Jour. Korean Earth Science Society, v. 23, no. 2, p. 140–146, January 2002

Pre-service Teachers' Conceptions of the Nature of Science

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Abstract: We have studied 73 pre-service science teachers' conceptions about the nature of science (NOS) using 120 true-false test items based on AAAS Benchmarks statements. We have found that participants have inadequate understanding of the NOS, especially in understanding of five categories of conceptions; change and continuity in science, bias in scientific investigations, hypothesis in scientific investigations, things common in science, and science ethics. The result also indicates that there is a difference between primary pre-service teachers and secondary pre-service teachers. From the analysis of consistency, we also found that this inadequate understanding comes from confusion rather than misconception. All the results support that there is a need of intense pre-service teacher education concerning thenature of science.

Key words: Nature of Science (NOS), NOS Conceptions of pre-service teachers NOS misconceptions, inconsistency

INTRODUCTION

The nature of science (NOS) has long been recognized as one of the important goals of science literacy. Although there is no single, preferred definition of the NOS, the general consensus at a certain level about the NOS was established among researchers (Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Akerson *et al.*, 2000; McComas *et al.*, 1998).

This general consensus is also believed to be accessible to pre-college students (Akerson *et al.*, 2000) and it has been included into various science standard documents such as Benchmarks for Science Literacy (AAAS, 1993) and National Science Education Standards (NRC, 1996). McComas and Olson (1998)'s comparative study of international science education standards documents showed it well.

In spite of such a long history and emphasis, however, lots of researchers have repeatedly reported that both students and teachers have inadequate understanding about the NOS (Lederman, 1992; Lederman *et al.*, 1998; Murcia & Schibeci, 1999).

Teachers' conceptions of the NOS is considered to be an important factor for students' conceptions of the NOS, because teachers can not properly teach anything that they do not understand.

For that matter, investigations about the teachers' conceptions of the NOS and efforts trying to improve it were made by many researchers (Kimball, 1968; McComas et al., 1998; Murcia & Shibeci, 1999; Lederman & Zeidler, 1987).

And the significance of the pre-service teacher education has incessantly been emphasized as well as the value of information about their conceptions of the NOS.

Many investigations trying to find out pre-service teachers' conceptions of NOS were focused on secondary teachers (Koulaidis & Ogborn, 1995; King, 1991; Aguirre *et al.*, 1990). In addition to them, there have also been several studies which investigated primary pre-service teachers' conceptions of the NOS (Bloom, 1989; Abell & Smith, 1994; Murcia & Shibeci, 1999; Choe & Everette, 2001).

In this study, the focus was placed on both primary and secondary pre-service science teachers. The purpose of this study is to obtain meaningful information about pre-service science teachers' conceptions of the NOS.

We tried to find out which parts of the NOS ideas are mostly misunderstood by pre-service teachers. We also approached to know from where this misunderstanding comes, and whether there is a

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difference between conceptions of primary pre-service teachers and those of secondary pre-service teachers.

We believe this information could give a clue to improve an understanding of the NOS.

PROCEDURE

Sample

The data are based on responses of 73 pre-service science teachers. 45 of them are primary pre-service science teachers and 28 of them are secondary pre-service science teachers. All of them are in their first year of college, aged 19 to 21, and have similar science background. They enrolled in earth science courses at the time of survey.

Questionnaire

The test instrument used in this study was originally designed to assess k-12 students' progress in understanding of the NOS based on Benchmarks for Science Literacy(AAAS, 1993) and it contains 256 true-false items covering four groups of grade level; k-2, 3-5, 6-8, 9-12 (Lee, 2001).

Each item has a statement containing a key idea from Benchmarks statements.

Respondents are asked to answer “true”, “false” or “I don't know” to each given statement.

Notes for readers in Benchmarks explains what “know” implies when they addressed “students must know”. According to that explanation, “students know the idea” implies following three statements (AAAS, 1993).

Students can explain the idea in their own words.

Students can relate the idea to other ideas in Benchmarks.

Students can apply the idea in the new context.

The test instruments adopted this implication and three types of test-items were produced from a single key idea (Lee, 2001).

E-type question focuses on the ability of explaining the key idea. R-type question focuses on the ability of relating the key idea to other ideas in Benchmarks, while A-type question focuses on the ability of applying the key idea in the new context. Table 1 shows some examples of three different types of items.

A respondent who understands the key idea well is supposed to consistently answer all three types of question(Lee, 2001).

For the survey used in this study, 120 test items from 6-8 grade level and 9-12 grade level were selected. The test instrument was approved to be available for any high school graduate (Lee, 2001). They covered broad areas of the NOS and fairly contained all three types of questions.

Data collection and analysis

120 selected test items were administered to participants.

Once scoring was done, we focused on “improper answers”. We did not use the term “incorrect answers”. For there is no single definition of the NOS and it is difficult to say which one is the correct view of the NOS and which one is not. Nevertheless, there is a general agreement about the NOS at a certain

Table 1. Examples of test items

key idea	test item	item type	T/ F
Scientists operate on the belief that the rules in the universe can be discovered by careful, systematic study.	Scientists believe that the rules in the universe cannot be discovered by scientific study because the rules range from very simple to extremely complex.	E	F
	As in other science, simplicity is one of the highest values in mathematics. Mathematicians try to identify the smallest set of rules from which many other propositions can be logically derived.	R	T
	Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study.	A	T

level, which is contained in Benchmarks and we addressed the close-to-Benchmarks view as a proper view and addressed others as improper views. We collected items that almost or more than half of respondents improperly answered and studied to find out which key ideas were largely misunderstood by respondents.

We also compared each item with its counterpart which has the same key idea but belongs to other types to see the consistency among answers.

RESULTS

We have obtained 11 mostly mistaken key ideas from this analysis and divide them into five categories (See Table 2).

These five categories are "change and consistency in science", "bias in scientific investigations and prejudice in scientific enterprise", "hypothesis", "things common in science", and "science ethics". We believe that they represent the NOS conceptions of which pre-service teachers easily misunderstood.

Many respondents do not seem to accept change in science and continuity in science together. More likely, they thought scientific progress has largely been made by revolutionary shift. 60% of respondents answered that change in science takes place in radical way and it implies that they believe, once a radical change is done, an old knowledge is gone and is completely replaced.

Even respondents who answered that small modification can be added to the body of old scientific knowledge and scientific knowledge is durable, still favored revolutionary changes.

How bias affects scientific investigations including data collecting and analysis was also misunderstood by many of respondents. Prejudice in scientific enterprise was another area of inadequate understanding. Respondents either believed that modern science and technology are contributed only by western world or denied any partiality of contribution in developing science and technology.

The value of and use of hypothesis in science were not fully understood by respondents. In spite of their science background, 48% of participants denied the importance of using hypothesis in science for choosing what data to pay attention to and what additional data to seek.

Respondents seemed to be confused in understanding things common in science. They believe either

Table 2. Categories of easily misunderstanding key ideas

Category	Key Ideas
Change and Continuity in Science	1. From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.
	2. With some modifications over the years, the same principles of motion have applied to other forces and to the motion of everything.
	3. New ideas in science usually grow slowly, through contributions from many investigators.
	4. The ongoing process in science such as the testing, revising, occasional discarding and/or retrieving of theories leads to an increasingly better understanding of how things work in the world, but not to absolute truth.
Bias in Scientific Investigation & Prejudice in Scientific Enterprise	5. Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings.
	6. Now people from all cultures contribute to the tradition on which modern science is based.
	7. Where their own personal, institutional, or community interests are at stake, scientists as a group can be expected to be no less biased than other group are about their perceived interests.
Hypothesis	8. Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek.
Things Common in Science	9. The rules in the universe may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study.
	10. Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy
Science Ethics	11. When it comes to participation in research that could pose risks to society, most scientists believe that a decision to participate or not is a matter of personal ethics rather than professional ethics.

that science disciplines have fixed boundaries and share nothing or that there are common steps which all scientific investigations must follow.

Ethics in science was controversial matter among respondents. Many respondents were not sure about that scientists' ethical decision is whether the matter of professional ethics or the matter of personal ethics.

We also compared responses of primary pre-service teachers with those of secondary pre-service teachers.

We compared the percentage of improper answers which present how many respondents misunderstood NOS conceptions in each category (Table 3).

For bias in scientific investigations and prejudice in scientific enterprise and for ethics in science, similar percentage of both groups had inadequate understanding.

But it is intriguing that large percentage of (70% and 60%) primary pre-service teachers have inadequate understanding about change and continuity and hypothesis, things common in science, while small percentage of secondary pre-service teachers had inadequate understanding.

Table 4 shows comparative results among three different types of item.

Once we collected items that almost or more than half of respondents improperly answered and found 11 key ideas of misunderstanding, we probed each item in comparative way. We compared every participant's answer for each item with his/her answer for its counterpart item to see how consistently a respondent answered to items which are different types but based on one key idea.

Apparently, most of respondents· inconsistently answered those items. For example, 47% of respondents agreed to false statement "No scientific knowledge is durable because change in knowledge is inevitable". But 86% of them also agreed to true statement "Change and continuity are persistent features of science". Those two questions come from the same key idea and one who understands it is supposed to consistently answer both questions. With this assumption, the result implies that most of respondents were confused about change and continuity in science.

Large percentage of respondents showed such inconsistency about all the key idea tested. Since we focused on improper answers, we only studied answers of respondents who gave improper answers.

Table 4. Inconsistency of reponses

category	key idea no.	inconsistent responses (%)
Change and continuity	1	83
	2	86
	3	56
	4	70
Bias & prejudice	5	100
	6	100
	7	100
Hypothesis	8	40
Things common in science	9	80
	10	57
Science ethics	11	100

DISCUSSION

We have found five categories of the NOS conceptions from this analysis and we believe these five categories represent conceptions that many pre-service teachers are easily mistaken or misunderstood.

Change and continuity in science is a controversial conceptions. As Lederman *et al.* (1998) pointed citing Cotham and Smith's (1981) example, there is a slight difference about how to view change in science

Table 3. Comparison of improper reponses from primary and secondary pre-service science teachers

category	% of improper responses (total)	% of improper responses (primary)	% of improper responses (secondary)
change and continuity in science	52	71	21
bias & prejudice	56	51	64
hypothesis	48	58	32
things common in science	48	60	29
science ethics	57	53	64

and therefore, there is an argument among researchers. As we accepted the view in Benchmarks as a proper view in general, we studied how close participants' view are to that of Benchmarks. According to the result, small number of respondents admitted the tentative nature of science, and most of them favored radical change in science. 52% of respondents seemed to think that there is absolute truth discovered in science, revolutionary change is more important in science than small modification, and development of the new idea is generally contributed by a few outstanding scientists. This tendency of thinking is more obvious among primary pre-service teachers. This result is consistent with Murcia and Shibeci (1999), and Choe and Everett (2001) which found the minimal awareness of tentative nature of science among pre-service teachers.

Bias in scientific investigation and prejudice in scientific enterprise were almost equally misunderstood by both groups. Mostly, respondents tended to improperly answer about key idea no. 6 and 7. They seemed to think that scientists can be objective in any circumstance and seemed to confuse objectivity in science with objectivity of scientists. Murcia and Shibeci (1999)'s result also showed uncertainty of respondents about objectivity in science.

Many respondents answered that western culture contributes to modern science and technology and other worlds are in the position of beneficiary of that contribution. Ironically, some of respondents fervently denied such dominant contribution and they even denied that Modern science is based on traditions of thought that came together in Europe about 500 years ago.

Hypothesis is another intriguing matter. It is surprising that even pre-service science teachers did not have adequate understanding about how and why a hypothesis is used in scientific investigations. Almost half of them seemed to have vague understanding about it, and it is worse among primary pre-service teachers.

Lots of respondents answered that there is a common steps in scientific investigation, which all investigations must take. They seemed to be trapped in some stereo types of experiments or observations. They admitted that there is something common in science, however, they thought it is a procedure or a method, not purpose and philosophy.

Most of respondents seemed to be confused about scientists' professional ethics and personal ethics because they answered that making decision to participate in works which could bring danger or problem is based on professional ethics.

Comparison between primary pre-service teachers and secondary pre-service teachers gave the interesting result. About bias and prejudice and science ethics, similar percentage of respondents improperly answered although the percentage of secondary group is little bit higher. But the difference between two groups is bigger in other categories, only in these cases, primary group showed higher percentage of improper responses. Both groups have similar scientific background until the graduation of high school, due to Korean national curriculum. And both groups enrolled in earth science courses at the time of survey. Therefore, the only difference of background is that they had been exposed to different curricula after highschool. But there is a minimal evidence that such a short time education in college could largely affect to their conceptions since they all are in their first year in college. What kind of factors caused such difference is still not clear.

Consistency among three different types is very important because test instrument we used is based on the assumption that consistency among answers implies that a respondent knows the idea well (Lee, 2001).

As shown in Table 4, there is a high percentage of inconsistency for almost every key idea. A respondent who improperly answered one type of question seemed to properly answer other type of question although both questions were asking about the same key idea. If a respondent improperly answered all three types, we can assume that this respondent had improper view about that particular NOS idea. It could be called misconception, misunderstanding or less acceptable view. But if respondent answered inconsistently, it means that he/she was confused about that idea and had vague or inadequate understanding.

Checking neutral answers also showed an interesting result. The more inconsistency among answers were showed, the more "I don't know" answers were included .

It implies that most of respondents did not simply misunderstand the NOS conceptions but was confused about them.

CONCLUSION

We have obtained following results from this study.

First, there is significant weakness in respondents' understanding of change and continuity in science, bias in scientific investigations and prejudice in scientific enterprise, hypothesis in scientific investigations, things common in science, and science ethics.

Second, respondents' inadequate understanding of the NOS conceptions do not only come from misconceptions but also come from confusion.

Third, there is a slight difference between conceptions of primary pre-service teachers and those of secondary pre-service teachers.

From the first result, we could conclude that our science education about the NOS has weakness in those five categories, and it could affect future NOS education for teachers' inadequate understanding would not positively works on their teaching. So far, more intense NOS program for pre-service teachers will be needed, especially in those five categories of the NOS conceptions.

The second result implies that we must focus on clearing students' and pre-service teachers' confusion. Vague understanding of the NOS or ambiguity might cause confusion. We, however, just brought out what they are mostly confused about the NOS. How and why they are confused and how to cope with this confusion are matters of further studies. Again, we support the need of intense pre-service teacher education that could cope with the confusion in those five categories of the NOS conceptions.

And, what causes the difference between primary pre-service teachers' conceptions of the NOS and those of secondary pre-service teachers? We only assume that some factors in their educational background and/or circumstances might have caused it, but it definitely needs further studies to probe.

We do not deny the limitation in this study. We could not surpass the basic problem of paper and pencil test and relatively small size of sample is not strongly supportive. Nevertheless, we believe that our finding could give a piece of meaningful information to the study of the NOS and then, to the future education.

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Manuscript received October 9, 2001
Revised manuscript received November 3, 2001
Manuscript accepted December 7, 2001