Journal of Korean Association for
Research in Science Education Vol. 23, No 4, pp. 401~418 (2003)

Philosophical Views on Science of Major Science Curriculum Documents in USA

Myoung-Duk Jang
(Korea National University of Education)

ABSTRACT

The purpose of this study was to examine philosophical views on science of two influential curriculum documents, AAAS' s *Benchmarks for Scientific Literacy (Benchmark)* and NRC' s *National Science Education Standards (Standard)*, and to get educational implications about a desired philosophical view on science at a school science level. In order to determine the philosophical views on science explicitly suggested in the documents, Soh's Philosophical Perspectives Probe (PPP) was used as a framework for analysis. Forty preservice teachers reviewed the documents, extracting paragraphs with which statements of the PPP' s questions would agree. The results of the study were as follows: First, the *Benchmark*' s philosophical view on science corresponds to the borderline between inductivism and eclecticism, or eclecticism close to falsificationism. The philosophical positions by the PPP' s themes are very different. Second, the *Standard*' s philosophical position on science corresponds to inductivism close to eclecticism. Its philosophical position by the themes of the PPP is very different like the *Benchmark*. These results indicate that philosophical positions of the documents are more complex than popular conceptions would have it. That is to say, the results suggest that the science curriculum documents hold not only a contemporary philosophical view on science but also a traditional view on science, and that the philosophical positions on science are different from each other by documents and even by the PPP's themes in the same document. The results suggest that the philosophical views on science in school science contexts need to be adjusted and presented to K-12 students according to topics related to philosophy of science.

Key words: nature of science, philosophy of science, philosophical view, scientific literacy, science curriculum documents

Ⅰ. Introduction

There is widespread agreement among science educators that 'nature of science' is a central component of school science curriculum for the preparation of scientifically literate citizen (Bentley *et al*., 2000; Collins *et al*., 2001; Glasson & Bentley, 2000; Lederman *et al*., 2002; Moss *et al*., 2001; Nott & Wellington, 1994; Rudolph, 2000). The reason is that students' adequate understanding of *knowledge of science* as well as *knowledge of science content* enables them to make an informed decision on science-related issues(AAAS, 1993; NRC, 1996; Ryder *et al*., 2001).

What is a desired understanding of nature of science, especially the philosophy of science, at all? Unfortunately, most of studies on students' and teachers' philosophical views have not clearly presented

*Received on 20 June 2003
**This work was supported by Korea Research Foundation Grant (KRF-2002-050-B00010)

desired philosophical views on science (Soh, 1998a). Instruments used to assess one's philosophical position on science are generally limited to labeling his/her view as adequate or inadequate-mostly by assigning his/her view cumulative numerical values, and instrument developers have not clarified what numerical value on such instruments constitutes an adequate view(Lederman *et al.*, 2002). And yet, studies on the nature of science have consistently reported results that students of all ages, as well as teachers, have not attained desired understandings, and exhibit naive views about the philosophy of science - strongly empiricist views about the nature of scientific knowledge(e.g., Abd-El-Khalick & Lederman, 2000; Larochelle & Desautels, 1991; Ryan & Aikenhead, 1992; Ryder *et al.*, 1999). This state of affairs must be caused by the fact that there are no ideas about the epistemology of science that acquire universal support, despite decades of conversation about the nature of science (Alters, 1997; Bentley *et al.*, 2000; Collins *et al.*, 2001; Lederman *et al.*, 2002; Meichtry, 1993; Moss *et al.*, 2001; Ryder *et al.*, 2001).

However, although there are a range of different perspectives on the philosophy of science, there are several aspects that acquire broad support at a level appropriate to school science (Moss *et al.*, 2001; Ryder *et al.*, 2001; Smith *et al.*, 1997). What is important to us as researchers or educators is to some extent agreed philosophical perspective on science in the context of K-12 science education, rather than the context of educating graduate students in philosophy or history of science (Lederman *et al.*, 2002; Moss *et al.*, 2001). Thus, it is needed to investigate appropriate philosophical views on science that might be successfully communicated to school students in the science learning context.

This study sought to examine philosophical views on science of current science curriculum documents, and to get educational implications about a desired philosophical view on science at a school science level. Thus, two major science education reform efforts, namely the *Benchmarks for Scientific Literacy* of the American Association for the Advancement of Science [AAAS, 1993] and the *National Science Education Standards* of the National Research Council [NRC, 1996], were selected and analyzed. The science curriculum documents are the most influential US national standards in science education (Lederman, 1999; Lederman *et al.*, 2002; Rudolph, 2000) and as such are believed to represent a core of the generally-agreed- upon principles of science by US science educators (Moss *et al.*, 2001).

Ⅱ. Methods

1. Curriculum Documents

After a review of the literature on nature of science, the focus was narrowed to two major curriculum documents, the 'Benchmarks for Scientific Literacy [henceforth called *Benchmark*]' (AAAS, 1993) and the 'National Science Education Standards [henceforth called *Standard*]' (NRC, 1996), because they are the most influential current documents in science education. While in the AAAS' *Benchmark* an entire chapter is devoted to the nature of science, in the NRC's *Standard* the nature of science elements are contained in each chapter following a discussion of content (McComas & Olson, 1998). Thus, for the Benchmark, '*Chapter 1. The Nature of Science*' (pp.3~20) was selected in order to analyze its philosophical views on science. For the *Standard*, however, contents of '*History and Nature of Science*' (p.107, p.108, p.141, p.170, p.171, p.200, p.201) out of '*Chapter 6: Science Content Standards*' are chosen. The contents of the selected parts were made in the form of printed handouts, and the handouts were 15 pages and 5 pages of

A4 size for the *Benchmark* and the *Standard*, respectively.

2. Participants

In order to choose explicit paragraphs related to the philosophy of science expressed in *Benchmark* and *Standard*, 40 preservice elementary teachers participated in this study. To begin with, the researcher explained the purpose of the study and the methodology of this activity, administered the reading materials, and demanded a thorough reading of it over ten times. One week later, the participants were divided into four groups and administered the 'Philosophical Perspectives Probe' instrument (see '3. Philosophical Perspectives Probe' and Appendix 1~4). The 24 questions of the PPP were assigned to the four groups by themes. Therefore, ten participants analyzed one of four themes by documents. The participants were asked to search one or two explicit and typical paragraphs in the reading materials with which statements of each question in the PPP would agree. Also, they were requested to draw lines under the representative paragraphs in the reading materials, and mark by signs (e.g., Q12-①: Q12 and ① represent the question number and the statement number of the PPP, respectively). The task lasted 50 minutes per a document. Thus, to analyze the two documents took 100 minutes.

3. Philosophical Perspectives Probe

The Philosophical Perspectives Probe (PPP) developed by Soh (1998a; 1998b) was originally intended to assess secondary school students' philosophical views on science. In this study, however, the instrument was used to determine the two documents' philosophical positions on science. Although it is not assumed that the PPP was created with completeness, it is believed that it addressed a wide variety of topics related to philosophy of science. Thus, the instrument was chosen as a framework for the analysis.

The PPP is a pool of 24 multi-choice items that address a wide range of philosophical topics of science and consists of all four themes as follows: the issues of (1) the criteria of demarcation, (2) patterns of scientific change, (3) epistemological status of scientific knowledge, and (4) scientific methods (see Appendix 1~4). The appendices show that each theme is composed of six items. The statements of the instrument as choice were derived from an analysis of various philosophical positions. The main philosophical systems of the instrument are inductivism, falsificationism, and relativism, respectively, and major distinctions depend on the four themes.

The PPP suggests expressing one's philosophical position on a triangle diagram by the combination of selected statements rather than by assigning his/her view cumulative numerical values <see Figure 1 and 2>. The philosophical position of a document is marked by a point in one of the four regions on the triangle diagram <Fig. 1>. The I, F, and R of vertex on the triangle diagram stand for Inductivism, Falsificationism, and Relativism, respectively, and the category (a), (b), (c), and (d) come under Inductivism, Falsificationism, Relativism, and Eclecticism(eclectic position), respectively.

Even though the positions of the document come under any point in the diagram, the sum of the three philosophical position is 100%. For example, the philosophical view of *Benchmark* or *Standard* can be expressed by the combination of Inductivism x%, Falsificationism y%, and Relativism z% [x+y+z=100%]<Figure 2>. As shown in <Figure 2>, if the philosophical position be shown a point(●) in the triangle diagram, the point falls under eclectic position close to inductivism.

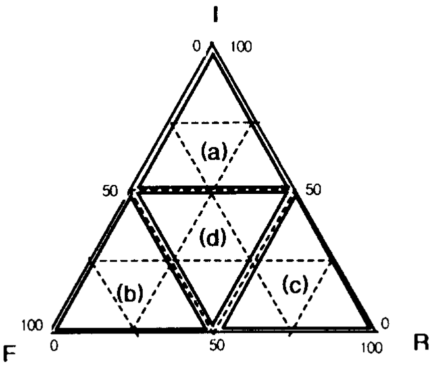


Fig. 1. The triangle diagram and categories of philosophical position

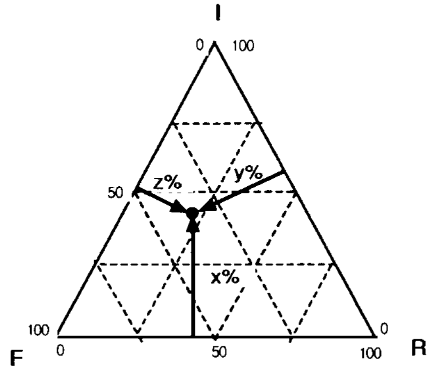


Fig. 2. The expression of philosophical views on science on the triangle diagram

4. Data Analysis

To begin with, paragraphs underlined and marked by signs were extracted from all the participants' reading materials, and classified according to questions and statements of the PPP. The paragraphs were texts selected by the participants as those with which statements of each question in the PPP would agree. And then, only paragraphs selected by three or more participants were picked out and were subjected to the next level of analysis (Appendix 1~6). Next, the two documents' philosophical positions were determined through the combination of all items of the PPP. Finally, the philosophical views were expressed on the triangle diagram as the developer of the instrument suggested (see Figure 3 and 4). The reason for the expression on the diagram is that the underlying philosophical position on science of the *Benchmark* or the *Standard* is a result of the combination of several epistemological positions.

Ⅲ. Results

Appendix 1, 2, 3, and 4 indicate the questions of the PPP by themes and their statements, and the codes of paragraphs which were selected by three or more participants in the documents by statements. The number of paragraphs which were picked out in the *Benchmark* was twenty-one (A~U) and that which in the *Standard* was fifteen (a~o) (Appendix 5 and 6).

Table 1 shows the phases of selection between the two documents by questions and themes of the PPP. As shown in Table 1, of these 24 questions, eleven questions (45.8%) are very similar to each other, or somewhat similar on the phase of selection. Four questions (16.7%), however, are very different from each other. Nine questions (37.5%) are selected by one of the two documents, or not selected by both of the documents.

The phases of selection by themes of the PPP are as follows. For the theme 'Criteria of Demarcation', three (50%) out of six questions were very similar to each other on the phase of selection, although the other three (50.0%) were selected by one of the two or not selected by both of the two. Thus, the theme holds higher consensus on the epistemological view between the *Benchmark* and the *Standard* than any other theme in the PPP. For the theme 'Epistemological Status of Scientific Knowledge', one (16.7%) and three (50.0%) out of six questions shows 'Being very similar to each other', and 'Being somewhat similar to each other,' respectively. For the theme 'Scientific Method', one (16.7%) and two (33.3%) shows 'Being very similar to each other', and 'Being somewhat similar to each other,' respectively. This result suggests a possibility that, in the documents, the three themes are described with similar philosophical positions. However, for 'Patterns of Scientific Change', three (50.0%) of the six questions were very different from each other. This result indicates a possibility that the two documents hold very different epistemological views on the theme.

Table 1. The phases of selection between the *Benchmark* and the *Standard* by questions of the PPP

Phase of selection	Theme			
	CD	PSC	ESSK	SM
Being very similar to each other	Q1, Q2, Q5	·	Q15	Q20
Being somewhat similar to each other	·	Q7	Q13, Q14, Q17	Q21, Q23
Being very different from each other	·	Q8, Q9, Q12	Q16	·
Being selected by one of the two	Q3, Q6	Q10	Q18	Q19, Q22, Q24
Not being selected by both of the two	Q4	Q11	·	·

CD: Criteria of demarcation, PSC: Patterns of Scientific Change, ESSK: Epistemological Status of Scientific Knowledge, SM: Scientific Method

1) The *Benchmark*'s philosophical views on science

For the *Benchmark* of AAAS, the number of the PPP's statements, selected by five and more participants in one (or two) identical paragraph out of 21 paragraphs (A~U), was ten out of all 72 statements [24 questions×3 statements] (Appendix 1~4 and Table 2). As shown in Table 2, two statements of two questions of the theme 'Criteria of Demarcation (CD)' [Q1-① and Q5-①], two statements in two questions of 'Patterns of Scientific Change (PSC)' [Q7-③ and Q9-③], two statements in two questions of 'Epistemological Status of Scientific Knowledge (ESSK)' [Q13-② and Q15-③], and four statements in three items of 'Scientific Method (SM)' [Q20-①, Q21-①, Q23-① and Q23-②] came under this category. This result indicates that the document includes the most explicit or precise description about the theme SM among the four themes of the PPP.

The philosophical view on science can be indicated as a point (●) in the triangle diagram, as shown in Figure 3-A. While the theme CD holds the position of extreme inductivism, the PSC has the view of utmost relativism. The philosophical position of the ESSK and the SM correspond to the borderline between falsificationism and relativism, and inductivism, respectively. The total philosophical view on science regarding the four themes corresponds to the borderline between inductivism and eclecticism.

The number of the PPP's statements, selected by three and more participants in an identical paragraph, were twenty-five (Table 3). As shown in Table 3, four statements in three questions of the CD corresponds to it [Q1-①, Q2-①, Q5-①, and Q5-③]. Five statements in four questions of the PSC [Q7-③, Q8-①, Q8-③, Q9-③, and Q12-②] and seven statements in five questions of the ESSK [Q13-②, Q14-②, Q15-②, Q15-③, Q16-②, Q17-②, and Q17-③] fall under this category. Nine statements in five questions of the SM also corresponds to this category [Q19-①, Q19-②, Q20-①, Q20-②, Q21-①, Q21-②, Q22-③, Q23-①, and Q23-②]. This result also suggests that the curriculum document contains relatively more explicit or precise descriptions about the SM than about three other themes, like the result in the Table 2. the theme ESSK follows the theme SM.

Figure 3-B shows the philosophical view on science regarding statements selected by three and over participants. While the philosophical position of the CD corresponds to inductivism, the position of the PSC belongs to relativism. This result is to some extent, but not entirely, similar to that in the Figure 3-A. For the ESSK and the SM, the epistemological position corresponds to falsificationism, and eclecticism between inductivism and falsificationism, respectively. The total philosophical position on science corresponds to eclecticism close to falsificationism, unlike the total philosophical position regarding statements selected by five and over participants.

Table 2. The number of the PPP's statements selected by five and more participants in one (or two) identical paragraph(s) in the *Benchmark*

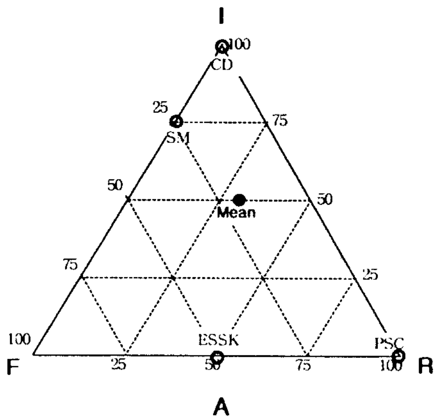
	Inductivism	Falsificationism	Relativism
Criteria of demarcation (CD)	2 (100.0)	0 (0.0)	0 (0.0)
Patterns of scientific change (PSC)	0 (0.0)	0 (0.0)	2 (100.0)
Epistemological status of scientific knowledge (ESSK)	0 (0.0)	1 (50.0)	1 (50.0)
Scientific method (SM)	3 (75.0)	1 (25.0)	0 (0.0)
Total	5 (50.0)	2 (20.0)	3 (30.0)

Table 3. The number of the PPP's statements selected by three and more participants in one identical paragraph in the *Benchmark*

	Inductivism	Falsificationism	Relativism
Criteria of demarcation (CD)	3 (75.0)	0 (0.0)	1 (25.0)
Patterns of scientific change (PSC)	1 (20.0)	1 (20.0)	3 (60.0)
Epistemological status of scientific knowledge(ESSK)	0 (0.0)	5 (71.4)	2 (28.6)
Scientific method (SM)	4 (44.4)	4 (44.4)	1 (11.1)
Total	8 (32.0)	10 (40.0)	7 (28.0)

2) The *Standard*'s philosophical views on science

For the *Standard* of NRC, the number of statements, chosen by five and more participants in one (or two) identical paragraph out of 15 paragraph (a–o), was seventeen (Appendix 1~4 and Table 4). This result is more than that of the *Benchmark*. As shown in Table 4, five statements in five questions of the theme CD comes under this category [Q1-①, Q2-①, Q3-①, Q5-①, and Q6-①]. It is particular noteworthy that



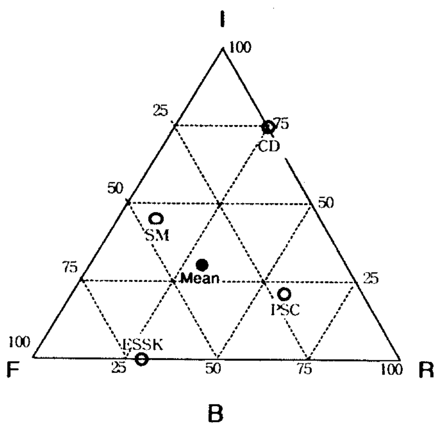


Fig. 3. The triangle diagrams of the *Benchmark*'s philosophical views on science

(A and B are philosophical views on science regarding statements selected by five and more, and three and more participants, respectively)

all the selected statements belonged to inductivism and that all participants who analyzed the theme chose statement ① in the question 2. The result also indicates that the identical paragraph can be interpreted differently according to the participants (e.g., Q3 and Q5 of Appendix 3). Two statements in two questions of the PSC [Q8-② and Q12], five statements in four questions of the ESSK [Q13-①, Q13-②, Q16-③, Q17-②, and Q18-③], and five statements in four questions of the SM [Q20-①, Q21-①, Q23-②, Q24-②, and Q24-③] came under this category. This result suggests that the *Standard* addresses relatively less descriptions about the PSC than about the other themes.

Table 4. The number of the PPP's statements selected by five and more participants in one (or two) identical paragraph(s) in the Standard

	Inductivism	Falsificationism	Relativism
Criteria of demarcation (CD)	5 (100.0)	0 (0.0)	0 (0.0)
Patterns of scientific change (PSC)	1 (50.0)	1 (50.0)	0 (0.0)
Epistemological status of scientific knowledge (ESSK)	1 (20.0)	2 (40.0)	2 (40.0)
Scientific method (SM)	2 (40.0)	2 (40.0)	1 (20.0)
Total	9 (52.9)	5 (29.4)	3 (17.6)

Figure A-A shows the philosophical view on science regarding statements selected by five and over participants. The epistemological position of the CD corresponds to extreme inductivism, like that of the *Benchmark*. The philosophical position of the PSC belongs to the borderline between inductivism and falsificationism, unlike that of the *Benchmark*. For the ESSK and the SM, the epistemological position corresponds to eclecticism. The overall philosophical position of the four themes on science corresponds to inductivism close to eclecticism.

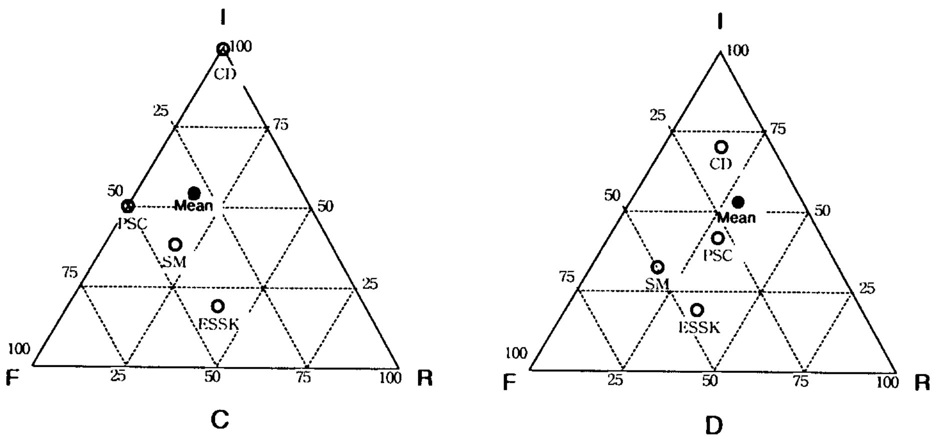


Fig. 4. The triangle diagrams of the *Standard*'s philosophical views on science

(C and D are philosophical views on science regarding statements selected by five and more, and three and more participants, respectively)

The number of the PPP's statements, chosen by three and more participants in an identical paragraph, was twenty-five (Table 5). As shown in Table 5, seven statements in five questions of the CD [Q1-①, Q2-①, Q3-①, Q3-②, Q5-①, Q5-③, and Q6-①], seven statements in five questions of the PSC [Q7-①, Q7-③, Q8-②, Q9-①, Q10-②, Q10-③, and Q12-①], eleven statements in six questions of the ESSK [Q13-①, Q13-②, Q14-②, Q14-③, Q15-②, Q15-③, Q16-①, Q16-③, Q17-②, Q18-②, and Q18-③], and six statements in four questions of the SM [Q20-①, Q20-②, Q21-①, Q23-②, Q24-②, and Q24-③] came under this category. This result suggests that the science curriculum document contains relatively more descriptions (or paragraphs) about the ESSK than about three other themes.

Table 5. The number of the PPP's statements selected by three and more participants in one identical paragraph in the *Standard*

	Inductivism	Falsificationism	Relativism
Criteria of demarcation (CD)	5 (71.4)	1 (14.3)	1 (14.3)
Patterns of scientific change (PSC)	3 (42.9)	2 (28.6)	2 (28.6)
Epistemological status of scientific knowledge (ESSK)	2 (18.2)	5 (45.5)	4 (36.4)
Scientific method (SM)	2 (33.3)	3 (50.0)	1 (16.7)
Total	12 (38.7)	11 (35.5)	8 (25.8)

The philosophical view on science can be indicated as shown in Figure 4-B. The CD holds the inductivistic position, and the PSC has the eclectic position close to inductivism. For the ESSK and SM, the philosophical views on science are eclecticism close to falsificationism, and the borderline between falsificationism and eclecticism, respectively. Both of the ESSK and the SM indicate that the positions are closer to falsificationism than those in Figure 4-A. The total philosophical view on science corresponds to inductivism close to eclecticism, like the philosophical view on science regarding statements selected by five and over participants in Figure 4-A.

Ⅳ. Conclusions

This work was done in the hope of portraying an appropriate philosophical view on science at a school science level, and getting educational implications for teaching and learning about nature of science. In order to do that, philosophical views on science of two major curriculum documents were analyzed by using Soh's PPP instrument (1998) as a framework for analysis. Based upon results of the study, the following conclusions can be drawn.

First, the philosophical view of the AAAS' s *Benchmark* on science corresponds to the borderline between inductivism and eclecticism, or eclecticism close to falsificationism. The *Benchmark*'s philosophical positions by PPP' s themes are as follows: On the theme 'Criteria of demarcation,' the *Benchmark* holds inductivistic position; On the 'Patterns of scientific change,' the document has a philosophical view which corresponds to relativism or relativism close to eclecticism; On the 'Epistemological status of scientific knowledge,' the document comes under a position of the borderline between falsificationism and relativism, or falsificationism; and On the theme 'Scientific Method,' the document holds inductivism, or eclecticism between inductivism and falsificationism.

Second, the philosophical position of the NRC' s *Standard* on science corresponds to inductivism close to eclecticism. The *Standard*'s philosophical positions by PPP' s themes are as follows: On the theme 'Criteria of demarcation,' the *Standard* has an inductivistic position as the *Benchmark* does; On the 'Patterns of scientific change,' the document holds the borderline between inductivism and falsificationism, or eclecticism close to inductivism, unlike the *Benchmark*; On the 'Epistemological status of scientific knowledge,' the document falls under eclecticism; On the 'Scientific Method,' the document comes under eclecticism close to falsificationism, or the borderline between eclecticism and falsificationism.

The results indicate that philosophical positions of the documents are more complex than popular conceptions would have it. That is to say, the science documents hold not only a contemporary philosophical view on science, relativism, but also a traditional view, inductivism, and the philosophical positions are different from each other by documents. In addition, the philosophical position in the same document is different by themes of the PPP. Therefore, it is not appropriate to attempt to provide students with a single philosophical view on science applicable in all school science contexts as Ryder et al. (2001) mentioned. Rather, these results suggest that the philosophical view on science in school science contexts needs to be adjusted and presented to K-12 students according to topics related to philosophy of science. The reason is that what is important to us as researcher or educators is to some extent an agreed philosophical view on science in school science context, rather than the context of educating graduate students in philosophy or history of science. As Matthews (1998) suggested, "it is unrealistic to expect students or prospective teachers to become competent historians, sociologists, or philosophers of science."

This study begins with several assumptions. First is the assumption that Soh's PPP contains more aspects of philosophy of science than any other instrument. The second assumption is that the nature of science, of course, is not a synonym for the philosophy of science (McComas & Olson, 1998), but the philosophy of science a more important component of the nature of science. Third assumption is that the selection by the majority of participants is more accurate than that by the minority. Thus, the conclusions stated above will be strengthened or contradicted only by using other instruments or research methods. It is expected that reviews of other science curriculum documents, an analyses by using other instruments, and so forth are implemented.

References

AAAS. (1993). *Benchmarks for science literacy: A Project 2061 report.* New York: Oxford University Press.

Abd-El-Khalick, F, & Lederman, N. G. (2000). Improving science teachers' conception of the nature of science: A critical review of the literature. *International Journal of Science Education*, 22(7), 665-701.

Alters, B. J. (1997). Whose nature of science?. *Journal of Research in Science Teaching*, 34(1). 39-55.

Bentley, M., Ebert, C., & Ebert E. S. (2000). *The natural investigator: A constructivist approach to teaching elementary and middle school science.* Belmont: Wadsworth/ Thomson Learning.

Collins, S., Osborne, J., Ratcliffe, M., Millar, R., & Duschl, R. (2001). *What 'idea-about-science' should be taught in school science? A Delphi study of the 'expert' community.* Paper presented at the Annual Conference of the National Association for Research in Science Teaching, March, 26-29, 2001, St Louis.

Glasson, G. E. & Bentley, M. L. (2000). Epistemological undercurrents in scientists' reporting of research to teachers. *Science Education*, 84, 469-485.

Larochelle, M. & Desautels, J. (1991). 'Of course, it's just obvious': Adolescents' ideas of scientific knowledge. *International Journal of Science Education*, 13(4), 373-389.

Lederman, N G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36(8), 916-929.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, E. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497-521.

Matthews, M. R. (1998). In defence of modest goals when teaching about the nature of science. *Journal of Research in Science Teaching*, 35, 161-174.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and Strategies* (pp. 41-52). Dordrecht: Kluwer Academic Publishers.

Moss, D. M., Abrams, E. D. & Robb, J. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education*, 23(8), 771-790.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academic Press.

Nott, M. & Wellington, J. (1994). Science teachers, the nature of science, and the National Science Curriculum. In J. Wellington, J. Henderson, V. Lally, J. Scaife, S. Knutton, & M. Nott, *Secondary science: Contemporary issues and practical approaches* (pp. 32-43). New York: Routledge.

Rudolph, J. L. (2000). Reconsidering the 'nature of science' as a curriculum component. *Journal of Curriculum Studies*, 32(3), 403-419.

Ryan, A. G. & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education*, 76(6), 559-580.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' image of science. *Journal of Research in Science Teaching*, 36(2), 201-219.

Ryder, J., Hind, A., & Leach, J. (2001). *The design of materials and strategies for teaching about the epistemology of science.* Paper presented at the European Science Education Research Association

Conference, Thessaloniki, Greece, August 21-25, 2001.

Smith, M. U., Lederman, N. G., Bell, R. L., MaComas, W. F., & Clough, M. P. (1997). How great is the disagreement about the nature of science? A response to Alters, *Journal of Research in Science Teaching*, 34, 1101-1104.

Soh, W. J. (1998a). *The effects of science teachers' philosophical views on science and science content describing styles on the changes of middle school students' view on science.* Unpublished doctoral dissertation, Korea National University of Education.

Soh, W. J. (1998b). Development of an instrument to assess secondary school students' conceptions of the nature of science. *Journal of the Korean Association for Research in Science Education* (JKARSE), 18(2), 127-136 (written in Korean with English abstract).

Appendix 1

Questions about the theme 'Criteria of Demarcation' of PPP and paragraphs of *Benchmark* and *Standard* selected as correspondents to statements of the questions

Item	Statement	*Benchmark*	*Standard*
Science	Q1. Some disciplines are called as science; others are said as non-science. What is science?		
	+① What one can definitely prove a claim by a direct method is science.	A*(5)**, O(5)	e(3), k(4)
	② What one can find out the falsity of a claim by means of testing is science.		
	③ What has continuously been studied and has the certain basis for the study is science.		
Pseudo -science	Q2. It is said that physics is scientific but superstition is not. What is the reason that a superstition is not scientific?		
	① Because a superstition can not observe (or experiment) and present evidences.	S(3)	k(10)
	② Because a superstition may be right or not, and it can't elucidate the reason as it is not right.		
	③ Because a superstition can't synthetically explain the reason why we believe it.		
Knowledge	Q3. What makes scientific knowledge different from knowledge in other disciplines?		
	① Scientific knowledge is carefully made through many evidences unlike other knowledge.		j(5),k(4),m(4)
	② Scientific knowledge is being tested by more rigid methods than other knowledge does.		m(3)
	③ Scientific knowledge is made like other knowledge and there is no special difference between the two.		
Subject	Q4. What is the subject of study in science?		
	① Physical world except the spiritual part.		
	② Human claims which can be found out their errors.		
	③ Every domain that are deeply investigated by many people.		
Evaluation	Q5. When there is a competition among theories, which theory is better than others?		
	① A good theory is that which is supported by many observational or experimental data.	R(4), T(4)	c(3), m(3)
	② A good theory is that which has strong possibility of falsification due to its precise content, but really is not rejected.		
	③ Competing theories can not be compared because they interpret the same observational/experimental results different.	N(3)	m(4)
Example	Q6. Which is more non-scientific than any other case?		
	① The act of finding out what will happen in the future by means of special power is non-scientific because it doesn't depend on a direct method.		k(7)
	② A study on dreams is non-scientific because the meaning of a dream depends on interpreters.		
	③ What an elementary student studies UFOs is non-scientific because it is not systematic.		

+ The statement ①, ②, and ③ means Inductivism, Falsificationism, and Relativism, respectively.

* A code of a paragraph [see Appendix 5 and 6]

** The numbers in parentheses indicates the number of participants who chose the specific paragraphs. The maximum number of participants by paragraphs is ten.

Appendix 2

Questions about the theme 'Patterns of Scientific Change' of PPP and paragraphs of *Benchmark* and *Standard* selected as correspondents to statements of the questions

Item	Statement	*Benchmark*	*Standard*
Change of meaning	Q7. Does a theory and a meaning of observational facts change as time goes by?		
	① A theory and a meaning of observational facts do not change.		a(3)
	② A theory changes, but a meaning of observational facts does not.		
	③ If a theory changes, a meaning of observational facts also changes.	I(5)	b(4)
Access to truth	Q8. How do we inquire into a truth?		
	① The more science progresses, the more a human being knows about a truth.	C(4)	
	② Science approaches a truth by discovering errors of its knowledge.		b(5)
	③ There is no truth and science does not approach a definite truth.	E(3)	
Advancement	Q9. How does science progress?		
	① Science progresses when newly established knowledge is added to existing knowledge.		o(4)
	② Science progresses when bold conjecture is established as a fact and an existing fact is found out as a falsity.		
	③ Science generally progresses in succession, but such a development is ceased when a special discovery arises.	B(4), K(3)	
History	Q10. In short, what is the history of science?		
	① Science is the history that new knowledge is produced and current knowledge is made firm on the basis of evidence .		
	② Science is the history that knowledge faces rigid tests and survives.		a(3)
	③ Science is the history that old knowledge is replaced by new knowledge.		g(3)
Hypothesis & Theory	Q11. What is the relationship between a hypothesis and a theory?		
	① A hypothesis are made by experiments, and when it turn out a truth the hypothesis become a theory.		
	② A hypothesis guides experiments, and a theory as a confirmed hypothesis are similar to a hypothesis.		
	③ Several hypotheses constitute a simple theory and several simple theories make up a complex theory.		
Advanced theory	Q12. Scientists propose new theories in place of existing theories. What is new theories?		
	① A new theory has more evidences and predicts the future facts more accurate than a previous theory does.		k(5)
	② A new theory endures more precise tests and explains more facts than a previous theory does.	T(4)	
	③ A new theory solves problems more convenient than a previous theory does.		

Appendix 3

Questions about the theme 'Epistemological Status of Scientific Knowledge' of PPP and paragraphs of *Benchmark* and *Standard* selected as correspondents to statements of the questions

Item	Statement	*Benchmark*	*Standard*
Reality	Q13. What is the relationship between scientific knowledge and truth?		
	① Scientific knowledge is a kind of truth discovered by many observations and experiments.		a(6)
	② Scientific knowledge is not true but close to truth because it has undergone a rigid examination.	G(3), L(4)	a(3), m(3)
	③ Scientific knowledge is regarded as truth by scientists, but it is not truth.		
Objectivity	Q14. To what extent is scientific knowledge objective?		
	① Scientific knowledge is objective regardless of human thinking.		
	② Although the world of objective knowledge exists, we can't know if scientific knowledge is objective.	J(4)	f(3)
	③ Scientific knowledge is made by human, and thus it is very subjective.		c(4)
Theory-laden observation	Q15. Does what scientists expect to observe affect what they actually do observe?		
	① Observations are certain, because scientists' expectations almost don't influence on their observing.		
	② Observations are reliable, although scientists' expectations influence on their observing.	Q(4)	i(4)
	③ Observations are doubtful, because scientists' expectations strongly influence on their observing.	Q(6)	i(3)
Construction of knowledge	Q16. What constitutes scientific knowledge?		
	① Scientific knowledge consists of definitely established facts.		k(4)
	② Scientific knowledge consists of claims to endure constant criticism.	F(4)	
	③ Scientific knowledge consists of facts that scientist's groups acknowledge.		f(5)
Reliability	Q17. To what extent is scientific knowledge reliable?		
	① Scientific knowledge is the most accurate knowledge establish -ed by direct methods.		
	② Scientific knowledge is incomplete and temporary, but even so it is the most reliable.	G(3)	n(5)
	③ Scientific knowledge is one out of kinds of knowledge obtained by diverse ways.	L(4)	
Superiority	Q18. Out of scientific knowledge and knowledge in other disciplines, which one is superior to the other?		
	① Because scientific knowledge is supported by bases, it is superior to knowledge in other disciplines (e.g., Literature).		
	② Although scientific knowledge can be upset some time, it is superior to non-scientific knowledge (e.g., superstition).		l(4)
	③ Scientific knowledge is not superior to knowledge in other disciplines (e.g., Literature, superstition).		l(5)

Appendix 4

Questions about the theme 'Scientific Method' of PPP and paragraphs of *Benchmark* and *Standard* selected as correspondents to statements of the questions

Item	Statement (position)	*Benchmark*	*Standard*
Departure	Q19. How do scientists go about their work?		
	① Scientists begin their work by observing facts.	M(3)	
	② Scientists begin their work by finding questions.	D(4)	
	③ Scientists begin their work by holding theories.		
Role of observation	Q20. What is the role of observation in science?		
	① Observations form the basis of producing scientific knowledge.	M(3), N(4)	a(7)
	② Tentatively accepted conclusion can be modified in the light of observations.	F(3)	b(3)
	③ Scientific knowledge can not be produced and modified only by means of observations.		
Definition of method	Q21. Scientists work by means of a scientific method. What is a scientific method?		
	① A Scientific method is a process of steadily collecting evidence in order to obtain true knowledge.	O(4), P(5)	m(5)
	② A scientific method is a process of boldly bringing to a conclusion and then modifying the conclusion.	P(3)	
	③ There is no single and upright method, but a scientific method is a process on which people can consent.		
Procedure	Q22. What is the general sequence of study followed by scientists?		
	① Scientists analyze collected specimens and then make conclusions without previously predicting.		
	② Scientists previously predict results, and then experiment and confirm if their conjectures are right.		
	③ Scientists do not study according to an identical procedure even in the same circumstance.	P(3)	
Regulation	Q23. What attitude of mind do scientists hold when they practice science?		
	① Scientists don't jump to a conclusion before many observational and experimental evidence are produced in various conditions.	H(4), O(3)	
	② Scientists don't avoid criticism of their theories and they modify their theories by newly interpreting evidence.	L(3), U(4)	b(5),f(6),h(3)
	③ Scientists don't doubt about and are not critical of theories that they believe.		
Controversy	Q24. What is the purpose of discussion among scientists?		
	① The purpose of discussion is to produce certain knowledge by adding evidence to existing knowledge		
	② The purpose of discussion is to modify their errors in the light of evidence.		d(6)
	③ The purpose of discussion is to persuade other scientists and to reach a consensus.		f(7)

Appendix 5

The *Benchmark*'s paragraphs selected by three and more participants as correspondents to specific PPP questions

Code	Paragraph in *Benchmark*
A	"The means used to develop these ideas are particular ways of observing, thinking, experimenting, and validating. These ways represent a fundamental aspects of the nature of science and reflect how science tends to differ from other modes of knowing." (p. 3)
B	"While 'breakthroughs' and 'revolutions' attract people's attention more than step-by-step growth, focusing on those rare events exclusively will give students a distorted idea of science, in that both incremental growth and occasional radical shifts are part of the story of science." (p. 4)
C	"But underlying their work are several beliefs that are not always held by nonscientists. One is that by working together over time, people can in fact figure out how the world works." (p. 5)
D	"Indeed, in finding answers to one set of questions about how the world works, scientists inevitably unearth new questions, so the quest will likely continue as long as human curiosity survives." (p. 5)
E	"Also, the human capacity for generating trustworthy knowledge about nature has limits. Scientific investigations often fail to find convincing answers to the questions they pursue. The claims that science will find answers always carries the implied disclaimers, 'in many cases' and 'in the very long run'." (p. 5)
F	"As new questions arise, new theories are proposed, new instruments are invented, and new techniques are developed. In response, new experiments are conducted, new specimens collected, new observations made, and new analyses performed. Some of the findings challenge existing theories, leading to their modification or to the invention, on very rare occasions, of entirely new theories." (p. 5)
G	"But that the ferment of change occurs mostly at the cutting edge of research. In fact, it is important not to overdo the 'science always changes' theme, since the main body of scientific knowledge is very stable and grows by being corrected slowly and having its boundaries extended gradually. Scientists themselves accept the notion that scientific knowledge is always open to improvement and can never be declared absolutely certain." (p. 5)
H	"When similar investigations give different results, the scientific challenge is to judge whether the differences are trivial or significant, and it often takes further studies to decide. Even with similar results, scientists may wait until an investigation has been repeated many times before accepting the results as correct." (p. 7)
I	"Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way." (p. 7)
J	"Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested objectively and those that are essentially matters of morality." (p. 7)
K	"From time to time, major shift 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. Change and continuity are persistent features of science." (p. 8)
L	"In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions." (p. 8)
M	"People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens." (p. 10)
N	"Scientists' explanations about what happens in the world come partly what they observe, partly from what they think. Sometimes scientists have different explanations for the same set of observations. That usually leads to their making more observations to resolve the differences." (p. 11)
O	"Scientists do not pay much attention to claims about how something they know about works unless the claims are backed up with evidence that can be confirmed and with a logical argument." (p. 11)

Appendix 5

(continued)

P	"Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence." (p. 12)
Q	"What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results. Scientists know about this danger to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions." (p. 12)
R	"Theories compete for acceptance, but the only serious competitors are those theories that are backed by valid evidence and logical arguments." (p. 13)
S	"Care also should be taken to dissociate the study of scientific prediction from the general public's notions about astrology and guessing the outcomes of sports events." (p. 13)
T	"In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings." (p. 13)
U	"Clear communication is an essential part of doing science. It enables scientists to inform others about their work, expose their ideas to criticism by other scientists, and stay informed about scientific discoveries around the world." (p. 16)

Appendix 6

The *Standard*'s paragraphs selected by three and more participants as correspondents to specific PPP questions

Code	Paragraph in *Standard*
a	"Scientists formulate and test their explanation of nature using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. These ideas are not likely to change greatly in the future." (p. 171)
b	"Scientists do and have changed their ideas about the nature when they encounter new experimental evidence that does not match their existing explanations." (p. 171)
c	"In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered." (p. 171)
d	"Different scientists might publish conflicting experimental results or might draw different conclusions from the same data. Ideally, scientists acknowledge such conflict and work towards findings evidence that will resolve their disagreement." (p. 171)
e	"It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations." (p. 171)
f	"Although scientists may disagree about explanations of phenomena, about interpretations of data, or about the value of rival theories, they do agree that questioning, response to criticism, and open communication are integral to the process of science. As scientific knowledge evolves, major disagreements are eventually resolved through such interactions between scientists" (p. 171)
g	"Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted." (p. 171)
h	"Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work. Violations of such norms do occur, but scientists censured by their peers." (p. 200)
i	"Scientists are influenced by societal, cultural, and personal beliefs and ways of viewing the world. Science is not separate from society but rather science is a part of society." (p. 201)
j	"Science distinguishes itself from other ways of knowing and from other bodies of knowing through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world." (p. 201)
k	"Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied. They should also be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and make knowledge public." (p. 201)
l	"Explanations on how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they not scientific." (p. 201)
m	"Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas where data or understanding." (p. 201)
n	"In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest." (p. 201)
o	"Usually, changes in science occur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations." (p. 201)