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Characterizing Naturalized Epistemology of Science Possessed by Korean Pre-Service Elementary Teachers

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Abstract

This study aimed at exploring how pre-service teachers possessed naturalized epistemology of science. The epistemology of science has been major topics of investigation in science education research targeting pre-service and in-service teacher education. How science works including scientific investigation for achieving science knowledge was well known item in school science. The role of scientific epistemology would play in science classroom. Therefore improving teachers' perspectives and designing advanced teaching-learning sequences along them have been substantial parts of the science education reform. Such efforts have been active when a new epistemological position emerged such as naturalized epistemology. Through this research Korean pre-service teachers' understanding of the naturalized epistemology was explored. The questionnaire to explore pre-service teachers' epistemological beliefs was adopted majorly focusing on naturalized epistemology of science knowledge. They were administrated to forty per-service elementary teachers. The questionnaire is composed of items using a Likert scale. According to the finding, Korean elementary teacher candidates in this study had more agreement for naturalized epistemology than for traditional one.

Keywords: Science inquiry; School science; Naturalized epistemology of science.

1. Introduction

The new era, called, the fourth industrial revolution, already begins as we agree on that the science fiction of yesterday is today becoming a reality in new products and services that we won’t be able to imagine having lived without. The technologies driving the fourth industrial revolution will fundamentally transform the entire structure of our communities and our human identities (Schwab, 2016). These profound changes highlight the great responsibilities we face as civilization. It will be the upcoming challenge to educators. We need school education program for better and happier citizens who currently are students satisfied with their life as self-esteemed and self-motivated learners as well as active learning community members.

In our classroom of science, students’ memorizing scientific words are frequently taking place still. Most of us, however, believe in doing science is more like the skillful exercise of a repertoire of ‘craft skills’ than the following of an algorithm as Polanyi (1958) and Ravetz (1971) asserted. In teaching children science, we are helping them to internalize the procedures and standards of scientific community. We are again assisting the child to construct for herself a mental representation of the scientific ways of working judging (Millar, 1989). It is because the training of scientists involves the process of coming to internalize these tacit canons of procedure and judgment.

Early back in 1926, Bobbitt (1926) described the importance of training students not only to reproduce facts but, more importantly, to develop the power to think in relation to the world's activities. Here 'the training' means scientific inquiry or scientific practice where students develop their knowledge about the nature of science. It will be more important for their teachers to have such training in order to train students in that way.

Resent works of activity theory view students in classroom not as the foundational agent. Rather source of change would be more resulted from social constitution and institutional embeddedness of agency (Engestrom, 2005). It will be used for validating why pre-service teachers’ perception of modern understanding of scientific epistemology had better be analyzed. In the science classroom, teachers would play an important role for interagency and their perception will affect or interplay with students’ capital. In this study, elementary teacher candidates’ view of naturalized epistemology was collected and characterized.

1.1. Theoretical Framework

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 (Song *et al.*, 2015). 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).

Using the developed epistemological framework, this study is concerned with prospective teachers' beliefs about the 8 epistemological aspects of scientific knowledge. The centralresearchquestion in this study is what pre-service elementary teachers' beliefs about the epistemology of science are.

2. Method

2.1. Research Context

This study occurred in the elementary science methods course for 40 junior year students of pre-service teacher education university. During the coursework, argument-based and open-ended inquiries were adapted for students' activities. It consists of seven sections to guide activities including beginning ideas, tests, observations, claims, evidence, reading, and reflection.

A lecturer provided materials and let students do their own inquiry from generating questions to claims. Most experiment materials were from elementary science textbooks. The 40 subject pre-service teachers worked with science investigation tasks from elementary science textbooks. The following is an example of them.

Task:Heavy Air?

Rubber balloons, electronic weighing scales, and 500mL plastic bottles with air compress caps were given to each group of students. Groups of students decide on the hypothesis including variables while they make one testable inquiry question tested only with using given materials and equipment. Most cases are to use a bottle with air compress caps. It is very typical experiment in elementary level science. After finishing the experiment, they collected and interpreted data in order to reach their own scientific claims. Even though all the group of students used the same given materials, each group had its own different inquiry question and hypothesis. Most groups reached the different scientific claims. After the whole inquiry, groups participated in the presentation of their own results and discussion with argument.

Such open inquiries were implemented in the whole semester. At the end of semester, participant pre-service teachers were administered the prepared epistemological belief questionnaire developed in this study.

3. Data Collection

In order to investigate the naturalized epistemology of science, the questionnaire of Frameworks for Naturalized Epistemology(FNE) was adopted. Itdescribes the scientific epistemology 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. The FNE has the full point of four: 1. Strongly disagree, 2.Disagree, 3.Agree, and 4. Strongly agree. More than a point of 3 means having agreement on the item.

Table 1.A Frameworks for Naturalized Epistemology (FNE) for the Use as a Questionnaire (Song *et al.*, 2015).

Theme	**Item**	**Classification N:Naturalized T:Traditional**
Origin of knowledge	1. Scientific knowledge must be discovered through experiment and observation.	T
	2. Scientific knowledge of the real world is created through human spirits.	N
Ontology of scientific theory	3. 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
	4. Theories must be statistically provable in terms of observations.	T
	5. Theories and models cannot and need not represent the real world exactly for they are products of human mind works.	N
Scientific law	6. Scientific laws are the accurate reports of data.	T
	7. Scientific laws are universal statements between natural phenomena.	T
Aim of science	8. The ultimate goal of science is to collect all the facts about natural phenomena.	T
	9. The ultimate goal of science is to explain the natural phenomena.	N
Epistemological status of observation	10. Scientific data and observation are objective.	T
	11. Experimental data provide accurate information about real world.	T
	12. Scientists' observations are affected by their preconceptions of phenomena being inquired.	N
	13. Data are selected by scientist in a sense of his design-making for observing what and how.	N
	14. Observation is objective, because scientist observes in a mental state of no preconceived idea.	T
	15. Objective observation cannot, in facts, exclude scientists' subjective elements because they see real world with their background knowledge.	N
Epistemological status of theory	16. To make sense of observations of natural phenomena, one must have some explanatory ideas.	N
	17.Scientists should consider only observational facts in sense-making of them, not in need of any theoretical backgrounds.	T
	18. The interpretation and explanation of data can lead to objective truth.	T
	19. Scientists can build different explanations on the same observational data.	N
	20. Science is objective in that theory can be tested by objective observations	T
Progress of science	21. The theory is rejected once an experiment is not fitted with the prediction of the theory.	T
	22. Theory is composed of proven statements.	T
	23. 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	25. Scientific knowledge is evolving body of concepts and theories	N
	26. The accumulations of facts and proved knowledge compose scientific knowledge.	T

After the coursework with open-inquiry practices, the FNE was administered to 40 subject pre-service teachers.

4. Results and Discussion

The forty pre-service teachers' view on the naturalized epistemology was briefly described as Table 2 and Figure 1. The results were summarized with dividing into two of traditional and naturalized epistemology.

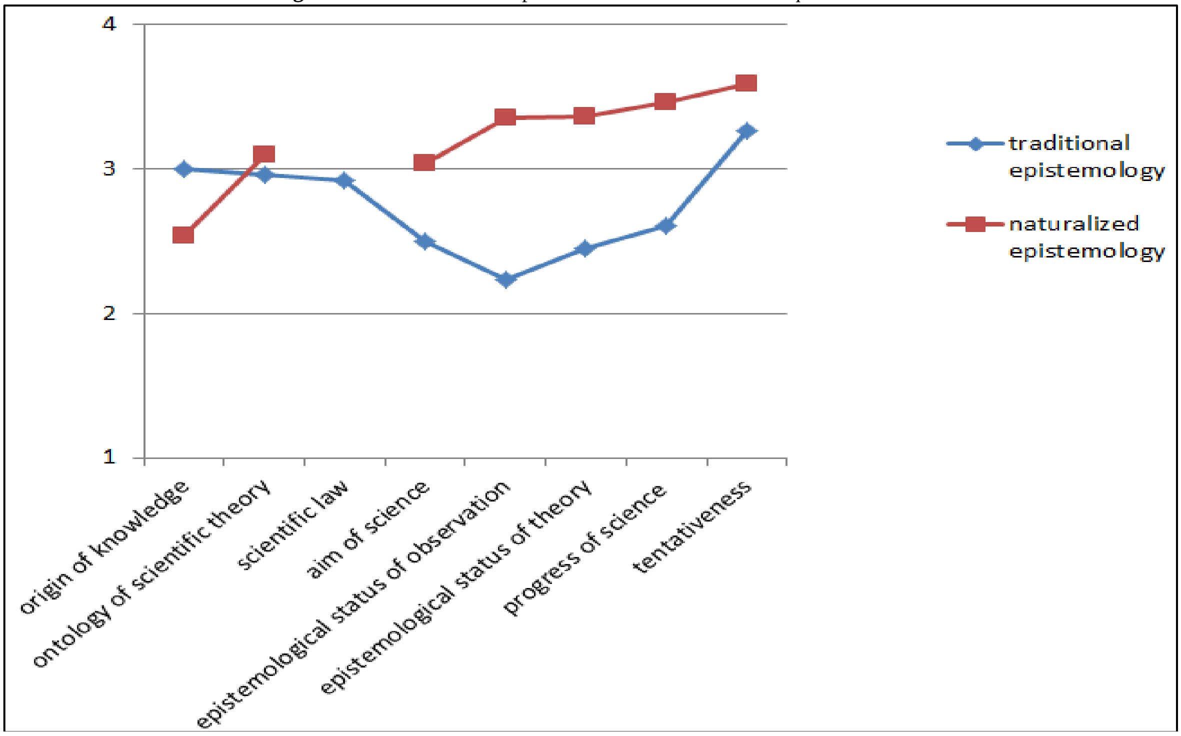
Table 2. FNE results of Korean pre-service teachers according to its sub-category(n=40).

	Origin of knowledge	Ontology of scientific theory	Scientific law	Aim of science	Epistemological status of observation	Epistemological status of theory	Progress of science	Tentativeness
Traditional Epistemology	3*	2.96	2.92	2.5	2.23	2.45	2.61	3.27
Naturalized Epistemology	2.54	3.1	-	3.1	3.04	3.35	3.46	3.59

*Bolded letter means agreements (more than 3) on the statement of the question item.

Korean elementary teacher candidates in this study had more agreement for naturalized epistemology in the most categories except Origin of knowledge. At the same time, a dual status of traditional and naturalized epistemology was found in the category of Tentativeness. Referring to Song (2011), 33 pre-service elementary teachers were analyzed in epistemological perspectives. They revealed mostly realist with naive inductivist view and positivism. They showed naive realist perspective in nature of science and used objective evidences to assist truth of scientific knowledge in epistemological aspects. It is interpreted as they don't view science experiments in school as testing their own questions. Pre-service teacher participants in this study answered the questionnaire after experiencing open-ended inquires including '*Task:Heavy Air?*'. Therefore this type of inquiry approach might well affect their epistemological beliefs. More open inquiry might intrigue them to move toward naturalized epistemology.

Figure-1. Results of Korean pre-service teachers from FNE questionnaire



Pre-service teachers' typical descriptions of science have the following characteristics. Firstly regarding the category of Origin of knowledge, traditional epistemology was more agreed while naturalized one was dis-agreed by participant subjects. 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.

Secondly for the ontology of scientific theory and the tentativeness, there seemed to be dual perspectives of traditional and naturalized epistemology. Their viewpoints on ontology of theorywere characterized by single-minded obsession with hypothesis and confirmation, at the expense of intervention and action and experiment in context of discovery. Regarding the category of tentativeness, scientific knowledge was believed as evolving body of concepts and theories by participants. At the same time they believed that scientific knowledge is composed with accumulated facts and proved knowledge.

Toward scientific law, there was found the little bit of traditional epistemology. Science is thought to be rational, and demarcated from other disciplines because of its being based on objective observations and objective method of inductivism.

The category of Aim of science showed participants' disagreement on traditional epistemology and their agreement on naturalized. They believed that the ultimate goal of science is not the accurate report of data, but universal statements between natural phenomena.

The other categories of Epistemological status of status of observation, the epistemological status of theory, and progress of science indicated participants agreement on naturalized and disagreement on traditional epistemology, too. 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.

Science should serve to human welfares which students think are brought about from the truthfulness of scientific knowledge. Historical episodes in changes of scientific theories can be easily misinterpreted by some students in terms of relativism or skepticism. 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.

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.

5. Concluding Remarks

While nature of science cares for the expert views of science, individuals have their own belief systems regarding how scientific knowledge is constructed and evaluated in the boundary of personal epistemology (Baxter-Magolda, 2004; King and Kitchener, 1994). 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 (Song *et al.*, 2015).

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 (Duschl, 1983; Kichawen *et al.*, 2004). Furthermore, teachers' views on epistemology might be passed onto students via education (De Medeiros, 1993). Indeed, scientific literacy is an important goal of science education. One component of scientific literacy is an understanding of the substantive and syntactical structure of science (Hodson, 2009).

As viewed in analyses of participants'responses on each item with regard to epistemological issues of scientific knowledge, pre-service teachers' beliefs could besummarized. 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. 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.

Currently, science education stresses the importance of students developing a deep understanding of core scientific knowledge and the methods of science in the name of scientific inquiry (Chiappetta, 2007). The learning there must encourage students to think and talk more like scientists. Teaching science as inquiry can be supported and complemented by other types ofinstruction in which investigative skills are refined, the applications of scienceare stressed, and the epistemology of science discussed.Planning for this type of curriculum can also address students' needsand interests, perhaps better than a course of study centering primarily on thedevelopment of fundamental concepts and principles. In order to do that, epistemological understanding of science should be possessed by teachers. In other words, such curriculum can be executed only with qualified teachers. Based on this study, pre-service teachers in Korea seem to have more agreement on naturalized epistemology of science. Intentional inception of epistemology of science in teacher education program as well as elementary science curriculum would be the following action for better teaching and learning outcome in school science inquiry.

The challenge has never been greater for elementary school science teachers tounderstand, plan, and implement the science-as-inquiry approach—an approachthat attempts to assimilate epistemological framework of science while accommodating the pressures of 4^{th} industrial revolution of future society.

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