education majors. They have had more courses in science compared to those in elementary education programs. All of them participated in survey with questionnaire. However, only 33 students from A university of education also participated survey with open-ended questions.

2.2 Method of Developing Framework Items

Data were collected by two different complementary survey methods, closed questions and open-ended questions. Closed questions were administered to large groups of participants whereas open-ended questions to subsamples of the surveyed group with closed questions. The survey with closed questions was viewed as a way to identify general aspects of the students' epistemological position. A further function of the survey with closed questions was to collect data for exploring the relationships between students' learning experiences and their epistemological beliefs. Finally, the survey with closed questions served as a ground for open-ended written questionnaire on epistemology.

The survey with open-ended questions served for two functions. One was to estimate the face validity and reliability of the closed questions. Another was to elicit the students' the viewpoints on epistemological issues.

2.2.1 Closed Questions

To develop closed and open questions, literatures related to philosophy of science and NOS in science education were reviewed, and two contrasting positions, traditionalism and naturalism, were identified, summarized as described in introduction. Three areas, the nature of scientific knowledge, the objectivity of science, and the rationality of science were established. They were further divided into 8 domains. The nature of scientific theory was sub-divided into four domains: origin of knowledge, ontological nature of theory, nature of law, and aim and role of theory. The objectivity of science area was sub-divided into two domains: objectivity of observation, and the objectivity of theory. The rationality of science was categorized into two domains: progress of science, and tentativeness of scientific knowledge.

At the outset, a pool of 40 statements was developed by reviewing related instruments such as TOUS, NOSS, NSKS, and in particular Waterman (1982). Two contrasting positions were represented by developing nearly the same number of statements in each position. Through the pilot study with 27 sophomores enrolled in earth science course at A university of education, and following in-depth interview with eight volunteers, 33 statements were selected and some of them were rephrased. After the pilot study, the selected statements were reviewed in terms of content validity, grammatical structure, ambiguity, and intelligibility by specialists including two science educators, one vice principal with doctoral degree in chemistry, and one doctoral student in physics. The final version of the closed question survey was made up of 29 statements with 5 point Likert scales: "strongly disagree" to "strongly agree" (1-4), or no opinion, don't know (5).

2.2.2 Open-ended Questions

To investigate to what extent prospective teachers understand some major ideas of naturalized epistemology, open-ended questions were developed. In open-ended questions participants were asked to explain the reasons for or justifications of their answers to the closed questions. As open-ended questions require much time and thinking to the participants, five closed items were selected from 29 items for each participant to answer using a technique similar to matrix sampling (Sirotnik, 1974). Matrix sampling may generally be used when it is not feasible to ask all participants all questions. Sampling is accomplished by drawing random samples from both the examinee pool and from the test items. Participants in this study were not initially sampled randomly. However the test items were randomly assigned to participants. Using this procedure, each item could have 8 to 10 responses.

The open-ended questions used the survey closed items as a way to open discussion about participants' epistemological beliefs. Thirty three freshmen in A university of education, participated. This approach was assumed to lead the participants to show their justifications of choice in more open ways, without either the risk of inducing a particular response or inviting them to digress. Therefore, it is possible afterwards to analyze their senses of words or phrases for significant details and hence to search for various viewpoints.

The results of the open-ended questions were also used for dual purposes: to obtain students' opinions of the survey items, and to assess the validity and reliability of closed items from students' interpretations.

2.3 Data Analysis

Statistical analysis was performed for closed questions. Descriptive and inferential statistics (unpaired t-tests) were used to have a rough idea about pre-service teachers' general epistemological positions and the differences between groups with different backgrounds. SPSS program was used for analysis.

For open-ended questions, hermeneutic analysis was used. As the expected responses for open-ended questions are phrases or extended comments, some form of content analysis is required. The probable plurality of possible meanings (for example, truth) required a special kind of analysis in which many possibilities were explored. So, adding the dimension of interpretation was necessary, with the exposure of the multiple hidden meanings. Hence hermeneutic analysis was needed (Hamlyn, 1987, pp. 229-230).

The researchers' own interpretation of the survey item statements as a means of constructing our own epistemological frameworks of analysis has been needed, in line with two perspectives of epistemology of science, traditional and naturalized, as was sketched roughly in introduction. Bearing those epistemological frameworks in mind, all the responses provided by the participants for item statements were read, trying to clarifying possible meanings of some key terms and expressions. As the closed survey data did not reveal the essence of the responses, the hermeneutic analysis clarified the meanings of many positions, looking for what students really seemed to understand by item statements.

This gave an idea of the degree of awareness the participants had of some important aspects epistemology, and led to the categorizations of the students' responses with respect to the 8 aspects of epistemology. The principal purpose of the analysis was to interpret the sort of respondents' arguments for their epistemological beliefs. This constituted the core of the analysis although some valuable comments have been addressed to the way participants expressed their particular epistemological positions toward two perspectives of epistemology.

Permission to use excerpts from open-ended answer sheet was obtained from all students. Each student's written responses of five survey items were analyzed by item-by-item analysis to get a sense of students' epistemological beliefs in relation to the following questions:

a) Are the items (statements for closed questions) unambiguous, not erroneous, and understandable (for judgement of face validity)?

b) What is the extent of convergence in interpretations (for judgement of reliability)?

c) What beliefs do students in pre-service teacher programs hold on the epistemological aspects?

2.3.1 Validity with a Pilot Study

The face validity of closed question items was estimated by participants' responses to open-ended questions. Students' answers to the open-ended questions were gathered: seven to ten students' answers were collected for each question, and the total of 251 written texts. Some students did not answer all the five items allocated. Or, some students only repeated item content in their writings. Each text was judged in relation to the soundness of the interpretation of the item. In the written texts, a student was either able to give a desirable interpretation of the item or gave evidence of not understanding all or part of the item content allocated. Texts were analyzed on the following criteria for validity evaluation (adapted from Watermann, 1982, p. 76).

+: Gave evidence of understanding the item as intended.

+?: Understood the item, but had to make a decision about a word

-: Had a reasonable interpretation of the meaning of the item, but was different from the intended meaning.

--: Gave evidence of not understanding the item.

Examples of the analysis of open-ended questions are provided in Table 3.

Table 3. Results of analysis of a questionnaire for developing frameworks in a pilot study

Item Number	Item	+	+?	-	--
1	Scientific knowledge is evolving body of concepts and theories	7	2		
2	Scientific knowledge must be discovered through experiment and observation.	8		1	
3	Scientific theory cannot claim more than observational facts on which it is based.	1	2	1	3
4	Scientific knowledge of the real world is created through human spirits.	7	2		
5	The accumulations of facts and proved knowledge compose scientific knowledge.	8			
6	To make sense of observations of natural phenomena, one must have some explanatory ideas.	7		1	
7	Scientific method will eventually let scientists learn the unique truth about the natural world.	4	1		3
8	Scientists should consider only observational facts in sense-making of them, not in need of any theoretical backgrounds.	5	2		2
9	We can never be sure we know the final truth, but it is a goal science to get as good an answer as possible.	7	1		2
10	Theories must be statistically provable in terms of observations.	6	3		
11	Scientific data and observation are objective.	9		1	
12	The ultimate goal of science is to collect all the facts about natural phenomena.	7		1	
13	The interpretation and explanation of data can leads to objective truth.	8			2
14	Scientific inquiry works for supporting theory or hypothesis probabilistically rather than proving it.	2	2	1	3
15	Scientists can build different explanations on the same observational data.	8		1	
16	The theory is rejected once an experiment is not fitted with the prediction of the theory.	8			
17	Experimental data provide accurate information about real world.	3		4	1
18	Theory is composed of proven statements.	8			
19	Scientists' observations are affected by their preconceptions of phenomena being inquired.	8	1		
20	Data are selected by scientist in a sense of his design-making for observing what and how.	8		2	
21	The acceptance or rejection of theory (hypothesis) is dependent only on observational data.	9			
22	Observation is objective, because scientist observes in a mental state of no preconceived idea.	8			
23	Scientific laws are the accurate reports of data.	7		2	
24	New theory is originated through continued interaction between current theory, alternative theories and new observations.	8			
25	Objective observation cannot, in facts, exclude scientists' subjective elements because they see real world with their background knowledge.	8			
26	Science is objective in that theory can be tested by objective observations	8			
27	Theories and models cannot and need not represent the real world exactly for they are products of human mind works.	7		1	
28	Scientific laws are universal statements between natural phenomena.	7	2		
29	The ultimate goal of science is to explain the natural phenomena.	7		3	
Total		198	18	19	16

+: Gave evidence of understanding the item as intended.

+?: Understood the item, but had to make a decision about a word

-: Had a reasonable interpretation of the meaning of the item, but was different from the intended meaning.

--: Gave evidence of not understanding the item.

Among 251 written texts 198 were judged to have desirable interpretation of the survey items. As can be seen in Table3, item3 and item7 were not valid. Based on the whole result, 26 out of 29 items were judged to have face value. These items were excluded from quantitative analysis because nearly half or more of the participants provided responses of misunderstandings about the items.

2.3.2 Reliability from a Pilot Study

To estimate the reliability of the developed Likert-type scale items, the responses of the participants to the open-ended questionnaire were analyzed hermeneutically. The reliability of items is participants' consistency of interpretation. To illustrate the reliability check, a student's written text is shown as an example. The number in parentheses at the end of the written response segment refers to a particular prospective teacher. The following is an example of analysis of reliability.

Item 7. Scientific method will eventually let scientists learn the unique truth about the natural world.

……*It has been said that science will eventually approach God's mind, by researching and proving scientific knowledge such as DNA. So, I am certain that as science develops increasingly more, human reaches the ultimately unique truth of the world which God created.* (α1544)

Interpretation of the item: See the unique truth as God's mind.

Epistemological viewpoint: the item content is absolutely correct. Scientists should necessarily pursue the ultimate truth as God's expression.

The students' interpretations of this item were summarized as follow.

a) Science will approach unique truth. (3/7)

b) There cannot be unique truth (1/7)

c) Unique truth? (3/7)

For this item, one interpretation was not held by most of seven respondents. As can be seen on the students' interpretations of item 7, it is probably not very reliably interpreted. In this way, most of items except 3 items (3, 7, 14) were judged to have sound reliability. For them one interpretation was held by most of the respondents. These interpretations were usually similar to the researchers intended.

3. Research Result

Closed survey questions were aimed to get a first sense of the pre-service teachers' epistemological positions, as well as a rough idea of the trends in changes in those positions over time and with science experiences in their course-works in university. Group mean responses were calculated for each item, excluding items whose validity and reliability were not sound. Qualitative analyses of the responses to open-ended questions were also provided to describe in-depth aspects of the participants' epistemology of science.

3.1 Defining Framework Items through Qualitative Analysis of Pre-service Teachers' Epistemological Beliefs

With closed questions students' epistemological positions could be roughly identified. However, in-depth understanding about epistemological beliefs could be identified with open-ended questions. Pre-service teachers' epistemological beliefs are described in the following areas: a) origin of scientific theory; b) ontological nature of theory; c) scientific law, aim of science; d) ontological nature of theory; e) nature of law, progress of scientific knowledge; f) tentativeness of scientific theory; g) epistemological status of scientific observation; and h) epistemological status of scientific theory.

Table 4. Developed frameworks for naturalized epistemology for the use as a questionnaire

Theme	Item	Classification (N:Naturalized T:Traditional)
Origin of knowledge	2. Scientific knowledge must be discovered through experiment and observation.	T
	3. Scientific theory cannot claim more than observational facts on which it is based.	T
	4. Scientific knowledge of the real world is created through human spirits.	N
Ontology of scientific theory	7. Scientific method will eventually let scientists learn the unique truth about the natural world.	T
	9. We can never be sure we know the final truth, but it is a goal science to get as good an answer as possible.	N
	10. Theories must be statistically provable in terms of observations.	T
	27. Theories and models cannot and need not represent the real world exactly for they are products of human mind works.	N
Scientific law	23. Scientific laws are the accurate reports of data.	T
	28. Scientific laws are universal statements between natural phenomena.	T
Aim of science	12. The ultimate goal of science is to collect all the facts about natural phenomena.	T
	29. The ultimate goal of science is to explain the natural phenomena.	N
Epistemological status of observation	11. Scientific data and observation are objective.	T
	17. Experimental data provide accurate information about real world.	T
	19. Scientists' observations are affected by their preconceptions of phenomena being inquired.	N

	20. Data are selected by scientist in a sense of his design-making for observing what and how.	N
	22. Observation is objective, because scientist observes in a mental state of no preconceived idea.	T
	25. Objective observation cannot, in facts, exclude scientists' subjective elements because they see real world with their background knowledge.	N
Epistemological status of theory	6. To make sense of observations of natural phenomena, one must have some explanatory ideas.	N
	8. Scientists should consider only observational facts in sense-making of them, not in need of any theoretical backgrounds.	T
	13. The interpretation and explanation of data can lead to objective truth.	T
	15. Scientists can build different explanations on the same observational data.	N
	26. Science is objective in that theory can be tested by objective observations	T
Progress of science	14. Scientific inquiry works for supporting theory or hypothesis probabilistically rather than proving it.	N
	16. The theory is rejected once an experiment is not fitted with the prediction of the theory.	T
	18. Theory is composed of proven statements.	T
	21. The acceptance or rejection of theory (hypothesis) is dependent only on observational data.	T
	24. New theory is originated through continued interaction between current theory, alternative theories and new observations.	N
Tentativeness	1. Scientific knowledge is evolving body of concepts and theories	N
	5. The accumulations of facts and proved knowledge compose scientific knowledge.	T

*Item 3, 7 and 14 are eliminated for their low reliability and validity for developing a questionnaire and open-ended questions.

3.1.1 Origin of Scientific Theory

The closed questions in this aspect are concerned with the relations among human beings, scientific knowledge and real world. They ask whether scientific theories are discovered just through observation or invented by human spirits. Three items of 2 and 4 are concerned with the constructive origin of theory. Item 2 reflected traditional epistemology and 4 naturalized.

From the writings to explain or justify their positions about the closed questions, participants' positions on the origin of theory seemed to be warranted by two general themes. Firstly, most students answered these questions from traditional methodology: naive inductivist and hypothetico-deductive methodology.

........It is essential that scientists should generalize scientific knowledge through direct experimental observation. (α1553)

Scientific knowledge is a generalized statement which is arrived by experimental observation on the natural phenomenon. Generalized things should be proven. It doesn't make sense that the intuitional explanation is scientific without experimental observation. F=ma is proven by experiments with strict controlled facts. Scientific knowledge is generalized through observation-hypothesis-experimental control-verification-law sequence. (α1542)

Secondly, a few students seemed to understand the creative nature of scientific theory. They all mentioned importance of imagination and creation of great scientists.

........It seems to me that Einstein's general relativity was created by his imagination. On the same observation, human spirit can create several different hypotheses. According to 'structure of scientific revolution', scientific knowledge have changed on many scientists' different spirits.....(α1537)

3.1.2 Ontological Nature of Theory

The nature of the ontological relationships between statements, models, and the world are important to distinguish between traditional and naturalized epistemology. The problem with the traditional statement approach is that it presumes a direct relationship between statements and the real world expressed in the semantic terms of reference and truth. On a model–based understanding of theories, the relationship between statements and the world is indirect by way of a model (Giere, 2001, p. 21-33).

Four items of 9, 10 and 27 were developed on this aspect. Item 7 and 10 represents traditional epistemology, and 9 and 27 naturalized.

Item 9 is concerned with scientific method and ontological status of its products, and the limits of science. Participants' responses showed various views on ontological nature of theory. A few students responded in the context of metaphysical realism or commonsense realism (Giere, 1988) that scientific theory should pursue the discovery of objective truth of the real world.

I surely agree on this question……They even said they already reached God's domain. That's why I think human could reach ultimate nature that created by God if the science keeps going on development (α1544).

But many students had negative positions toward ultimate metaphysical realism on accounts of the limitations of human faculty of perception (β 1020, β 0701, α1538), the complexity of nature (β 1006), and arrogance of science against God (α1542). Rather, they gave evidence of believing that science advances step by step in Popperian way of verisimilitude.

The nature is of ultimate truth. However, the nature is so complicated that human cannot reach the ultimate truth. Rather, scientific developments are brought about through persevering in scientists' efforts toward more true theories. (α1006)

Several students used different arguments to support some of skepticism toward scientific knowledge on the following grounds: a) Cartesian doubt (β0619); b) problem of induction (α1538); c) falsification of famous theory (α1541); and d) doubt about truth itself (α1536).

If we mistake only one of hundreds of hundreds of observations, we should not argue for truth. Although all observations are correct, how our knowledge can be true. Scientists are just humans. Truth cannot be obtained by induction which is the only scientific method. (α1538)

Items 10 and 27 were designed to determine whether or not the students understood the relation between scientific theory and real world which it represents. In item 10, many students said that scientific knowledge should be proven on repeated experiments (β1030), hypothetic-deductive method (α1545, α1556), mathematical proof (β0480) and induction-deduction method (β0627).

No wonder, theory should be proved. This is the reason for the existence of experiment and enquiry. Hypothesis is not yet proved, but someday it will be proved as truth on observational facts. Ohm' law, theory of evolution, Newtonian theory was proved like this.... (β1030).

But a few students talked about frequent impossibility to prove theory on the ground of limitation of human perception (β1030) and method (α1556), ethical problem (α1545), or religious intervention in science (β1006, α1556).

What we call scientific theory should be established on strict proof... Proof of theory must be achieved by way of being fit exactly with observations. However, ethical problems sometimes prevent scientists from proving the theory on the hypothetico-deductive method of proving (α1545).

On the way theory represents real world, several students shared the attitude of α1531 on item 27:

I agree that theory cannot exactly describe real world.........Even though human sprit cannot describe exactly real world, it should make an effort to reach describe the real world (α1531).

These students took account of incomplete description of real world in terms of human subjectivity (β1007), the limitation of human reasoning (α1531), complexity of nature (β0912, β0906). α1553 expresses a kind of idealism on ontological issue of theory.

As Plato said, we might not see the real world. We are small beings who could only long for real world in mirror of idea world (α1553).

In short, students' responses regarding ontological nature of scientific theory showed follows: a) Scientific theory is a collection of proven statements; b) commonsense realism; c) isomorphism between theory and real world; d) idealism.

3.1.3 Nature of Law

Scientific theories are understood to be sets of statements, at least some of which are laws, which is to say, universal generalizations. A major source of dissatisfaction with law-statement is that claims in modern science typically involve complex systems described in precise mathematical terms. In model-based account of scientific theories, however laws are models which fit designated systems in context of practice (Giere, 2001). Two items of 23 and 28 were developed on this issue. Both reflect traditional epistemology.

In relation to nature of law, many students took account of laws in terms of universal truth which exists objectively in the world which is called commonsense realism, sharing their opinion with α1534.

Scientific law is the essential substance which Creator establish for the workings of the universe. So, scientists should discover these mystical laws. (α1534)

Some students viewed scientific law through logical empiricism of a kind.

....Scientific law is discovered by observing the natural phenomena objectively. Experimenter's value or subjective intervention should be excluded from scientific inquiry.... Scientific law should organize observed phenomena logically (β1179).

Student β1116 responded in perspective of epistemological solipsism in terms of sense data. So, he is skeptic of epistemological status of scientific law.

Most people regard scientific law as objective, clear and absolute. But scientific law cannot objective because law is also perceived by human eyes. ....Each people can perceive color differently in different mental state. Therefore, scientific law is doubtful (β1116).

The last remarkable viewpoint about scientific law was expressed by α1539 which can be interpreted as central model in radial structure of family of models (Giere, 1999, p. 106).

........Scientific law is not stated in consideration of all different variables. So, it needs to represent different things considered to generalize all the cases. For example, the scientific law that water boils at 100℃ is representative of many situations of variability (α1539).

On issue of nature scientific law, students' responses could be analyzed as being made in context of following perspectives: a) commonsense realism; b) traditional empiricism; c) solipsism; d) central model in family of models.

3.1.4 Aim of Science

In naturalized understanding of science, scientists intent to use model to represent a part of the world for the explanations of phenomena and events which bring about understandings in problem solving context. However, in line with traditional lines, truth (or verisimilitude), predictive power, collection of facts were aims of science.

Two items of 12 and 29 were developed on this issue. Item 12 reflects traditional and 29 naturalized epistemology. These items are about goals and values which scientists pursuit. On these items, students' responses were categorized roughly as follows.

To begin with, a few students thought fact-gathering to be ultimate goal of science.

Goal of science is to collect facts about nature. Scientists make a direct discovery or collection of facts about nature in laboratory, outer field or spaceship. (α1539)

Secondary, many students thought the goal of science in contexts of utility for human welfare (α1545, A1534), control of nature (B0926, α1550), satisfaction of human desire (B1030), or convenience of human life (α 1543)

Science is not meaningful without being useful for daily life. Science on its own itself is of no use. (α1543)

Thirdly, 'Explanations of the natural phenomena' appeared in the students' responses to these items.

I think that the ultimate goal of what we call science is to explain the natural phenomena. I think that the ultimate goal of science is to find out the complicated and inscrutable causes and effects behind the everything in the universe.....(β1022).

Fourthly, there were a few students who thought that the goal of science should be regarded both as explanation and utility.

.....By inquiring into the mysteries of nature to understand nomological relations, science should aim to adapt them for human convenience. (α1449)

On issue of goal of science, students' responses could be categorized as follows:

a) fact gathering; b) fact gathering and utility c) explanation of natural phenomena; d) both explanation and utility.

3.1.5 Progress of Scientific Knowledge

In traditional perspective of progress of science, **s**cientific knowledge advances through logical reductive process of accumulating. In naturalized philosophy of science, however, scientific change can be explained by dialectical process of interaction between human spirits and world in context of STS.

Five items of 16, 18, 21, and 24 were written on this issue. Item 24 reflects naturalized and 16, 18, and 21 traditional epistemology.

Several different 'mini-accounts' of progress of scientific knowledge appear in the students responses to item 16. To wit:

..... I learned the 'inductive proof' in math class. Like this, scientific method proves theory through experimentative inductive method....If scientific hypothesis are established on all cases of observation, it become theory. Therefore, theory is rejected once a single experiment is not fitted with prediction of theory. (α1535)

This student' comment is very similar to accounts given in naive inductivism. A few students had idea similar naive falsification method.

Hypothesis should be rejected without hesitation if experimental results are not fitted in the course of hypothesis-prediction- experimental design- information gathering- rejection of hypothesis. Theory is made up of laws. Law is not useless in case of not congruent with a single observation. (β0919)

But many students have a somewhat more sophisticated view of falsification. They disagreed with naive falsification method on the basis of observational factors such as error of data (α1551), failure in control of variables (α1537), complicated properties of nature (β1551). Therefore, their conceptions of progress of science are similar to the idea of the observation-driven changes of theory.

Scientists should always leave open the possibility of mistakes on control of variables. Only following repeated failures of experimental results, hypothesis can be rejected. (α1537)

Meanwhile, somewhat more students talked about social factors such as a scientist of high repute (α1540), funding for science (β0711), and beliefs of majority of scientists (α1544) in relation to falsifications of a scientific hypothesis. But they all regard the factors as affecting on progressiveness of science negatively.

... The matter of whether one hypothesis is accepted or rejected is dependent on the reputation of the relevant scientist.... (α1540)

β0701 was critical of falsification method using the concept of paradigm in context of history of science.

Suppose that a certain theory becomes firmly established as facts and a contemporary scientist finds out new results in contradiction with prediction current theory makes. Notwithstanding these new findings, they are not likely to be accepted.......Paradigm never changes easily.

In connection with item 18, most students had the belief that scientific theory should be proved to be objective truth (α1552), universal truth (β1014), absolute theory (β0380), axiom (β1113) and so on.

If theory is not made up of proved hypothesis, it can not be considered as having scientific status. Theory must be made up of true necessary and sufficient propositions. (β1014)

But α1546 were in a chaotic state between the term 'prove' and historical facts of frequent historical changes of theories.

The proof is essential for scientific knowledge......but as we can see history of science, for example, geo-centric vs. heliocentric theories, proved theory had turned out to be false. I can not understand the term 'proof'. But I think that theory may be proved. (α1546)

On issue of progress of science in relation to item 16 and 18, students' responses could be categorized as follows: a) naive inductivism; b) naive falsificationism; c) commonsense realism; d) critics of falsification from paradigm concept.

In case of item 21, most students thought new observation to be the most important factor in growth of scientific knowledge. Furthermore, they considered various human factors, such as scientist's subjectivity (α1544), belief (α1016), cultural climate (βB0919), social condition (β1113, α1550), powerful theory (α1548), famous scientist (β0727) as having negative effects on scientists' decision-making in accepting theories.

Acceptance or rejection of theory should be dependent on objective reasonable data. But scientist as a person could be influenced by distortions of social conditions or beliefs. (β1113)

These ideas also appeared in case of item 24. Most students had a narrow point of view that science makes gradual progress owing to falsification on new observations.

I think scientific theory interacts with observation through stages of observation-hypothesis-test-revision or rejection (α1543).

α1555 recognized the importance of the ideas in the course of scientific advancement.

Scientists have an idea before observing. For example, think about Galileo's thought experiment. Galileo proposed a law of inertia through idea without observational data. Science makes progresses rather by idea than data. (α1555)

On issue of progress of science in relation to item 21 and 24, students' responses could be categorized as follows: a) decisive role of observation in progress of science; b) method of observation- hypothesis-test-revision or reject; c) negative effects of various social and personal factors on theory choice; d) importance of idea in growth of knowledge.

3.1.6 Tentativeness of Scientific Theory

In traditional perspective of science, scientific progresses are brought about by reduction and accumulation. In naturalized perspective, the origin and evaluation of theory are dependent on historical context which sometimes bring about scientific revolution.

Two items of 1 and 5 were written on this issue of conceptual changes. Item 1 reflects naturalized epistemology and 5 traditional.

In reference to item 5, most students have the same way of thinking along with the naive inductivism or positivism. They made a judgement of scientific knowledge in connections with objectivity (α1554), accuracy (α1549), fact (α1538), objective truth (β1179), verification (α1162).

Scientific knowledge is made up of curricular contents which students learn in school. Scientific knowledge is discovered directly from experiments, observations, inquiry.. .... Knowledges should be proved and verified. These are just the facts we learn. (α1538)

A few students like β0380 made their position of skepticism in context of history of science.

.....The scientific knowledge which we had thought to be correct turned out

to be mistake because of new results of experiment.....As we can see historical change from geo-centric to helio-centric theory of universe, scientific knowledge can not verified because of continuous change with age. (β0380)

β0919 took his stand on probability on confirmation of scientific knowledge.

Creationism, Evolutionism and Big-Bang theory cannot be proved. Like this, even if it is not proved, it can be scientific knowledge. Probability, not proof, should be considered to be ground for scientific knowledge.

In contrast to responses to item 1, most students understood well the changing nature of scientific knowledge in context of item 1. They understood theory changes approximately in the following five contexts: a) history of science (geo-centric vs. helio-centric theory: α1560,α1554; earth's shape; β0923; atomism: β0906); b) new observational evidence (α1537, β0727); c) method of falsification (β0923, α 1557; d) limitation of human capability ; e) changing nature of world itself.

Scientific knowledge has changed until now through new experiment or enquiry. ......Therefore, scientific knowledge is not determined absolutely but change. For example, People believed in geo-centric theory instead of helio-centric until Copernicus. .....As continuous observational evidences were discovered, scientific knowledges have enough possibility of changing. (α1560)

But a few held the view of invariability of scientific knowledge.

Almost all of scientific knowledge are established through endless experiments and proofs. So, scientific knowledge cannot change in itself because of its status of proof. (α1547).

On issue of tentativeness of scientific knowledge in relation to item 1 and 5, students' responses could be categorized as follows: a) objectivity, accuracy, truth, invariability of scientific knowledge in context of H-D method; b) tentativeness in perspectives of history of science and falsificationism method; c) limitation of human perception; d) the evolution of nature itself; e) eternal everlasting truth of scientific knowledge.

3.1.7 Epistemological Status of Scientific Observation

In traditional perspective, verification or confirmation is the foundation of meaning.

Observations are pure direct sensing of reality. In naturalized epistemology, however, observation is made within the context of modeling on a certain perspective. Experimental instruments are also laden by theoretical perspectives. Six items of 11, 17, 19, 20, 22, and 25 were written on this issue. These items and the general epistemological views they reflect are item 11, 17 and 22 represent traditional and 19, 20, and 25 naturalized.

11. Scientific data and observation are objective. (T)

With respect to these items, students' responses were classified as following four ideas, being based on the characteristics of how subjectivity intervenes into observing: Firstly, observation should be objective; Secondary, observation should be objective, but actually is not frequently because of many factors. So scientists should try to be objective as possible as they can; Thirdly, observation can be objective but its interpretations can not be objective; Fourthly, observation is inter-subjectively objective; Fifthly, observation can never be objective.

First idea was seemed to be derived from typical naive inductivism among many students.

Observation means to see the real world as it is. So, science is trustworthy. Misconduct of doctor Whang is the result of disregarding this point. (α1545)

A little more students blamed the failure of objective observation on such factors as background knowledge (β6013, α1536), bias(α1546, α1548, β0925), authority (β0916), prejudice(β0920, α1547, β0920), value(α1542), shortage of discipline, religion(β0609).

Data and observation should be objective. But they are not often the case because scientist's philosophical prejudice intervenes. For example, scientists who believe in geo-centric universe could not observe earth's revolution because of their prejudice. So, it was proved to be false. (β0925)

A few students held the view that observation must objective but its interpretation is subjective, in line with logical empiricism.

Lastly, β1552 argued for actively subjectivity of observation.

Certainly, scientist can not exclude his subjective elements in every case.....Scientist's own background knowledges have been accumulated in paradigm, so his subjective cognitive resources is needed to break up fixed ideas. Paradigm can be broken only by his own idea. (β1552)

On issue of epistemological status of scientific observation in relation to item 11, 17, 19, 20, 22 and 25, students' responses could be categorized as follows: a) naive inductivism; b) observation should be objective, but interpretations are subjective; c) objective observation is impossible because of limitation of human perception; d) positive role of subjective observation; e) advocate of inter-subjectivity of observation.

3.1.8 Epistemological Status of Scientific Theory

In traditional perspective, scientific knowledge should be established on doubt-free firm foundation. Verification, confirmation, and falsification are criteria of demarcation. But, in naturalized philosophy of science, the objectivity and rationality of science should be understood in socio-historical context. The choice among the alternative theories by scientific community should be explained by non-bayesian decision-making theory.

Six items of 6, 8, 13, 15, and 26 were written on this issue. Item 6 and 15 represent naturalized, and 8, 13, and 26 traditional epistemology.

First of all, it is notable that students had a good understanding of subjective aspects of scientific enterprise, in context of questions with regard to item 15 and 20 which include scientists explicitly. But in the remaining items which does not include scientist explicitly, students were considering the relation between theory and observation in perspectives of naive empiricism, as can be seen in graphs of quantitative analysis.

Firstly, most students could have a good understanding that data could be interpreted in many ways, on the basis of theories (α1539, α532, β0926, etc.), hypothesis (β1014, β0726, β546), novel ideas (α1551, α1532, β0905), fundamental knowledge (α1553), imagination (β0916).

It is said that one can see as much as he can think. More one can see, more he experiences. Like this, scientists observe in light of their own experiences. (β 1015)

Secondly, a few students thought that the interpretations of data should be objective.

Science can stand only on objective interpretations of observations. Otherwise, science can not reach truth. (β0727)

Thirdly, some students had the idea that scientists should take precautions against the often subjective interventions such as human opinions(β1007), bias(β 1012) which make the scientific theory not to be true.

....If the observer's subjective opinions intervene the process of interpreting data, scientific theory turns out to be false. This is the case with doctor Whang.......(β1012)

Fourthly, some students argued that observation in itself should be objective but after observing, scientists often need to draw on background knowledge for generating hypothesis (β2016), getting more certain knowledge (β0701), for explaining hidden causes (β0908).

In my opinion, objective observation in itself is objective fact, which needs theory to explain its depths more accurately.......(β0907)

Fifthly, β0920 and β1015 propose an issue of epistemology of activities of observing in context of scientific inquiry, which leads to theory-ladeness.

I am certain that theoretical, conceptual backgrounds are needed for sense-making of all things......If it were not for preconceptions, scientists could not make sense of the objects they see. In these cases, they feel only obscure situations..... (β1015)

Lastly, β1007 and α1549 understood a kind of contextual objectivity using historical episode.

I think that generally most new theories are tested in context of contemporary accepted objective theories. Although present theories can be falsified in the future, they are at least objective theories in present time on basis of contemporary criteria. (α1549)

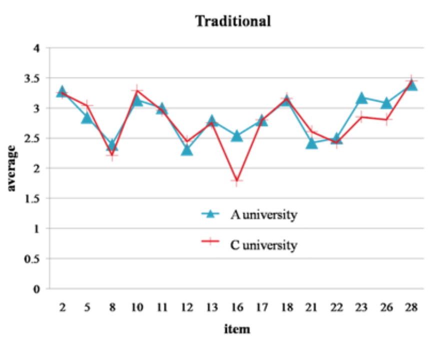
On issue of epistemological status of scientific theory in relation to item 6, 8, 13, 15, 20 and 26, students' responses could be categorized as follows: a)arguing in perspective of naive inductivism; b) arguing for objectivity from hypothetico-deductive method ; c) arguing for objective observations but against objective hypotheses; d) arguing for subjective theory from observational nature of theory-ladeness; e) arguing for a kind of contextual objectivity on the basis of historical episode of science.

3.2 Case of Analyzing Pre-service Teachers' Epistemological Beliefs with the Proposed Framework

The developed framework through the pilot study and open-ended questions were finalized with 26 items except item 3, 7, and 14. This framework was used as a questionnaire administered for two groups of pre-service teachers participants in this study. The questionnaire used Likert scale with a full point of 4.: 4 is ‘very much agree with the given statement’, 3 is ‘agree’, 2 is ‘not disagree, 1 is ‘very much disagree’ and 0 is ‘no idea’. The items were categorized by epistemological viewpoints: traditional vs. naturalized.

3.2.1 Comparison of Epistemological Beliefs between Elementary and Secondary Pre-service Teachers

The comparison between freshmen of A university of education and juniors or seniors of C national university is presented in Figure 2 for traditional content items and for traditional items.



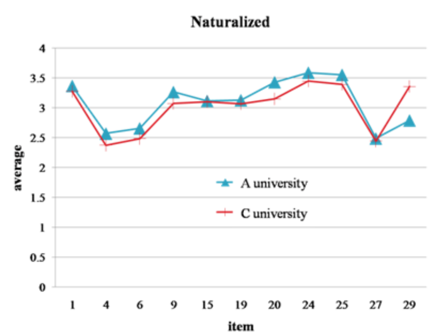


Figure 2. Comparison of Epistemological Beliefs between Elementary and Secondary Pre-service

The result of t-test is presented in Table 5.

Table 5. T-test Results of Epistemological Beliefs between Two Elementary Pre-service Teacher Groups

Epistemological beliefs	Group (N)	Mean Total(sd) Mean Scale	df	t-value	P value
Naturalized (11 items)	A(33)	33.64(3.04) 3.06	51	1.006	.319
	C(20)	32.80(2.75) 2.98			
Traditional (15items)	A(33)	42.7(5.78) 2.85	51	.340	.735
	C(20)	42.3(3.06) 2.82			

This analysis shows that the difference between two groups of elementary and secondary pre-service teachers are not significant in terms of both of traditional and naturalized view points as can be seen from Table 5. Both group showed more tendency toward naturalized epistemology.

Although the secondary pre-service teachers have even more science courses than the elementary pre-service teachers, their understanding of nature of scientific knowledge are shown to be very similar in both traditional and naturalized approaches. Little difference except two items (16, 29) is found among two groups in spite of their differences in science courses taken in college.

In cases of 16 and 29 items, which express naïve falsificationism and the aim of science respectively, it is notable that secondary pre-service teachers have strikingly different viewpoints than their elementary counterparts. Interviews with several participants from C national university after survey informed that the earth science education major students (11 students) learned about Lakatosian research program in criticism of Popperian falsificationist epistemology just one week earlier in their course of 'introduction to science education'. In case of item 29, secondary pre-service teachers' experiences in science rather than engineering in university might enable them to understand the aim of science which is the explanation, rather than utility or welfare for human beings.

One of the most outstanding features of students' responses is concerned with epistemological nature of scientific observation on items 20, 24, 25, 11. On first three of these items in which scientist are explicitly stated in naturalized items, all of the three groups got good marks averaged above 3. That is, students of all groups have right understanding of theory-laden nature of observation. But on the last item, item 11, which asks simply, without explicitly stating scientist, whether observation is theory-independently objective, all of the three groups have poor scores on the nature of observation. This evidence of variability shows that students' epistemological beliefs about scientific observation are not stable features of their understanding but variable with context.

In sum, the quantitative analyses of two pre-service teachers' groups of participants show that their science course experiences and other course experiences in college curriculum have hardly influence upon the understanding of epistemological nature of scientific knowledge.

3.2.2 Summary of Pre-service Teachers' Epistemological Beliefs

As viewed in analyses of participants' responses on each item with regard to epistemological issues of scientific knowledge, pre-service teachers' beliefs could be summarized. By and large, many students understood the substantive structure of science in line with nomological statement-view of theory and its commonsense realism on warrants of naïve empiricism, including naive inductivism and H-D methodology. Significantly, experiments are considered mainly in context of justification rather than in that of discovery in line with positivists. Students sometimes seemed to use carefully selected elements of historical episodes to reinforce their "inadequate" epistemology.

Students' typical descriptions of science have the following characteristics: ① scientific knowledge was regarded as facts being discovered through "the" scientific method or algorithmic procedures which lead to the truth about the real world, with the ground of scientific knowledge being derived from objective observation, experimental verification by objective scientists who are rational, logical, disinterested, value-free Bayesians; ② students' viewpoints are characterized by single-minded obsession with hypothesis (theory) and confirmation, at the expense of intervention and action and experiment in context of discovery; ③ science is thought to be rational, and demarcated from other disciplines because of its being based on objective observations and objective method of inductivism and H-D method, ands students don't have epistemological awareness of the methodological topic of H-D; ④ Scientific knowledge constitutes true or approximately true knowledge of the real world, which means many pre-service teachers' epistemological conceptions of science were almost in line with common sense realism or objective realism, based on methodologically naive inductivism and H-D method; ⑤ Science should serve to human welfares which students think are brought about from the truthfulness of scientific knowledge; ⑥ Historical episodes in changes of scientific theories can be easily misinterpreted by some students in terms of relativism or skepticism; ⑦ Almost all students could not clarify the meaning of and relations between some naturalized concepts of epistemology, such as creativity, tentativeness, subjectivity, confirmation, rationality, scientific progress, sociocultural embeddedness of science.

But, a few pre-service teachers hold views that incorporate a diversity of elements drawn from more than one philosophical position depending on contexts under consideration. For example, inductivists in methodology tend to be rationalist on demarcation, but relativists on interpretation of history of science.

In addition, although many pre-service teachers could understand theory-dependent nature of observation, their epistemological conceptions did not reach, as a whole, the constructivist understanding of the rationality and objectivity of science. Rather, subjective nature of human perception led a few students to relativism and skepticism of scientific knowledge.

4. Discussions and Epilogue

The purpose of the study is to investigate pre-service teachers' epistemological beliefs against naturalized position of epistemology. Major findings were as follows.

First of all, irrespective of science experiences in their science courses in university most of pre-service teachers seemed not to understand explicitly the aspects of complicated recursive construction of scientific knowledge. That is, their epistemological understandings of traditional inductutivist viewpoint and hypothetico-deductivist method could be said to be very inadequate because scientists don't simply begin with data and then move to theories, but are involved in a continuous loop of data collection and theory formation. These results are thought to be derived from pre-service teachers' philosophical and logical inclinations toward scientific knowledge as a representation of the real world which is similar to logical empiricism rather than toward interpreting science in standpoints of scientific practices which have cognitive, historical, and social dimensions of knowledge construction. Accordingly, their understanding of epistemological aspects of scientific knowledge are restricted to superficial logical dimensions, and so they could not consider their dialectical and critical dimensions of scientific knowledge by practitioners in scientific community. Indeed, to increase students' understanding of important epistemological aspects of scientific knowledge, it should be advised to be concerned with existential authentic situations in which scientists might actually do rather than with scientific method. For this study show that students' arguments for the epistemological aspects are mainly warranted on nearly algorithmic steps (e.g. observing-hypothesizing-controlling of variables-testing-verification or confirmation-law), tending to obscure the complexities and limitations of scientific research and scientific knowledge.

In addition, pre-service teachers' epistemological conceptions were normative rather than descriptive. They conflated contexts of discovery and justification by fettering strict inductive shackles on hypothesis formations all along, in neglect of human creation of reasoning. In these outlooks, they command a view of history of science and demarcate science and non-science Therefore, it seems to them that science advances toward truth in a cumulative way from hypothesis to theory and to law step by step. In short, pre-service teachers thought that objective evidences are always over there in nature and nature, as exists in itself, is the bedrocks of discovery for order, harmony and law.

In this context, unsophisticated epistemological conception-based curriculums and teaching on them could be thought to bring about the epistemological flatness of 'rhetorical conclusion' in science educational outcomes. This is shown by little differences in epistemological conceptions between students of C college of education and students of A university of education who have very different learning experiences of science coursework in schools and colleges.

These findings lead to the suggestions that science education should include appropriate epistemology as preconditions for the students' understanding of science. When students with substantial exposure to traditional views of epistemology and ontology of science are presented with a school science curriculum, they may experience great difficulty in understanding of authentic science which is required for critical scientific literacy.

Understanding substantive and syntactical structure of science could be inhibited not so much by the cognitive demand of the learning task as by the discomfort caused by some of the epistemological features of science, features that are often exaggerated and distorted by school science compound of commonsense realism, naive empiricism, credulous experimentation, excessive objectivity and rationalism based on it. These situations can be interpreted by the phenomenon what Kuhn called "the invisibility of revolutions" in the textbooks which inevitably disguise not only the role but also the very existence of revolutions. This may be grounds of students' own sense-making of epistemology of science: data should be objective, explanations should be logically or disinterestedly derived from data, so explanations become absolute conclusions, science should be presented as truth.

Although the notion of science as objective truth would be doubtful on naturalized philosophical grounds of all kinds, this particular myth still are thought to play a central role in science education across of all level of schools. Although not all students will internalize all the distortions of image of science in the courses of their school lives, this study shows that there is ample evidence that many students, including pre-service teachers, do leave their high schools and colleges with deficient understanding of epistemology of science, scientists and scientific practice.

It is important that science curriculum should achieve a sensible balance between the view that science is absolute truth, ascertained by using entirely the objective algorithmic method, and relativist view that "scientific truth" is any view that happens to change with time. Furthermore, it should be aware of students' skepticism of scientific knowledge which results from their understanding of subjectiveness of human perceptions and historical changes of scientific theories.

From a pedagogical perspective, reconstructing of theories in terms of their confirmations as an explicit argument could be too easily lead to a epistemological flatness contributing little to the student's ability to evaluate epistemic status of theories.

In conclusion, as progress toward epistemic abilities and epistemological understanding for all students are certainly determined by teachers themselves adopting a more realistic and authentic view of science, this study suggests that science curriculums for pre-service and in–service teacher training institutions should introduce all aspects of the findings of naturalized philosophy of science which explores not only the substantive and syntactical nature of scientific knowledge, but also language of science on the basis of cognitive sciences, philosophy of science, history of science, sociology of science.

Cleary, teachers will not incorporate epistemology-oriented teaching unless they understand and believe it to be important. Despite some efforts of science educators over the past decade to promote the nature of science in Korea, this study shows that substantial number of pre-service teachers remain inadequate. Clearly, much more needs to be done in this regard. Both of pre-service and in-service teachers need support in their epistemological understanding and translating it into coherent teaching strategies and effective classroom activities across all sorts of teacher training institutions.

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