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Comparative Analysis of the Presentation of the Nature of Science (NOS) in Korea and US Elementary Science Textbooks

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A R T I C L E I N F O

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A B S T R A C T

The national reform document, Science for All Americans (AAAS, 1990), and the Next Generation Science Standards (NRC, 2012) emphasize the importance of the nature of science in guiding science educators in accurately portraying science to students. Therefore, it is important that textbook materials convey an accurate conception of the nature of science. This study employs content analysis to examine the content of textbooks in US and Korea elementary science textbooks with regard to the four aspects of the nature of science: (a) nature of scientific knowledge; (b) nature of scientific inquiry; (c) nature of scientific thinking; and (d) nature of interactions among science, technology, and society (Chiappetta, Fillman, & Sethna, 2004). Intercoder reliability was determined by calculating Cohen's kappa (Cohen, 1960). Findings show that while US elementary science textbooks are not balanced in presenting the four aspects of the nature of science regardless of the publishing companies, the presentation of the nature of science in Korean elementary science textbooks have better balanced treatment of the four themes across the grade levels. On the other hand, both US and Korean elementary science textbooks are attempting to convey an idea of what science is by emphasizing scientific knowledge and investigation.

I. Introduction

The nature of science has been a persistent goal of science education (American Association for the Advancement of Science [AAAS], 1990, 1993; Ackerson, Buzzelli, & Donnelly, 2010; McDonald, 2010). Science for All Americans (AAAS, 1990) emphasizes the importance of the nature of science in guiding science educators in accurately portraying science to students. The National Research Council [NRC] (1996) also calls for teaching students the nature of science in its National Science Education Standards which specifically includes standards for teaching the nature of science across all grade levels. Presently, the Next Generation Science Standards (NGSS) address the significance of the nature of science and the interaction of the three domains: science practice, crosscutting concepts, and the core disciplinary ideas to inform how to teach the nature of science in the Framework for K-12 Science Education (NRC, 2012). Likewise, there is significant agreement among science educators in the science education community that understanding the nature of science is important and has recently been reemphasized in the national reform efforts in science education (NRC, 2012).

However, even though helping students achieve an adequate understanding of the nature of science has been a consistent goal for science education, research continues to show that a large majority of K-12 students possess naïve views of the nature of science (Abd-El-Khalick & Lederman, 2000; Lederman, 2002; Oliveira *et al*., 2012). One of the reasons for this problem is that science curriculum including science textbooks does not present the picture of the nature of science appropriately. Providing students with an authentic view of the nature of science presents a big challenge for all teachers, especially those at the elementary level. One means to accomplish this goal is for the textbooks teachers use to include an accurate and balanced presentation of the nature of science. Therefore, the need exists for educators to examine how science textbooks present the nature of science. The purpose of this study is to compare the balance of the nature of science themes in elementary science textbooks between U.S. 1^{st}-5^{th} grade and Korean 3^{rd}-6^{th} grade. Given this purpose, a content analysis has been designed to address the following research questions:

1. What is the balance of the themes for the nature of science in U.S. and Korea elementary textbooks?
2. How does the presentation of the nature of science compare between U.S. and Korea elementary science textbooks?
3. What are the similarities and differences of the presentation for

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the nature of science in the elementary science textbooks between U.S. and Korea?

II. Research Methods

The purpose of this investigation was to content analyze elementary science textbooks in U.S. and Korea. The quantitative research approach employed the modified four-theme nature of science conceptual framework to study the balance of the four themes of the nature of science in elementary science textbooks. The four-theme nature of science conceptual framework was modified by adding more descriptors from national-level documents, such as Science for All Americans (AAAS, 1990) Benchmarks for Science Literacy (AAAS, 1993) and the National Science Education Standards(NRC, 1996), as well as science education research reports (Lee, 2007; Lee, 2013c). Each theme reflects aspects of science that philosophers, historians, scientists, and science education researchers have written about. The four-theme framework is the four aspects of the nature of science, which are (a) nature of scientific knowledge; (b) nature of scientific inquiry (c) nature of scientific thinking and (d) nature of interactions among science, technology, and society (STS). This four themes of the nature of science framework has been used by other researchers to analyze science curriculum for the past several decades in science education (Chiappetta, Fillman., & Sethna, 1991; Chiappetta & Fillman, 2005; Chiappetta *et al*., 2006). Additionally, since the framework was revised by the researcher to reflect the current views of the nature of science from the literature, it is an inclusive and valid tool to examine the authentic views of the nature of science (Lee, 2013c). Table 1 presents the modified nature of science framework that was adopted for this research.

Four different types of elementary science textbooks published by the four major publishing companies in the U.S. were selected for the study - three of which are among the most widely adopted texts by school districts in the state of Texas.

The U.S. elementary science textbooks used in this study are:

1. Science, First-Grade, Second-Grade, Third-Grade, Fourth-Grade, and Fifth-Grade (Harcourt, 2000)
2. Science - Discovery Works, First-Grade, Second-Grade, Third-Grade, Fourth-Grade, and Fifth-Grade (Houghton Mifflin, 2001)
3. Science, First-Grade, Second-Grade, Third-Grade, Fourth-Grade, and Fifth-Grade (McGraw Hill, 2002)
4. Science, First-Grade, Second-Grade, Third-Grade, Fourth-Grade, and Fifth-Grade (Scott Foresman, 2001)

Because elementary science textbooks in Korea are published by the Ministry of Education and Science Technology [MEST] nationally, there is no different publishing company for elementary school science textbooks. Thus, four elementary science textbook from 3rd to 6th grade were analyzed for this study. This is because there is no science subject separately in Korean elementary school since science was integrated with other subjects in 1st and 2nd grades.

Table 1. A Modified Framework of Nature of Science (NOS) based on the Four Categories

Theme I: Nature of scientific knowledge
1) Science is organized into content disciplines such as facts, concepts, laws, theories, etc.
2) Scientific knowledge explains and predicts the nature.
3) Scientific knowledge is tentative but durable.
4) There are different types of knowledge in science (laws and theories are different).
5) New scientific knowledge emerges from the process of scientific inquiry.

Theme II: Nature of scientific inquiry
1) Science is based on empirical evidence.
2) Science relies on observation and inference.
3) There are various scientific methods in science (no single step-by-step scientific method)
4) Experiments are important to test ideas using science process skills.

Theme III: Nature of scientific thinking
1) Both reasoning and imagination (creativity) are important in science.
2) Scientists are not totally objective but try to avoid bias.
3) Scientific knowledge is based on interpretation.
4) Scientific knowledge is developed with its history.
5) Skepticism and criticism are critical in scientific thinking.

Theme IV: Nature of interactions among science, technology, and society (STS)
1) Science can be used in society both positively and negatively.
2) Science and technology impact each other but they are not the same
3) Science is a complex social activity.
4) There are social and cultural influences on science.
5) Science and its method cannot solve all problems in society (limitation of science)
6) Science is conducted corporately (contribution of diversity)
7) There are ethical principles in science.
8) Scientists participate in public affairs both as specialists and citizen.

The Korean elementary science textbooks used in this study are:

1. Science 1 and 2, Third Grade (Ministry of Education and Science Technology, 2010)
2. Science 1 and 2, Fourth Grade (Ministry of Education and Science Technology, 2010)
3. Science 1 and 2, Fifth Grade (Ministry of Education and Science Technology, 2011)
4. Science 1 and 2, Sixth Grade (Ministry of Education and Science Technology, 2011)

The sample included a 20% random sample of the entire of the chapters from each of the textbooks. This random sample was selected using an online randomizer found at: http://www.randomizer.org/. Before the coding of the textbooks was undertaken, coders of the analysis and researchers practiced a protocol of the modified four themes nature of science framework. The protocol was developed by Lee (2007) to train individuals who use this approach for content analysis. The researcher of this investigation solicited the help of two coders for analyzing U.S. elementary science textbooks, who are very familiar with this line of research and coding system, to undertake the establishment of the reliability of the protocol, then to categorize the text paragraphs, figures, and assessment items in the textbooks. Two researchers of the study participated as coders in analyzing U.

Table 2. Intercoder Reliabilities in the Korean Elementary Science Textbooks (3rd-6th Grade)

Textbook Grade Level	Percentage Agreement	Cohen's kappa
3rd Grade	89.8%	.88
4th Grade	81.0%	.78
5th Grade	89.6%	.88
6th Grade	89.2%	.87

Table 3. Intercoder Reliabilities in the U.S. Elementary Science Textbooks (1st-5th Grade)

Publishing Company	Percentage Agreement	Cohen's kappa
Harcourt	90.4%	.89
Houghton Mifflin	84.7%	.80
McGraw Hill	93.3%	.93
Scott Foresman	94.9%	.94

Table 4. Percentage of Nature of Science Categories Found in Korea Elementary Science Textbooks

Textbook Grade	Nature of Science Categories			
	I	II	III	IV
3rd Grade	52.4	29.5	11.8	6.3
4th Grade	47.1	38.0	11.0	3.9
5th Grade	22.8	30.1	29.7	17.4
6th Grade	33.7	29.9	20.8	15.6

Note. Nature of Science Categories: I=nature of scientific knowledge; II= nature of scientific inquiry; III=nature of scientific thinking; and, IV=nature of interaction among science, technology, and society (STS).

S. and Korea elementary science textbooks after training of the protocol with the modified the four themes of the nature of science framework.

For a study to be valid and reliable it is important that the tools and procedures used should be valid and reliable. To accomplish this goal, inter-rater agreement was calculated using percent and also inter-rater reliability was calculated using Cohen's (1960) kappa. Table 2 and 3 present the inter-coder agreement and reliability values for the analysis of four categories of the nature of science in Korea and U.S. elementary science textbooks. Results of the reliabilities indexes for the analyses of the U.S. and Korea elementary science textbooks under examination are reliable ranging from 81.0% to 94.9% for percentage agreement and .78 to .94 for kappa and resulted in good to excellent agreement for all coding of the textbooks. Specifically, the reliabilities indexes for the analyses of the elementary science textbooks in 3rd – 6th grade Korea textbooks range from 81.0% to 89.8% for percentage agreement and from .78 to .88 for kappa and from 84.7% to 94.9% for percentage agreement and from .80 to .94 for kappa in U.S. elementary science textbooks. Thus, the reliabilities for elementary science textbooks analyses indicate good agreement beyond chance for all textbooks analyses. These reliability indexes permit very good level of confidence in interpreting the quantitative results of U.S. and Korea elementary textbooks analysis.

III. Results and Discussion

1. Presentation of the Nature of Science in Korean Elementary Science Textbooks

With regard to presentation for the four themes of the nature of science in 3rd-6th grade Korea elementary science textbooks, the presentation of the four themes are shown to be plausibly balanced throughout the all textbooks. Although Korea elementary science textbooks seem to emphasize on the nature of scientific knowledge (theme I) and the nature of Scientific Inquiry (theme II), other two themes; the nature of scientific thinking (theme III) and the STS (theme IV) were also emphasized in reasonable attention across the grade levels.

However, Korean elementary science textbooks give less emphasis on the interaction of science with technology and society (STS theme IV) comparing to other three themes ranging from 6.3% to 17.4% in all grade levels. This is interesting because while generally secondary science textbooks seem to emphasize on the aspect of the nature of interactions among science, technology, and society (STS) by including a separate section of the content named "STS corner" throughout the textbooks (Lee, 2013a; Lee, 2013b), elementary science textbooks place little emphasis on this aspect of the nature of science in their content. The authors of elementary science textbooks seem to think that the characteristic of STS nature of science might be complicated for elementary students to understand scientific enterprise. Fortunately, upper grade levels (5th and 6th grades) emphasize on reasonably more attention to the nature of interactions among science, technology and society. This is nice because even young students in elementary school level need to understand how science works with other areas in our society to gain the appropriate insights of scientific literacy.

For the presentation of the nature of science in terms of grade level, 3rd and 4th grade science textbooks place more focus on the natures of scientific knowledge (Theme I) and scientific inquiry (Theme II) while 5th and 6th grade science textbooks are shown to be balanced treatment with more consideration to the nature of scientific thinking (theme III) and STS (theme IV) in their content. Specifically, these two grade levels, 3rd and 4th grades, science textbooks heavily emphasize on the scientific knowledge (Theme I) by devoting approximately 50% of the entire content in the textbooks. This finding is deficiency because younger students seem to be forced to understand more scientific information and knowledge rather than presenting multi-dimensional nature of science as an authentic view of the nature of science. Also, these two lower levels of science textbooks pay little attention to the nature of interactions among science, technology, and society (Theme IV) giving less than 10% of the content. This is also limitation of the presentation of the nature of science in Korean elementary science textbooks. Currently, even though there are lots of issues and topics related with the aspects of the nature of

Table 5. Mean Percentage of Nature of Science Categories Found in U.S. Elementary Science Textbooks

Textbook Grade	Publishing Company	Nature of Science Categories I	II	III	IV
1st Grade	H	51.4	45.1	3.5	0.0
	H.M	40.8	58.3	0.0	0.9
	M	48.1	46.1	2.7	3.1
	S	49.0	49.0	0.0	2.0
	Mean	47.3	49.6	1.6	1.5
2nd Grade	H	48.3	49.7	1.6	0.5
	H.M	29.1	68.1	0.0	2.8
	M	51.0	47.9	0.0	1.1
	S	43.5	54.2	0.0	2.2
	Mean	43.0	54.9	0.4	1.7
3rd Grade	H	61.1	30.8	4.9	3.2
	H.M	52.1	40.2	1.0	6.7
	M	48.6	46.6	1.1	3.6
	S	63.9	30.8	0.0	5.4
	Mean	56.3	37.1	1.8	4.8
4th Grade	H	58.2	33.1	3.7	5.0
	H.M	43.9	45.4	2.5	8.2
	M	47.2	44.1	3.9	4.7
	S	60.9	30.3	1.4	7.3
	Mean	52.6	28.2	2.9	6.3
5th Grade	H	51.9	39.7	2.0	6.4
	H.M	52.3	42.6	1.4	3.7
	M	53.7	39.0	2.4	4.9
	S	61.5	31.0	1.5	5.9
	Mean	54.9	38.1	1.8	5.2

Note. Publishing Company. H=Harcourt; H.M=Houghton Mifflin; M= McGraw-Hill; S=Scott Foresman

interactions among science, technology, and society that young students might be interested in, current elementary sciencetext books do not reflect this part of the nature of science with reasonable consideration in their materials.

2. Presentation of the Nature of Science in U.S. Elementary Science Textbooks

With regard to presentation for the four aspects of the nature of science in U.S. elementary science textbooks, all of the elementary science textbooks reviewed in this study heavily emphasize on the nature of scientific knowledge (Theme I) and nature of scientific inquiry (Theme II). Content is provided in all textbooks for students to learn about science knowledge in general and to generate interest for furthering their inquiry investigations. In addition, all U.S. elementary science textbooks across the grade levels place little emphasis on the category III and IV ranging from 0.4 to 6.3 % in the entire chapters. This unbalanced treatment of the four themes of the nature of science in U.S. elementary science textbooks might be a shortcoming. Although one should not to find an exact balance of 25% of text material devoted to each of the four themes (Chaippetta & Fillman, 2005), it might be desirable to find some reasonably balanced treatment among the four categories in science curriculum due to the multifaceted features of the nature of science. Thus, this unbalanced treatment of the four aspects of the nature of science could produce the undesired effect of providing the students and teachers with a narrow view of the scientific enterprise. Even though understanding the natures of scientific thinking and interaction among science, technology, and society (STS) is not easy for young students, the textbooks should include those aspects of the nature of science in their content to reflect of multidimensional nature of scientific activities. Again, this finding is substantial because although national-level documents and reports of science researchers have emphasized the interaction of science with technology and society, current elementary science textbooks do not reflect this aspect of the nature of science with reasonable attention in their content. Thus, it indicates that the science education reform goals are not being translated into a balanced treatment of the nature of science in U. S. elementary science textbooks. Fortunately, textbook publishers seem to be slowly moving toward a more balanced representation of the nature of science in elementary textbooks as the grade level goes up by emphasizing slightly more focus of the scientific thinking (theme III) and STS (theme IV).

On the other hand, all textbooks are providing science content with greater emphasis on hands-on, minds-on opportunities for students to engage themselves in inquiry investigations by focusing on the nature of scientific inquiry (Theme II). All publishing companies of the elementary textbooks provide students with the process for conducting inquiry investigations, however most textbooks portray the scientific method as more a step-by-step process for organizing scientific inquiries. It indicates that the authors of most of U.S. elementary science textbooks are attempting to convey an idea of what science is and how the scientific enterprise works by emphasizing investigation and the processes of inquiry -- not by presenting scientific thinking or the interaction of science with technology and society. These findings also indicate that the authors of U.S. elementary science textbooks seem to want elementary students to understand the nature of science as a process of science.

3. Comparison of the Presentation of NOS in Korea and U. S. Elementary Science Textbooks

The current analysis of U.S. and Korean elementary science textbooks demonstrates that while U.S. elementary science textbooks are not balanced for the four themes of the nature of science regardless the publishing companies in presenting the four themes of the nature of science, the presentation of the nature of science in Korean elementary science textbooks are better balanced treatment of the four aspects of the nature of science across the grade levels. The findings infers that while authors of U.S. textbooks seem to work on writing on the content of textbooks with more personal manner and emphasis, Korean authors seem to attempt to follow the national education

standards and guidelines when they publish the textbooks. In other words, this assumes that the most authors of Korea textbooks seem to be more informed about the national-level science education standards as well as the current researches and attempt to incorporate them into their curriculum materials.

On the other hand, both authors of U.S. and Korean elementary science textbooks are attempting in the content to convey an idea of what science is and how the scientific enterprise works by emphasizing scientific knowledge and investigation -- not by presenting scientific thinking and STS aspects of science. These findings indicate that both authors of U.S. and Korean elementary science textbooks seem to want young students to learn about the scientific knowledge (Theme I) and to understand the nature of science as a process of science (Theme II) rather than engaging in scientific thinking (Theme III) and STS (Theme IV). This is challenging because, according to the national reform documents and standards, young students should understand multifaceted views of the nature of science and the interaction of science with other areas in society to prepare for the next level of science education (NRC, 2012; Ackerson, Buzzelli, & Donnelly, 2010). It is hoped that in future publications of textbook authors continue to shift towards incorporating different aspects of science including science as a way of thinking as well as science and its interaction with technology and society to provide a more authentic view of the nature of science.

IV. Conclusion and Implication

The current analysis demonstrates that Korean elementary science textbooks reflect a well balanced treatment of the four themes of the nature of science than its U. S. elementary science textbooks. This suggests that the authors of Korean elementary science textbooks attempt to incorporate national science education goals into their materials with a better balanced treatment of scientific literacy in their textbooks while the authors of U.S. elementary science textbooks attempt to portray the view of the nature of science in their personal manners and approach. This unbalanced coverage of U.S. elementary science textbooks is critical, and perhaps should be changed to include a broader conception of the nature of science in curricula materials. Despite that education agency and school districts in U.S. make an effort greatly in building and adopting textbooks due to the importance of textbooks, many of teachers in U.S. elementary schools hardly utilize their instructional materials from their textbooks when they teach science lessons in the classrooms (Dole & Johnson, 1981; Moss, 1991; Butzow & Butzow, 2000). It must be a big loss of educational efforts in U.S. and the findings of the study might explain why these important curricular materials are hardly utilized in U.S. elementary science classrooms in some ways. One wonders why so little attention is dedicated to these great educational resources and curricula materials that are available for all teachers that they can employ in their everyday instructions.

In addition, this study adds to a line of science textbook analysis research that began over 20 years ago to examine a major instructional resource that influences greatly what teachers teach and students learn. Because of the position of textbooks, many nations invest heavily in creating and revising textbooks, particularly since science education plays an essential role not only for individual development, but also for national development (Chrisman, 1984). This comparative analysis of elementary science textbooks between U.S. and Korea, which are scientifically developed nations, may enhance science education by providing 1) a summary of the presentation of the authentic view of science, 2) an assessment of the current level of science curricular presented to students and teachers, and 3) some guidelines on development and revision of textbooks. In addition, in view of reports that science education in other counties may be superior to that in the United States (McFadden, 1982; Wirszup, 1981; Yager, 1983), this study may contribute to the call for international comparative study to improve the quality of science curricular materials and science education reform in both U.S. and Korea.

The content analysis of science textbooks and other curriculum resources should be undertaken by more researchers because these efforts provide important information about the extent to which these materials have been informed by science education reform documents, especially how authentic science is explicitly and implicitly presented to the learner. It is surprising that there is little research on middle school and especially elementary school science textbooks (Chiappetta *et al*., 2006) and very little international comparative data published in the United States and other nations (Swart, Anderson, and Swetz, 1994). Further, many conceptual frameworks should be used to analyze curricular materials. While the present study employed a four-theme approach to the nature of science, frameworks that examine coherence, readability, cognitive demand, etc. can be used. Also, the scholars who have a philosophical, sociological, and psychological expertise, as related to science, might undertake this type of research in order to provide different and valuable perspectives as to what constitutes a reasonably appropriate view of the scientific enterprise in science curriculum.

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