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Research Article

Comparative Analysis of the Presentation of the Nature of Science in U.S. High School Biology and Korea High School Science Textbooks

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Abstract

The aim of this study was to conduct a content analysis to compare the presentation of the four themes of the nature of science in the first chapter of four U.S. high school biology textbooks and five Korea high school general science textbooks with the modified four themes of the nature of science framework, which are: (a) science as a body of knowledge; (b) science as a way of investigating; (c) science as a way of thinking; and (d) science, technology, and society. The current analyses of U.S. and Korean textbooks demonstrates with a good level of reliabilities ranging from .63 to .96 in U.S. and from .79 to 1.00 in Korea textbooks for Cohen's kappa. While only some U.S. high school biology textbooks reflect a reasonably balanced treatment of the four themes in the first chapter, most of Korea high school general science textbooks reflect a reasonably balanced treatment of the four themes of the nature of science. Also, both authors of U.S. high school biology textbooks and Korean high school science textbooks are attempting to convey an idea of what science is by emphasizing investigation and the thinking processes of scientists -- not by presenting scientific knowledge.

Keywords: nature of science, textbook analysis, comparative analysis, high school biology, high school science, content analysis.

INTRODUCTION

The nature of science is a central element of the science education reform (AAAS, 1990; Lederman, 1992). *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1990) begins with a chapter on the nature of science, and the *National Science Education Standards* (NRC, 1996) stresses the importance of understanding the nature of science throughout the document. Currently, the *Next Generation Science Standards* (NGSS) address the importance of the understanding 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). As such, helping K-12 students acquire an informed view of the nature of science has been a constant goal of science education for which extensive research and development efforts have been directed toward its achievement (Ackerson et al., 2010; McDonald, 2010).

The *nature of science* has been defined as the "epistemology of science, science as a way of knowing, or the values and beliefs of scientific knowledge and its development" (Lederman, 1992, p. 331). As researchers have explored many aspects of the nature of science to describe and inform science education about the character of science itself, they have developed a more encompassing definition. “The nature of science is a fertile hybrid arena which blends aspects of various social studies of science including the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group, and how society itself both directs and reacts to scientific endeavors” (McComas et al., 1998, p. 4).

There is significant agreement among science educators in the science education community that understanding science and the how science works is important. For science educators, the term “nature of science (NOS)” is used to describe the issues addressed by the philosophy, history, sociology, and psychology of science as they apply to and impact science teaching and learning (McComas et al., 1998). In this view, the nature of science is a fundamental domain for guiding science educators in portraying science to students, and few people doubt that an authentic science curriculum must contain ideas about the nature of science.

Although helping students to achieve an adequate understanding of the nature of science has been a consistent goal for science education for over half a century, current research reveals that the majority of students and teachers have naïve views of the nature of science (Abd-El-Khalick and Akerson, 2004; Bianchini and Colburn, 2000). This problem could be attributed not only to the complex nature of science, but also to the way the nature of science is presented to students during instruction. In spite of significant progress toward characterizing the nature of science, sometimes reading about the nature of science can become confusing because the nature of science is neither universal nor stable (Lederman, 1992). Yet one of the central responsibilities of science teachers remains to provide an accurate description of the nature of science rather than to engage students in the arcane arguments that occur among philosophers of science (McComas et al., 1998).

Science textbooks play a central role in science instruction. These resources not only serve to provide content, hands-on activities, and assessment of key ideas, they also convey a particulate point of view about the nature of science, which is unique to a given publisher. While science textbooks hold the potential to convey an authentic view of science, this may not be the case. Because science textbooks comprise a multi-billion dollar industry, providing written and electronic materials for science courses in grades K though college (Biggs, 2004), they influence the way science teachers and students view science. Therefore, research is needed to analyze the messages science textbooks convey about the scientific enterprise in needed. Moreover, even though the nature of science has long been seen as an important element of science education, efforts to integrate an authentic view of the nature of science into the curriculum have often met with little success (Abd-El-Khalick and Akerson, 2004).

The aim of this study was to conduct a content analysis to compare the presentation of the four themes of the nature of science in the first chapter of four U.S. high school biology textbooks and five Korea high school general science textbooks with the four themes of the nature of science framework. The four-theme nature of science conceptual framework: (a) science as a body of knowledge; (b) science as a way of investigating; (c) science as a way of thinking; and (d) science, technology, and society. The balance of the nature of science four themes was examined by comparing their presentation in different data types, such as paragraphs, figures (diagrams, graphs, and tables), and assessment sections. At the same time, the study compared the balance of the four themes of the nature of science with the percentage devoted in each theme between the four U.S. high school biology textbooks and the five major Korea high school general science textbooks. The study may provide systematic, research-based reviews of science curriculum materials as a means for improving curriculum quality, influencing teacher practice, and supporting science education reform.

METHODS

This investigation adapted the content analyze research method to examine the first or introductory chapter of high school biology in U.S. and general science textbooks in Korea to study the balance of the four themes of the nature of science using the modified four-theme nature of science conceptual framework. Because the introductory chapter particularly presents the methods of science and how scientists go about their work, the study analyzed the first entire chapter to examine the following research questions;

Research Questions

1. What are the reliability indexes of the coding of the first chapter on the methods of science in four U.S. high school biology textbooks and five Korea high school general science textbooks for the four themes of the nature of science framework?
2. How does the balance of the nature of science presentations compare, in the methods of science chapters in four U.S. high school biology textbooks, among different types of presentation such as text, figures (diagrams, graphs, and tables) and assessment with the four themes nature of science framework?

3. How does the balance of the nature of science presentations compare, in the first introductory chapters in five Korea high school general science textbooks, among different types of presentations such as text, figures (diagrams, graphs, and tables) and assessment with the four themes nature of science framework?
4. How do they present the four themes of the nature of science compare in U.S. and Korean high school science textbooks?

Research Design – Content Analysis

A content analysis was used to examine the balance of the four themes of the nature of science in U.S. textbooks and Korean textbooks. Content analysis has been defined as "a research technique for the objective, systematic, and quantitative description of the manifest content of communication" (Berelson, 1952, p. 18). Currently, Krippendorff (2004) described content analysis as "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use" (p. 18). He stated that content analysis is a scientific tool because the techniques are expected to be reliable and must also yield valid results. A central idea in content analysis is that the text's many words are classified into fewer content categories. To make valid inferences from the text, the classification process must be reliable, that is, generate variables that are valid (Weber, 1990). A discussion of reliability and validity is vital to content analysis.

1) Validity

In content analysis, validity should work on the primary idea that the texts under analysis have a significant relationship with their chosen context, such as the texts' conceptual framework, selected sample, or analytical construct (Chiappetta et al., 2006).

Chiappetta et al., (2006, p. 2) described validity in content analysis as

- How accurately the selected sample (e.g., words, paragraphs, pages) represents the entire body (e.g., science textbook) in whose place the sample is analyzed;
- The extent to which the categories of an analysis of texts correspond to the meanings these texts have within the chosen conceptual framework; and
- How accurately the adopted analytical constructs represent the established uses and meanings of the texts in the chosen context (e.g., K–12 science education).

Because the validity of categories and analytical construct is closely related to the given conceptual framework and the results of the research in content analysis, the validity refers to the correspondence of the categories to the conclusions and the generalizability of results to a conceptual framework (Chiappetta et al., 2006).

2) Reliability

Reliability is a crucial issue in content analysis because the researcher must be confident that her data has been generated with all plausible defense against biases and distortions and that her data mean the same thing for everyone who use them (Krippendorff, 2004). When a research procedure on a given piece of data with the same instrument yields similar results regardless of the circumstances of its implementation, the research procedure and measure must be reliable (Holsti, 1996).

Despite reliability's importance, there is neither a single accepted technique for arriving at it nor is there acceptable level of agreement of reliability. Intercoder reliability is the most widely used form, and it is a critical component of content analysis (Lombard et al., 2002). Intercoder reliability is essential in content analysis because it measures only "the extent to which the different judges tend to assign exactly the same rating to each object" (Tinsley and Weiss, 2000, p. 98).

The following list gives several ways that this process can be conducted: as a percentage agreement, Holsti's percentage agreement index, Scott's *pi,* Cohen's *kappa (k)*, or Krippendorff's *alpha*. To achieve appropriate intercoder reliability, the researcher has to create a representative set of units for testing reliability and the coding decisions must be made independently under the same conditions (Lombard et al., 2002). In reality, many researchers who are conducting content analysis often fail to assess the reliability of their coding in a desirable way (Krippendorff, 2004). Lombard et al., (2002) also pointed out that mass communication researchers often not only failed to evaluate intercoder reliability but also relied on percent agreement, which is a poor means to arrive at intercoder reliability.

Instrument – A Conceptual Framework

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 and Chiappetta, 2008). Each theme and their respective descriptors reflect aspects of science that philosophers, historians, scientists, and science education researchers have written about. Since the four themes were revised from review of the literature, this framework of the nature of science supports the call for reforms in science education, in addition to those required by Science for All Americans (AAAS, 1990) and the National Science Education Standards (NRC, 1996).

The Nature of Science themes used for this study included:

1. Science as a body of knowledge; text that presents knowledge produced by science and this category includes the nature of scientific knowledge, such as tentativeness, durability, and distinctness of knowledge:
(a) Facts, concepts, principles, and laws;
(b) hypothesis, theories, and models; in addition to,
(c) asking students to recall knowledge or information,
(d) tentativeness and durability of scientific knowledge, or
(e) distinctness of scientific knowledge (laws and theories are different).

2. Science as a way of investigating; text that engages students in investigations, science process skills, and reasoning:
(a) Requires the student to answer a question through the use of materials,
(b) requires the student to answer a question through the use of charts, tables, etc.,
(c) requires the student to make a calculation,
(d) requires the student to reason out an answer,
(e) engages the student in a thought experiment or activity,
(f) instructs the student to get information from the Internet,
(g) asks students to make observation, inference, etc., or
(h) requires analysis and interpretation of data. However, if a question simply asks for recall of information or is immediately answered in the text, it is classified as Category1, science as a body of knowledge.

3. Science as a way of thinking; text in this category that illustrates thinking, work of scientists, and scientific enterprise:
(a) Describes how a scientist experimented,
(b) shows the historical development of an idea,
(c) emphasizes the empirical nature and objectivity of science,
(d) illustrates the use of assumptions,
(e) shows how science proceeds by inductive and deductive reasoning,
(f) gives cause and effect relationships,
(g) discusses evidence and proof,
(h) presents the scientific method(s) and problem solving steps,
(i) shows that skepticism and criticism are part of the scientific enterprise,
(j) illustrates how subjectivity, bias, and other human characteristics are evident among scientists, or
(k) demonstrates there are many ways to understand the world.

4. The interaction of science, technology, and society; Text in this category that shows interaction among science, technology, and society, and the social construction of knowledge:
(a) Describes the usefulness of science and technology on society,
(b) stresses the negative effects of science and technology on society,
(c) discusses social issues related to science and technology,
(d) brings out careers and jobs in scientific and technological fields. (Chiappetta and Koballa, 2002),
(e) illustrates the contribution of diversity in science,
(f) describes the societal and cultural influences on science,
(g) Explains how scientists make public their work and how they collaborate,
(h) the limitations of science (science cannot answer all questions in society), or
(i) stresses the ethical issues in the scientific field.

Table 1. Modified Four-Theme Nature of Science Categories

	I. Presents knowledge produced by science and nature of knowledge
a	facts, concepts, laws, and principles
b	hypothesis, theories, or models
c	questions asking for recall of information
d	*tentativeness and durability of scientific knowledge*
e	*distinctness of scientific knowledge (laws and theories are different)*
	II. Engages students in investigations, science process skills, and reasoning
a	learn through the use of materials
b	learn through the use of charts and tables
c	make a calculation
d	reason out an answer
e	participate in a "thought experiment"
f	get information from Internet
g	*use of scientific observation and inference*
h	*analysis and interpretation of data*
	III. Illustrates thinking and work of scientists, and scientific enterprise
a	describe how a scientist discovered or experimented
b	historical development of an idea
c	empirical basis of science
d	use if assumptions
e	inductive or deductive reasoning
f	cause and effect relationship
g	evidence and proof
h	present scientific method(s) and problem-solving steps
i	*skepticism and criticism*
j	*human imagination and creativity*
k	*characteristics of scientists (subjectivity and bias)*
l	*various ways of understanding of world*
	IV. Shows interactions among science, technology, and society and social construction of knowledge
a	usefulness of science or technology
b	negative effects of science or technology
c	discussion of social issues related to science or technology
d	careers in science or technology
e	*contribution of diversity*
f	*societal, cultural influences*
g	*make public and peer collaboration*
h	*limitation of science (cannot answer all question in society)*
i	*ethics in science*

Note: The italicized terms are descriptors added from the literature.

Sample and Coding

Four high school biology textbooks in U.S. were selected for the study – three of which are among the most widely adopted texts by school districts across the nation in U.S., the fourth is one that was produced by the Biological Sciences Curriculum Study, which is different in emphasis. The textbooks are as follows: *Holt Modern Biology (Holt et al., 2002), Prentice Hall Biology (Miller and Levin, 2004), Glencoe Biology (Bigg et al., 2004), and BSCS Biology: A human approach (Biological Sciences Curriculum Study, 2003)*.

Five high school general science textbooks in Korea were selected for this study. These five textbooks were most widely used in high school classrooms of Korea and published by several major publishing companies in Korea. Because the introductory chapter of the high school general science textbooks generally present the methods of science and how science works, the study adapted the high school general science textbooks, instead of biology textbooks, to examine the way of presentation for the nature of science in Korea. The textbooks are as follows: *Dae-Han General Science (Lee et al., 2001), Kyohak-Sa General Science (Kang et al., 2001), Kym-Sung General Science (Lee et al., 2001), Chug-Ang Education General Science (Woo et al., 2001), and Jeehak-Sa General Science (Lee et al., 2001).*

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 and Chiappetta (2009) to train individuals who use this approach for content analysis. The protocol is 55 pages, contains 62 examples of units of analysis to code. The first set of units to code requires a categorization, followed by the answer. This offers an orientation and initial practice. The next set requires the coder to categorize the units, which are then checked with a key to determine the accuracy of the rating. The authors of this investigation solicited the help of two coders for analyzing U.S. high school biology 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 introductory chapter of the textbooks. Also, two researchers of the study participated as coders in analyzing Korea high school science textbooks after training of the protocol with the modified the four themes of the nature of science framework.

RESULTS

Results of the reliabilities indexes for the analyses of the first chapter in the four U.S. high school biology textbooks under examination, in regard to the four-theme nature of science framework, are reliable, as indicated by the Cohen's *kappa* values range from .63 to .96 across the three types of data. The content analysis procedure used for assigning text units to the nature of science categories resulted in good to excellent agreement on 6 out of 11 sections; all sections of text, figures, and assessments with *kappa* values greater than .75, and fair to good agreement on 5 out of 11 with *kappa* values between .40 and .75. The reliabilities indexes for the analyses of the first chapter in five Korea high school general science textbooks range from 82.4% to 100% for percentage agreement and from .79 to 1.00 for *kappa*. Thus, the reliabilities for Korea high school general science textbooks analyses indicate good to excellent agreement beyond chance for all five textbooks analyses. These reliability indexes permit a reasonably good level of confidence in interpreting the quantitative results of U.S. textbooks analysis and very good level of confidence in presenting the results of Korea textbooks analysis.

Table 2. Intercoder Reliabilities in the Four U.S. High School Biology Textbooks by Data Location

Biology Textbook	**Percentage Agreement**			**Cohen's *kappa***		
	Text	Figure	Assessment	Text	Figure	Assessment
BSCS Human*	73.0%	77.8%		.63	.71	
Glencoe	83.1%	79.5%	79.4%	.80	.74	.74
Holt	83.5%	96.1%	81.6%	.80	.96	.78
Prentice Hall	81.3%	85.7%	76.1%	.77	.83	.69

* *BSCS Human Biology* did not have an assessment section at the end of the first chapter

Table 3. Intercoder Reliabilities in the Five Korean High School Science Textbooks by Data Types

Science Textbook	**Percentage Agreement**			**Cohen's *kappa***		
	Text	Figure	Assessment	Text	Figure	Assessment
Daehan	93.6%	95.5%	95.2%	.93	.95	.95
Kyohaksa	92.5%	100%	96.8%	.92	1.00	.97
Kymsung	91.9%	90.9%	95.8%	.91	.90	.96
Chuang	96.5%	100%	82.4%	.96	1.00	.79
Jeehaksa	91.5%	100%	91.7%	.91	1.00	.91

With regard to balance of treatment for the four aspects of the nature of science in the first introductory chapter from the four U.S. high school biology textbooks, the pattern of percentage of presentation of the four themes at different data -- text, figures, and assessments -- are shown to be similar across these three types of data. Specifically, one of U.S. high school biology textbooks under examination devoted more than one second portion of content in Category II, Science as a Way of Investigation and some of textbooks places emphasis on Category III, Science as a Way of Thinking across the different types of data. On the other hand, in terms of the publishing company, the pattern of presentation of the four themes categories was shown to be diverse. For instance, while some of U.S. high school biology textbooks focus on Category II, Science as a Way of Investigation, some textbooks place emphasis on Category III, Science as a Way of Thinking. Therefore, while the authors of U.S. textbooks appear to be consistent in presenting their messages about how science and biology should be conveyed to students across the different parts of the chapter, the balance of presentation of the four themes of the nature of science varies by publishing company, which is evident in the approach, organization, and depth of treatment.

Table 4. Mean Percentages of Nature of Science Categories Found In Four U.S. High School Biology Textbooks by Data Location

Biology Textbook	**Data Location**	**Nature of Science Categories**			
		I	II	III	IV
BSCS Human	Text	2.9	50.7	26.5	20.1
	Figure	5.0	55.0	30.0	10.0
	Assessment*				
Glencoe	Text	11.1	44.1	32.2	12.8
	Figure	40.6	22.0	18.6	18.7
	Assessment	21.4	18.8	47.4	12.5
Holt	Text	36.1	14.3	34.2	15.5
	Figure	48.1	15.4	25.0	11.6
	Assessment	28.1	49.3	12.5	10.2
Prentice Hall	Text	15.7	25.3	37.3	21.6
	Figure	20.2	34.2	31.4	14.2
	Assessment	23.0	28.4	39.0	9.8

* *BSCS Human Biology* did not have an assessment section at the end of the first chapter.
Note. Nature of Science Category I presents knowledge produced by science & nature of knowledge; Category II engages students in investigations, science process skills, & reasoning; Category III illustrates thinking and work of scientists, and the scientific enterprise; and, Category IV shows interactions among science, technology, and society and the social construction of knowledge

Table 5. Mean Percentages of Nature of Science Categories Found In Five Korean High School Science Textbooks by Data Types

Biology Textbook	Data Location	Nature of Science Categories			
		I	II	III	IV
Daehan	Text	14.7	43.8	11.6	30.0
	Figure	8.3	4.2	25.0	62.5
	Assessment	53.7	3.7	12.0	30.8
Kyohaksa	Text	18.3	27.3	23.5	30.9
	Figure	8.9	0.0	42.2	48.9
	Assessment	9.0	53.9	6.7	30.3
Kymsung	Text	11.8	37.1	20.0	31.0
	Figure	27.3	0.0	41.0	31.9
	Assessment	47.2	10.6	15.9	26.4
Chuang	Text	14.3	36.8	18.8	30.1
	Figure	21.4	14.3	28.6	35.7
	Assessment	28.5	32.7	9.7	29.1
Jeehaksa	Text	21.2	30.6	25.0	23.3
	Figure	33.3	11.1	22.2	33.3
	Assessment	53.1	21.8	6.2	18.7

With regard to balance of treatment for the four themes of the nature of science in the five Korea high school general science textbooks, the pattern of percentage of presentation of the four themes are shown to be diverse in three different types of data – text, figures, and assessment. While most Korea high school general science textbooks place emphasis on Category II, Science as a Way of Investigation and IV, Interaction of Science with Technology and Society in text section, most of assessment focus on Category I, Science as a Body of Knowledge. This is an interesting finding because most Korea high school general science textbooks place great emphasis on the product of science (Science as a Body of Knowledge) when they assess students' understanding of the nature of science even though they attempt, in the first or introductory chapter, to convey an idea of what science is by emphasizing investigation and the processes of scientists.

On the other hand, the pattern of presentation of the four themes categories in the five Korea high school general science textbooks was shown to be relatively similar in terms of the publishing company. All of Korea high school general science textbooks in text section place emphasis on Category II, Science as a Way of Investigation and Category IV, Interaction of Science with Technology and Society with approximately one third portion of the content in each two themes across the different publishing companies. In general, most of Korean high school general science textbooks reflect a rationally balanced treatment of the four themes of the nature of science by devoting a reasonable portion of content materials in the four themes of the nature of science. Therefore, while the authors of Korea high school general science textbooks appear to be diverse in presenting their message about how science works by different types of data – text, figures, and assessment, the balance of presentation of the four themes of the nature of science seem to be comparable across the different publishing companies.

DISCUSSIONS AND CONCLUSIONS

The current analyses of U.S. and Korean textbooks demonstrates that while U.S. high school biology textbooks are considerably different in presenting the four aspects of the nature of science by the different publishing companies, the presentation of the nature of science in Korean textbooks is relatively similar across the publishing companies. The findings show 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. Similarly, the comparison of the analyses of U.S. and Korea textbooks present that while only some U.S. high school biology textbooks reflect a reasonably balanced treatment of the four themes of the nature of science in the first chapter, most of Korea high school general science textbooks reflect a reasonably balanced treatment of the four themes of the nature of science by devoting a portion of content materials in the four themes of the nature of science. This suggests that while some authors of U.S. high school biology textbooks attempt to incorporate national science education goals into their materials in the first chapter of high school biology textbooks, the authors of Korea textbooks seem to be more informed about the national-level science education standards and attempt to incorporate the standards into their curriculum materials with a more balanced treatment of scientific literacy. This is because system of publishing textbooks in Korea must be more national-level based than it's of U.S.

In addition, both authors of U.S. high school biology textbooks and Korean high school general science textbooks are attempting, in the first or introductory chapter, to convey an idea of what science is and how the scientific enterprise works by emphasizing investigation and the thinking processes of scientists -- not by presenting scientific knowledge. On the other hand, while the authors of U.S. high school biology textbooks have little emphasis on interaction of science and technology and society, the authors of Korea high school general science textbooks are presenting the nature of science by emphasizing STS. These findings indicate that both authors of U.S. high school biology textbooks and Korean high school general science textbooks seem to want high school students to understand the nature of science as a process of science (Science as a Way of Investigation and Science as a Way of Thinking) rather than emphasizing the products of science (Science as a Body of Knowledge).

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 importance of textbooks, many nations invest heavily in creating and revising textbooks, particularly because science education plays an essential role not only for individual development, but also for national development (Chrisman, 1984). This comparative analysis of science textbooks between U.S. and Korea, which are scientifically developed nations, may enhance science education by providing 1) a summary of the four themes of the authentic view of science, 2) an assessment of the current level of science curricular currently presented to students, and 3) some guidelines on development and revision of textbooks. In addition, in view of reports that science education in other countries 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. Finally, the examination of an entire section of the textbook provides a more fine-grained analysis than taking a random sample of text passages.

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