The portrayal of the nature of science in early childhood instructional materials

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The portrayal of the nature of science in early childhood instructional materials

by

Brandon Alan Schrauth

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Education

Program of Study Committee:
Joanne K. Olson, Major Professor
Corey J. Drake
James T. Colbert

Iowa State University
Ames, Iowa
2009

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CHAPTER 1. OVERVIEW

Science education has a dual role for society as it seeks to help students to understand what is currently known and accepted in regards to the natural world the content as well as help students to come to understand how science works the nature of science. While both must occur simultaneously as one without the other will not lead to science literacy, explicit teaching of the nature of science (NOS) is often overlooked. Many explanations may account for this oversight, this thesis will explore the portrayal of NOS in early childhood instructional materials. While many of the aspects of the nature of science are inherently abstract ideas, early childhood students should be provided experiences that provide a foundation for an accurate understanding later. Otherwise, misconceptions are developed early on and then reinforced leading to a very fuzzy portrayal for students.

Introduction

One issue plaguing science education and science teaching is the way in which the nature of science is portrayed in science classrooms. The consensus vision of international reform documents is for students to gain an accurate understanding of the nature of science (e.g. American Association for the Advancement of Science, Project 2061, Council of Ministers of Education, 1997; Curriculum Council, 1998; National Center for Educational Research and Development, 1997; National Science Teachers Association, 1982, 2000). However,
teachers and students still hold many misconceptions about the nature of science even with an abundance of research available (McComas, Clough, & Almazroa, 1998). The mismatch of science education reform documents and what is being portrayed in classrooms raises serious concerns for teachers. As the United States education system is increasingly focused on accountability measures, external and internal pressures have coincided to increase science content while decreasing time allotted for science instruction because literacy and math are consuming more time (McMurrer, 2007). While an objective of science education is to develop scientific literacy, and bring to maturation an adequate student understanding of the nature of science we do not know the extent to which instructional materials (e.g. published textbooks, teachers manuals, and kits) may not accurately and consistently portray the nature of science in ways advocated by the reform documents. Instructional materials are of particular importance because teachers traditionally have misconceptions regarding the NOS, and lack preservice preparation in nature of science and NOS pedagogy.

Research consistently shows that the majority of students and teachers continue to have naïve views of major aspects of the NOS (Abd-El-Khalick, 2005; Abd-El-Khalick & Akerson, 2004; Bianchini & Colburn, 2000; Clough, 1995). Research repeatedly demonstrates that teachers' and students' understanding of the NOS is limited, incomplete, and inaccurate. Not surprisingly, an early understanding of scientific phenomena can lead to a better understanding of scientific concepts later (Eshach & Fried, 2005). Likewise, providing science instruction that supports an
accurate understanding of the nature of science early in a student’s educational experience has the potential to prevent some of the misconceptions that are seeded and then reinforced over and over through K-12 classroom instruction.

**Background**

The purpose of this study is to examine the extent to which the nature of science is presented in early childhood instructional materials and the accuracy of those NOS portrayals. Commercial instructional materials are published educational materials that are purchased by a school district, often requiring state approval, and used to aid teachers’ instruction in the classroom. This study acknowledges that teachers often adjust and adapt these materials; however, for the purposes of this study, only published materials were examined.

Instructional materials are in many ways the teacher’s best way to gain support in content knowledge, pedagogical content knowledge as well as an accurate view of the nature of science. Elementary teachers plan and teach several subjects throughout the day and their preservice education provides them with a generalist background. Elementary teachers consider themselves less qualified to teach science compared to other curriculum areas (Bayer, 1995; Anderson & Mitchener, 1994; Cochran & Jones, 1998). This increases teachers’ reliance on curriculum materials to help them increase their own content knowledge as well as how to teach the content (Abell, Bryan, & Anderson, 1998; Chochran & Jones, 1998; Davis, Petish, & Smithey, 2006). This becomes a significant problem when the
materials are of poor quality (Kesidou & Roseman, 2002; Stern & Roseman, 2004), inaccurately portray content, and are a mismatch to students’ backgrounds (Kesidou & Roseman, 2002; Stern & Roesman, 2004). Despite district and state standards and benchmarks, these materials become the curriculum determining what is taught and how it is learned (Chiappetta, Ganesh, Lee, & Phillips, 2006). In the case of elementary teachers, instructional materials often become the curriculum and the teachers’ only avenue for professional development opportunities in science education.

For this study, commercial instructional materials were investigated because they are a critical mediator in what the teacher knows and presents to students during a science lesson. Previous studies have found that elementary teachers often rely heavily on these materials to teach science because of a lack of both content knowledge and NOS understanding (Akerson, Abd-El-Khalick, & Lederman, 2000; Bayer 1995). Because of teachers’ reliance on instructional materials, determining the representation of the NOS and degree that it is presented is of utmost importance if the vision of the reform documents is to be realized.

**Research Questions and Methodology**

*Question One: What nature of science aspects are represented in early childhood teaching guides?*

To answer question one, a rubric developed and utilized by Abd-El-Khalick, Waters, and An-Phong (2008) in their review of NOS in high school chemistry
textbooks was modified. The modifications incorporated an NSTA position statement regarding the nature of science, and a recent study of elementary teachers who effectively improved their students’ NOS views (Hanuscin, Lee, and Akerson, 2008). The rubric was tailored to fit the K-2 grade span with descriptors of what each NOS aspect might look like for children of this age group.

Physical science units were selected for three kit-based programs: Full Option Science System (FOSS), Insights, Science and Technology for Children (STC), and one textbook-based program, Scott Foresman. Each teacher’s guide was evaluated. The content of the teacher guide consisted of the background information for the teacher and the lessons as they were intended to be taught. For this question, the researcher was specifically evaluated which aspects were present within the materials. This was done by reading through the lesson and coding if there was evidence of specific NOS aspects in regards to what the students would experience.

Question Two: How explicit or implicit is the nature of science addressed in early childhood curriculum materials?

To answer question two, the rubric (see appendix) was used to evaluate the lesson plans to measure the extent to which the nature of science was addressed for each of the target NOS aspects. Each time there was evidence of a representation of NOS in regards to what the students would experience the researcher determined the degree of explicitness using the criteria on the rubric.
CHAPTER 2. REVIEW OF LITERATURE

Introduction

The National Science Teachers Association (2000) has taken the position that teachers are responsible for teaching the nature of science to their students. They have outlined the characteristics they believe to be essential: (a) scientific knowledge is both reliable and tentative; (b) no single scientific method exists, but there are shared characteristics of scientific approaches (c) creativity plays a role in the development of scientific knowledge; (d) there is a relationship between theories and laws; (e) there is a relationship between observations and inferences; (f) though science strives for objectivity, an element of subjectivity always exists in the development of scientific knowledge; and (g) social and cultural contexts also play a role in the development of scientific knowledge.

We know there is a mismatch between reform documents and teachers’ and students’ beliefs regarding the nature of science. Much research has documented high school and college students’ misconceptions of the nature of science (e.g. BouJaoude, 1996; Griffiths and Barman, 1995; Meichtry, 1993; Moss, 2001; Smith et al. 2000). Studies have identified that elementary teachers also hold uninformed view of the NOS (e.g. Abd-El-Khalick, 2005; Akerson, Morrison, McDuffie, 2005; Lederman, 1995; Martin-Diaz, 2006). Recent work points out that elementary-aged students not surprisingly have inaccurate and naïve ideas of the nature of science (Finson, Thomas, & Pedersen, 2006; Akerson & Abd-El-Khalick, 2005; Akerson &
Volrich 2006; Akerson & Volrich 2006). A striking disconnect exists between what is proposed through reform documents and what is revealed in the literature.

**Elementary Students’ Conceptions of the NOS**

What NOS conceptions elementary students have is not well understood (Smith, Maclin, Houghton & Hennessey, 2000), but what little is known indicates elementary students have uninformed NOS ideas. Recent studies have indicated that 6-7 year old students held uninformed NOS views (e.g., Abd-El-Khalick, 2002; Akerson & Abd-El-Khalick, 2005; Meichtry, 1993; Akerson & Volrich 2006). In fact, prior to explicit instruction of the NOS aspects early childhood students hold many misconceptions about the role of creativity, the tentativeness of scientific knowledge and the distinction of observation and inference (Akerson & Volrich, 2006, Lederman & Lederman, 2004). Research in this area is relatively recent; much remains to be learned and understood.

The literature has attributed three fundamental reasons why little is known about elementary students’ conceptions of the nature of science. First, the NOS aspects have been thought to be too abstract for this age group. Second, elementary teachers themselves hold misconceptions regarding the NOS. Third, disagreement exists regarding how to assess young students’ NOS views. Recent studies demonstrate that early childhood students are capable of developing an understanding of NOS and scientific literacy (Akerson & Donnelly, 2009; Lederman & Lederman, 2004). Currently, a revised version of an instrument, VNOS-D, was
transformed into an elementary version with lower vocabulary, called VNOS-E (Lederman & Lederman, 2004). This assessment has demonstrated some success in revealing what students know pre- and post-instruction in regards to the NOS aspects. Akerson and Abd-El-Khalick (2005) reported that fourth graders in a study they conducted had conceptions of NOS that were inconsistent with the recommendations of reform documents (AAAS, 1993; NRC, 1996). This trend continues through middle school and high school (e.g. BouJaoude, 1996; Griffiths & Barman, 1995; Khishfe & Abd-El-Khalick, 2002; Meichtry, 1993).

Elementary teachers’ naïve and inaccurate views of the nature of science have prevented them from being able to readily identify and explicitly teach towards an accurate student understanding of these important ideas. However, a strong correlation exists between inquiry-based instruction and explicit NOS – leading to positive NOS outcomes in elementary aged students (Khisfe & Abd-El-Khalick, 2002; Akerson & Abd-El-Khalick, 2003, 2005; Akerson & Volrich, 2006). Recent research indicates that K-2 students developed adequate views of empirical NOS, creative NOS, observation vs. inference, and to a lesser degree, the subjective NOS (Akerson & Donnelly, 2009) with explicit NOS instruction (Akerson & Volrich, 2006).

Much more is known about how high school and undergraduate students view the nature of science. Ryan and Aikenhead (1992) categorize these common misconceptions regarding nature of science as:

1. Existence of a universal scientific method
2. Science is objective
3. Confusion of hypothesis, theory, and law
4. Tentative nature of scientific knowledge
5. Scientific knowledge is discovered
6. Confusion of science and technology

Existence of a universal scientific method:

This misconception of science states that there is a set series of steps that all scientists follow when they are doing science. Often these steps are characterized as the “scientific method,” which traditionally has steps including hypothesis, research, data collection, experimentation or testing, conclusions, and reporting. Ryan and Aikenhead (1992) found that 64% of students assessed held the belief that a pattern to doing science existed; some to a greater extent than others. In a study conducted by Moss (2001), many of his participants viewed the “ordered, systematic nature of the process of science as the only criteria in characterizing whether an activity was representative of science” (p 779). Many students in Moss’ (2001) interviews tried to recall “the steps” to the scientific method when talking about what scientists do. Stein and McRobbie (1997) found that around 50% of students contributed ideas about science being a process. For these students, science seems to be reduced down to a series of isolated actions or processes.

Interestingly, Griffiths and Barman (1992) found national differences in responses to NOS questions. Overwhelmingly, 75% of the American students agreed that scientists follow the traditional scientific method. Only 30% of Canadian
students held such a view and Australian students hardly ever spoke in terms of the traditional scientific method, although frequent references to experimenting were made.

**Science is objective:**

Society tends to view science and scientists as objective and that the observations that scientists make are completely objective and devoid of opinion. In Griffiths and Barman’s study 60% of Australian, 45% of Canadian, and 25% of the American students held the position that observations come before theories, thus ignoring the ideas that theories drive what scientists choose to observe (1992).

In Moss’ (2001) study, one student stated that variables were the reason why different scientists may come to differing ideas. Ryan and Aikenhead (1992) also found that students “were not so worldly when asked if ‘the best scientists are always very open-minded, logical, unbiased, and objective in their work’ (pg. 568)”.

In the study by Abd-El-Khalick, et. al. (2001) an expert group studied mentioned the subjectivity in science based on scientists backgrounds, but the novice group focused on differences and inadequacies of the data.

One study (Haslam & Gunston, 1996) specifically targeted students’ ideas on observation. Most viewed observation as a tool in science, or something they only did when it was teacher-directed. There was some discussion on how observation being theory-laden or results in inferences. Of the students in the study none used
the word inference and when introduced, only one claimed to have heard it before, but was unable to suggest a definition.

Confusion of hypothesis, theory, and law:

Much confusion exists about the definitions and roles of hypothesis, theory, and law in science. It doesn't help that society often uses the terms incorrectly as well, such as using theory to mean a guess or speculation. Ryan and Aikenhead (1992) found 64% of their participants held a hierarchical relationship of the three in which a hypothesis becomes a theory and then a law as the amount of proof increases. For example a student said that gravity was a fact because it is a proven theory (Griffiths & Barman, 1992), another stated theories were "an idea that hasn't yet been proven," and 15% described theories as an educated guess. Yet another student said "after it has been tested over and over again then the theory will become stronger until it becomes law or fact." Other studies (Abd-El-Khalick et al., 2001) also found a high percentage, 78%, of the participants believe in a hierarchical relationship of theories and laws. Some Canadian students related scientific laws to governmental laws that guide what scientists do (Griffiths & Barman, 1992).

Tentative nature of Scientific Knowledge:

More often then not, scientific knowledge is seen as unalterable truth; this unchanging body of knowledge that science continually adds onto. "Compared to philosophy and religion...science demands definitive answers with right and wrong
answers (Abd-El-Khalick, 2001).” Griffiths and Barman (1992) received mixed answers on “What is a scientific fact?” and “Are scientific facts open to question?”. Most students stated that a fact was something proven, something that was always true. Upon additional questioning a few students stated that they could change later or become better as technology advanced. However, the students seemed reluctant to acknowledge that a fact could change. In the same study, 45% of American students said a law won’t change or that they are definitive. Stein and McRobbie (1997) also had students who acknowledged that science could change, but only a few mentioned scientific knowledge changing. “Knowledge changes with time as new and better theories are developed or new evidence is discovered” (pg 617).

*Scientific knowledge is discovered only:*

While discovery is part of the work of a scientist, scientific knowledge is often wrongly seen as discovery *only*. When scientific knowledge is viewed in this light often the creative and inventive side of science is lost. Scientists are seen as geniuses that know a lot of information and are able to find the right pieces to the puzzle. One student said science is not creative – either you prove it or you can’t (Griffiths & Barman, 1992). Luckily not all students hold this bleak outlook on science. Abd-El-Khalick et al. (2001) had many responses that scientists use creativity even from their novice group. Unfortunately, participants stated that any “conjecturing” could be determined correct by use of the scientific method.
Ryan and Aikenhead had a majority of their participants squarely in the middle between discovery and invention. The second highest group, 34%, held the ontological view that science describes what is “real” in the universe. One student wrote “The process of experimenting and searching for knowledge; the study of truth,” (Griffiths & Barman, 1992 p. 6, 1992) when describing what science was. Moss (2001) found a lack of students seeing the role of what he calls serendipity in obtaining scientific knowledge. Moss states, “the history of scientific discovery is filled with accounts of scientists being able to capitalize on unanticipated circumstances.” There are some troubles with a statement like this because the author, when describing serendipity, uses the word discovery and seems to imply discovery as being important to obtaining scientific knowledge.

Confusion of science and technology:

The confusion between science and technology can be seen in how funding decisions are made about science. More often society will vote or lobby that funding should be concentrated on things that have an immediate benefit or product. This shows a misunderstanding of the relation of science and technology. Moss (2001) had many students respond that science is everything, that everything has science to it, and that even fixing a car was science. The students when thinking of science as all around them, were likely wrongly thinking of technology such as computers, cars, light bulbs, medicines, etc. Stein and McRobbie had a whole category of student responses that viewed science as a consumable product. Students stated
that science was products that had been invented to help people and applications such as medicine and machinery.

This is not to say that all students hold these misconceptions. In fact, all the studies thus far described had some students who held accurate conceptions of the nature of science. Often students hold accurate conceptions about some aspects and naive conceptions of others. While understanding widespread student misconceptions is useful individual teachers should assess students to obtain an understanding of specific students’ conceptions on the nature of science.

**Nature of Science Curriculum Analysis**

Despite the large role of instructional materials in defining elementary science, little is known about the representation of the nature of science in elementary curriculum materials. Babikian (1975) speculated that elementary school science textbooks did not provide an accurate portrayal of the nature of science and the work of scientists. Results from Babikian’s survey (1975) indicated that elementary science texts present an abbreviated view of science. Since that study, little if any investigation has occurred, with respect to how NOS is represented in science instructional materials. This is especially interesting, as inquiry-based kit programs have regained their popularity. Current kit-based instructional materials are based upon inquiry-oriented programs such as “Science Curriculum Improvement Study” (SCIS) and “Science - A Process Approach” (SAPA) – both of which developed in the 1960s and directly advocated that children should learn
science in authentic ways. Given the attention to “doing” science, and the prominence of NOS in current reform documents, one could expect that NOS would be present and more accurately represented.

More is known about the representation of NOS in the middle school and high school curriculum materials. Abd-El-Khalick et al. (2008) conducted a study that assessed the representation of NOS in high school chemistry textbooks over the last four decades. The textbooks were found to poorly represent NOS and with few exceptions little had changed over the last four decades. In Hong Kong, Yip (2006) found that science textbooks focus mainly on the transmission of scientific facts and concepts contrary to the goals for the junior science curriculum.

Carvalho and Carvalho (2002), point out that textbook writers fail to deal with subjects such as history and philosophy of science. Abd-El-Khalick (2002) suggested that the naïve views of NOS that secondary students held could be attributed to the way science is represented in science textbooks and taught in the classroom. Studies of middle and high school curriculum materials demonstrates a mismatch between the reform documents goals for science literacy in regards to the nature of science and the content and manner in which it is to be presented by teachers to students.

**Teachers’ Use of Instructional Materials**

The materials that are readily accessible to teachers to have at their fingertips play a critical role in the planning and delivery of instruction. Instructional materials
have a role in helping to initiate and sustain reform in science education because they are concrete, tangible vehicles for embodying the essential ideas of science education reform (Powell & Anderson, 2002). The use of these materials can be problematic when the materials are inconsistent with research-informed by the science education reform documents. For example, science textbooks present a distorted view of scientific investigations, using a classical experimental design that perpetuates the notion of “The Scientific Method” (Lederman, n.d.). This is a NOS misconception that is repeatedly reinforced through curriculum materials and transmitted to students by teachers. Research indicates that explicit teacher professional development on what is meant by the nature of science as well as how the materials support specific aspects benefits teachers’ use of materials (Lederman, n.d.). “One-shot” professional development that is often provided for teachers does not pave the way for successful use (Powell & Anderson, 2002).

Like their secondary colleagues, elementary teachers need continuous support as they develop an accurate understanding of NOS (Lederman, n.d.; Akerson, Morrison, McDuffie, 2005) and pedagogical content knowledge that helps them to explicitly teach the nature of science (Powell & Anderson, 2002). Teacher professional development is insufficient to promote reform needed for effective NOS instruction. Lederman (n.d.) indicates that teachers’ understandings of NOS do not carry over into classroom instruction.

Three overall approaches have been delineated in the literature for teaching the nature of science: implicit, historical, and explicit. The implicit approach
proposes that by “doing science” students will gain an accurate understanding of the nature of science (Lawson, 1982; Rowe, 1974). Several studies deem this approach as ineffective in helping students gain an accurate understanding of the NOS (e.g., Riley, 1979; Spears & Zollman, 1977; Trent, 1965). A contrasting approach, endorsed by the National Science Education Standards (NRC, 1996), is the historical approach. This approach presents students with contextualized vignettes that depict the process development of scientific ideas. The impact of this approach is minor (Solomon, Duveen, Scot & McCarthy, 1992). A more direct method is an explicit approach with instruction focused on specific aspects of the nature of science that incorporates elements of history and philosophy (e.g. Akindehin, 1988; Billeh & Hasan, 1975; Carey & Stauss, 1968, 1970).

In spite of a considerable amount of documented research showing its ineffectiveness, teachers continue to provide opportunities for students to simply “do science” and hope that they will gain an accurate understanding of the nature of science (Lederman, n.d.) This is contrary to approaches that result in an accurate understanding of NOS.

Evidence suggests more potential exists when the materials are formatted in a manner that educates teachers in an integrated manner. Educative curriculum materials, formatted to promote teacher learning, have demonstrated they can help elementary teachers overcome the obstacles of teaching science accurately (Dietz & Davis, 2009). Descriptions of teaching within lesson plans can promote productive reflection and increase pedagogical content knowledge (Dietz & Davis, 2009).
Teachers used educative features addressing pedagogical content knowledge more often and more effectively than those materials that addressed either pedagogical or content knowledge only (Schneider & Krajcik, 1999).
CHAPTER 3. METHODS AND PROCEDURES

Introduction

This study examined the representation of the nature of science in seven grades K-2 commercial physical science curriculum materials using a rubric-based structured lesson analysis. The scoring rubric was developed for this study identifying six fundamental aspects of the nature of science (Abd-El-Khalick, Waters, & Le, 2007; NSTA, 2009) with specific sub-criteria that were defined by the researcher for the targeted age group. Six of the teacher guides were from kit-based programs and one was a textbook series. Each of the materials was self-described as being aligned with current reform documents regarding the teaching of science.

Methods

Scoring Rubric

The work to define the representation of the nature of science in early childhood instructional materials began with identifying fundamental aspects of the nature of science. In order to do this several reform documents were consulted (e.g. AAAS, 1993; NRC, 1996; NSTA, 2000) NOS concepts used for this study were based on a rubric developed by Abd-El-Khalick et al. (2007). Once each of the aspects were identified, further description was necessary to define indicators of each NOS aspect that were appropriate for K-2 students. Currently, very few explicit descriptions of NOS for early childhood education exist. Current literature indicates that it is not developmentally appropriate to target the NOS aspect of formation of
theories and laws (e.g. Akerson & Abd-El-Khalick, 2005; Akerson & Volrich, 2006; NSTA, 2000; AAAS, 1993) so this NOS concept was intentionally removed.

Each NOS concept was given a set of score categories ranging from +3 to -3, which comprised the final scoring rubric used in this study (See Appendix A and Table 1). The “Targeted NOS Concepts” remained the same but much work was done to explicitly describe what the NOS aspect would look like in specific terms (Table 1). These descriptors were formulated by reviewing the previous study of the representation of the nature of science in high school chemistry textbooks (Abd-El-Khalick et al. 2007) and the work of Hanuscin et al. (2008) to understand elementary teachers' pedagogical content knowledge for teaching the nature of science. They were further revised and altered as the rubric was employed upon the lessons to ensure it was responsive to the needs of this study.

<table>
<thead>
<tr>
<th>Targeted NOS Concept</th>
<th>Descriptor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific knowledge is simultaneously reliable and tentative.</td>
<td>• Scientists try to organize the natural world.</td>
</tr>
<tr>
<td></td>
<td>• Scientists can get the same results repeatedly.</td>
</tr>
<tr>
<td></td>
<td>• Scientists can change their ideas.</td>
</tr>
<tr>
<td>No single universal step-by-step scientific method exists.</td>
<td>• Scientists use various methods of investigation.</td>
</tr>
<tr>
<td>Creativity is a vital part of doing science.</td>
<td>• Scientists create new ideas.</td>
</tr>
<tr>
<td></td>
<td>• Scientists’ backgrounds help them with their ideas.</td>
</tr>
<tr>
<td></td>
<td>• Scientists explain their observations.</td>
</tr>
<tr>
<td>Science is based on naturalistic methods and explanations.</td>
<td>• Scientists collect data</td>
</tr>
<tr>
<td></td>
<td>• Scientists use evidence to explain their ideas.</td>
</tr>
<tr>
<td>Contributions to science can be made and have been made by people the world over.</td>
<td>• Scientists work together.</td>
</tr>
<tr>
<td></td>
<td>• Scientists review and discuss findings with other scientists.</td>
</tr>
<tr>
<td>Social and Cultural context of science.</td>
<td>• Scientists are affected by their culture.</td>
</tr>
<tr>
<td></td>
<td>• Scientists can help society.</td>
</tr>
</tbody>
</table>
Explicit versus Implicit Representations

When coding curriculum materials, the researcher considered both explicit and implicit NOS messages that would be communicated to students. Explicit representations are described as a direct, clear, and obvious representation of NOS. Implicit representations are those that were not stated directly, but consist of those messages about science and how it works that a student will likely develop as a result of completing a unit as described in the curriculum materials. It is important to note that the materials were viewed in light of what they were intended to portray to students. Therefore, the focus was on what the teacher was instructed to portray through the lesson: activity/investigation, prompts, and questions. For example, if a unit requires students to work alone and compete, with a clear “winner” at the end, students are sent an implicit message that scientists work alone and in a competitive environment. The goal of this study was not to identify opportunities for the teacher but instead how is the nature of science being represented for students.

Determining NOS Accuracy: Scoring Categories

As stated earlier, each NOS aspect was scored using a scale that ranged from 3 to -3. High positive scores, consistent with the literature on effective NOS instruction, convey science accurately and explicitly. Lower positive scores are also accurate, but are more implicit. A score of “zero” is used when the NOS concept is not present. Negative scores were used when materials were implicit and partially accurate in their NOS portrayals, or explicit and inaccurate. (See Table 2).
Table 2. NOS Explicitness Rating Scale

<table>
<thead>
<tr>
<th>Number</th>
<th>Representation Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The lesson conveys: Explicit, informed, and consistent representation of the target NOS aspect.</td>
</tr>
<tr>
<td>2</td>
<td>The lesson conveys: Explicit, partially informed representation of the target NOS aspect.</td>
</tr>
<tr>
<td>1</td>
<td>The lesson conveys: Implicit, informed, and consistent representation of the target NOS aspect.</td>
</tr>
<tr>
<td>0</td>
<td>The target NOS aspect is not addressed in the lesson.</td>
</tr>
<tr>
<td>-1</td>
<td>The lesson conveys: Implicit misrepresentation of the target NOS aspect.</td>
</tr>
<tr>
<td>-2</td>
<td>The lesson conveys: Mixed explicit and/or implicit messages about the NOS aspect.</td>
</tr>
<tr>
<td>-3</td>
<td>The lesson conveys: Explicit, naïve representation of the target NOS aspect.</td>
</tr>
</tbody>
</table>

Selection of Materials

Curriculum materials were selected based on their structure (kit-based or textbook-based) as well their stated alignment to reform documents (See Table 3). The cluster of the three kit-based programs each describe themselves as hands-on and inquiry-based. All of the kit-based programs were developed with NSF funding and are actively promoted in NSF-funded professional development and school reform projects at the elementary level. Thus, these programs are in wide use throughout the country and should be consistent with national reform efforts in science education. These programs include Full Option Science System (FOSS), Insights, and Science and Technology for Children (STC). The other teaching manual was textbook-based published by Scott Foresman yet claimed that it was correlated with the NSTA standards. A textbook was included because many districts continue to use textbooks due to financial issues.

From the curriculum materials selected, physical science units were analyzed for this study. This was done to provide a consistent content band across the study.
A concerted effort was made to obtain the most current version of each of the teacher manuals ranging from 1996-2006.

<table>
<thead>
<tr>
<th>Name of Curriculum</th>
<th>Grade(s)</th>
<th>Unit Title/ Publication Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insights K-1</td>
<td></td>
<td>Balls and Ramps (2003)</td>
</tr>
<tr>
<td></td>
<td>2-3</td>
<td>Lifting Heavy Things (2003)</td>
</tr>
<tr>
<td>Full Option 1-2</td>
<td></td>
<td>Balance and Motion (2002)</td>
</tr>
<tr>
<td>Science and Technology for Children K/1</td>
<td>Solids and Liquids (1996)</td>
<td></td>
</tr>
<tr>
<td>Scott Foresman 1</td>
<td></td>
<td>Observing Matter, Ch. 8, (2006)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sound and Movement, Ch. 9, (2006)</td>
</tr>
</tbody>
</table>
CHAPTER 4. FINDINGS

Introduction

Lessons were reviewed, analyzed, and scored with the aid of the before mentioned rubric (Appendix A) and the data was compiled. To enable comparisons across published materials with differing numbers of lessons a mean score was calculated for each targeted nature of science aspect. Comparisons were then made between mean scores across NOS aspects to gain perspective of NOS portrayals within each physical science unit. Second, comparisons were made across materials to ascertain how a particular NOS aspect is addressed in physical science published instructional materials for this age group.

Analysis

The rubric was used to holistically score each lesson in each teacher manual for a single unit in physical science. The lessons were scored using only the printed materials. As the lesson was read from start to finish, the “NOS Scoring Rubric” was used to note when a targeted NOS aspect was represented, and then it was determined the degree of the representation using the explicitness scale on the “NOS Scoring Rubric” (Appendix A, Table 1). Table 4 provides an example of how a single lesson was scored using the rubric. After each lesson had been scored, those scores were compiled to develop a set of frequencies for each NOS aspect for the entire unit. This enabled the researcher to determine the extent to which NOS is
accurately and explicitly present in the unit as a whole. The mean score enabled the researcher to provide an overall average of the entire units representation of the target NOS aspects. Units from different publishers could then be compared to determine the status of NOS in early childhood physical science instructional materials.

Table 4. NOS Scoring Analysis

|-------------------|--------|-----------------------------------------------------------------------------------------------|
| Scientific knowledge is simultaneously reliable and tentative. | 1 | +Students are asked to compare previously observed solids to a new set of solids. Students are asked to determine what is the same or different.  
+The class works together to chart properties of the objects observed. This list of properties is utilized in later lessons.  
+It is specifically stated, “scientists call materials like this: solids, liquids, and gases”. (p. 13)  
- Students’ attention was not directed to the idea that scientists try to organize the natural world and they document the results of observations and try to determine their reliability of those observations even though students are performing these actions within this specific lesson. |
| No single universal step-by-step scientific method exists. | 0 | This lesson does not address this NOS aspect. |
| Creativity is a vital part of doing science. | 1 | +Students are asked to draw on their prior knowledge and explain their observations of the solids in this lesson.  
+Students work together as a class to create a list of words that can become properties for the solids they observe.  
- Students are not given the opportunity to define how they could go about learning more about solids.  
-Students’ attention was not explicitly directed to the idea that scientists use their backgrounds to help them with their ideas; they create new ideas; and use their creativity to explain their observations. |
### Continued Table 4. NOS Scoring Analysis

<table>
<thead>
<tr>
<th>Target NOS Aspect</th>
<th>Rating</th>
<th>Analysis of <em>Full Option Science System (FOSS): Liquids and Solids (2002)</em> Lesson 1 pgs: 13-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science is based on naturalistic methods and explanations.</td>
<td>-2</td>
<td>+ Students are directed to observe the solid objects (look, feel, smell, and what sounds they make).&lt;br&gt; + Students are asked to explain their observations and assign them properties.&lt;br&gt; + Students help the teacher construct a “Content Chart” where they list that “We use our senses to observe properties of solids” (pg. 16).&lt;br&gt; + Students have opportunities to record their observations.&lt;br&gt; - The word “discovered” is explicitly used to indicate the result of their observations.&lt;br&gt; - Students’ attention was not explicitly directed to the idea that scientists collect data and use evidence to support their ideas even though students are performing these actions within this specific lesson.</td>
</tr>
<tr>
<td>Contributions to science can be made and have been made by people the world over.</td>
<td>1</td>
<td>+ Students meet as a whole class to discuss observations of solids, liquids, and gases.&lt;br&gt; + Students have opportunities to work in small groups to investigate properties of solids and share their observations.&lt;br&gt; + Students meet at the end of the lesson to discuss a list of properties of solids.&lt;br&gt; - Students’ attention was not directed to the idea that scientists work together and review and discuss findings even though they are performing these actions within this specific lesson.</td>
</tr>
<tr>
<td>Social and Cultural context of science.</td>
<td>0</td>
<td>This lesson does not address this NOS aspect.</td>
</tr>
</tbody>
</table>

### Findings

**Question One: What nature of science aspects are represented in early childhood curriculum materials?**

**Overall Findings**

Four key findings describe what NOS aspects are represented in the physical science instructional materials examined:
The idea that scientists work together to review, discuss, and develop claims is represented consistently, but implicitly, throughout the kit-based programs reviewed.

Several of the kit-based materials accurately, but implicitly, represented the NOS concept that science is based on naturalistic methods and explanations.

The social and cultural context of science was rarely represented in the selected instructional materials.

The textbook instructional materials scored low but positive on each of the target NOS aspects.

In the section below, findings for each NOS aspect are further described.

**NOS Aspect 1: Scientific Knowledge is Reliable and Tentative**
None of the instructional materials had explicit representation or misrepresentation of this NOS aspect. The kit-based curriculum materials reviewed had some degree of implicit representation of the reliable and tentative nature of scientific knowledge. The FOSS Teaching Guide “Solids and Liquids” had the highest mean score indicating that it provided the most implicit representation for the teacher. Both STC Teaching Guides had consistently high mean scores for implicit representations. These three teaching guides recommended that teachers help the class create content charts, and have students make revisions to them at the conclusion or beginning of a teaching sequence in light of new evidence. It was often suggested that the teacher connect back to previous learning experiences and have students draw on that evidence to make decisions, and design future learning experiences. Based on these episodes, the conclusion was drawn that an understanding scientific knowledge as both reliable yet tentative was implicitly present. Both Scott Foresman chapters scored low for this NOS aspect, as there was little evidence that this was conveyed except at the end of the chapter during one guided inquiry lesson. The one opportunity occurred in an accurate yet implicit form.
None of the teaching guides provided explicit informed and/or explicit naïve representations of the various methods scientists use to investigate the natural world.

Implicit messages, however, were more common. The FOSS guide provided the teacher several “investigations” that were teacher-led and were step-by-step conveying an implicit message that science is procedural and prescriptive in nature. There were minimal opportunities for students to explore and question how things balance or move. The guided inquiries were presented in a numbered step-by-step process as well. The Scott Foresman teaching guide suggested little opportunity for
the exploration – in fact the bulk of both chapters were text that emphasized learning content and vocabulary. It was determined that the teacher would receive an implicit message that science follows this step-by-step process and is simply based on content knowledge.

**NOS Aspect 3: Creativity is vital part of doing science:**

![Figure 3: Creativity](image)

<table>
<thead>
<tr>
<th>Insights #1</th>
<th>Insights #2</th>
<th>FOSS #1</th>
<th>FOSS #2</th>
<th>STC #1</th>
<th>STC #2</th>
<th>Scott Foresman Ch. 8</th>
<th>Scott Foresman Ch. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Score</strong></td>
<td>0.56</td>
<td>0.93</td>
<td>0.6</td>
<td>0.92</td>
<td>1</td>
<td>0.56</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Creativity was most often represented in an implicit, informed, and consistent manner in the kit-based curriculum materials. However, the textbook series did not address this NOS aspect except during the inquiries at the beginning and end of the chapter. This can be attributed to the fact that it most often included content and did
not convey the idea that scientists use their creativity to create new ideas or explain their observations. Many of the kit-based programs structured lessons so that students had opportunities to explain their observations and develop with ideas regarding how they could learn more about the concepts they were studying. The teacher’s attention was not specifically drawn to this aspect of science, making the score reflect an implicit representation.

**NOS Aspect 4: Naturalistic Methods and Explanations**

![Figure 4: Naturalistic Methods and Explanations](image)

<table>
<thead>
<tr>
<th>Insights #1</th>
<th>Insights #2</th>
<th>FOSS #1</th>
<th>FOSS #2</th>
<th>STC #1</th>
<th>STC #2</th>
<th>Scott Foresman Ch.8</th>
<th>Scott Foresman Ch. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Score</td>
<td>0.89</td>
<td>0.93</td>
<td>0.1</td>
<td>0.77</td>
<td>1</td>
<td>0.56</td>
<td>0.25</td>
</tr>
</tbody>
</table>

The use of evidence to explain ideas, and student collection of data occurred frequently within kit-based lessons. Unfortunately, students were not explicitly
attended to the similarities between these activities and the activities of scientists. The two Insights Units reviewed suggested in all but one or two lessons that students explore, make observations and follow with a discussion that often was intended to lead students to develop an idea or claim grounded in their observation. The examined lessons suggested that students make observations and then gather as a group and debrief their observations. These observations were followed by the development of a science concept or claim with the guidance of the teacher through prompts or questions. Student observations are scaffolded by the teacher through prompts or questions, but it was never explicitly brought to students’ attention that this is something that scientists do.

One kit-based program scored comparatively lower than the others – FOSS #1. This kit, Balance and Motion, provided students with a series of challenges and problem solving tasks. Unlike the other programs, the lessons in this unit do not enable students to even know that what they are doing is science. For example, on page 11 of Investigation One, the teacher is prompted to say, “This is a special crayfish that can do tricks. Its best trick is balancing on one of your fingertips” (FOSS, 2002). Students are instructed to figure out different ways to balance different objects and terms are eventually asked to identify characteristics of balancing objects. Students are not asked to make observations and develop ideas or claims based on their observations.

Other programs included only minimal instances of the concept that science relies upon naturalistic methods and explanations. In both chapters of Scott
Foresman this NOS concept has minimal representation as it only appeared twice in
the chapter at the beginning and at the end of the chapter through a directed and
guided inquiry lesson.

*NOS Aspect 5: Global Contributions*

![Figure 5: Global Contributions](image)

<table>
<thead>
<tr>
<th>Curriculum Materials</th>
<th>Insights #1</th>
<th>Insights #2</th>
<th>FOSS #1</th>
<th>FOSS #2</th>
<th>STC #1</th>
<th>STC #2</th>
<th>Scott Foresman Ch. 8</th>
<th>Scott Foresman Ch. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 9. Findings for “Contributions World-Wide”</strong></td>
<td><strong>Mean Score</strong></td>
<td>0.78</td>
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<td>0.8</td>
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<td>1</td>
<td>0.13</td>
</tr>
</tbody>
</table>

The idea that scientists work together, review and discuss findings with other
scientists is implicitly, but not explicitly, represented throughout the kit-based
programs. Throughout the kit-based curriculum materials, lessons were structured
so that student work in partnerships, small groups, or as a whole class to make
observations, record evidence, or discuss findings. The lessons in the kit-based
programs were fashioned in this manner on a regular basis. This NOS aspect was represented in the selected materials at a higher degree than any other aspect but was always an implicit representation.

The Scott Foresman materials had an implicit representation of this at the end of each of the chapters as part of a guided inquiry. The lessons provided in these textbook materials heavily emphasized science content knowledge rather than inquiry, process skills, or the nature of science. The student is given a textbook to read along from or a class chart that the teacher could read from. Discussion was present in the lesson but it was always about the pictures in the book or content presented within the text of the book. Lessons such as these did not address the NOS concept that scientists work together to collect data, discuss evidence, and develop claims.

**NOS Aspect 6: Social and Cultural Context of Science**
The work of scientists can help society, and is also affected by their own culture. This important concept was not represented but once in a few of the instructional materials reviewed. It was not present in the majority of the materials and lessons reviewed. The minimal representations that were present were implicit as they at the minimum made reference to ways particular results or findings of an investigation could help people.

The implicit, yet minimal, representation is illustrated best in FOSS #2 Solids and Liquids. This kit recommends that students are asked to consider how engineers might use the information they had collected regarding solids to help them build something. While it is implicit in nature students consider the impact their findings have on a greater community. Small episodes like this occurred in Insights #2, STC #1 and FOSS #2. There were no other references to how students’ or scientists observations, findings, or claims could help a larger community or that scientists’ understanding could be affected by their own culture.

*Question Two: How explicit or implicit is the nature of science addressed in early childhood curriculum materials?*
Not only were NOS aspects unevenly represented across curricular materials but the extent to which each aspect was represented also varied. The rubric was based on a range from explicit, informed, and consistent (+3) to explicit, naïve representations (-3).

**Overall Findings**

When the mean scores were compared within specific curriculum materials distinctions were made regarding the explicitness of the representation the NOS aspects. Three central findings were developed from this analysis:

- The selected materials most often represented the nature of science accurately and implicitly.
- None of the materials selected for this study had explicit, informed, and consistent representations of the nature of science within the lessons.
- Kit-based curriculum materials overall had a better representation of the target nature of science aspects compared to the textbook-based curriculum materials.
Teaching Guide 1: Insights: Lifting Heavy Things: Grades 2-3 (Insights #1)

Figure 7: Insights #1

Table 11. Findings for “Insights #1”

<table>
<thead>
<tr>
<th></th>
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<td>Mean</td>
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<td>0.11</td>
<td>0.56</td>
<td>0.89</td>
<td>0.78</td>
<td>0.00</td>
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</tbody>
</table>

This kit-based unit had consistently accurate, yet implicit representation of naturalistic methods and explanations and contributions worldwide. Half of the lessons had accurate and implicit representations of the NOS target aspects: science is creative, and scientific knowledge is reliable yet tentative. None of the target NOS aspects in this set of curriculum materials was represented explicitly and
there were no inaccurate representations of the nature of science. Overall, this unit had little representation of two NOS concepts: no universal scientific method and the social and cultural context of science.

*Teaching Guide 2: Insights: Balls and Ramps, Grades K-1 (Insights #2)*

![Figure 8: Insights #2](image)

**Table 12. Findings for "Insights #2"**

<table>
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</table>
This kit-based unit had consistent accurate, yet implicit representations of creativity, naturalistic methods and explanations, and contributions worldwide. About half of the lessons had accurate implicit representations of two, NOS target aspects: no universal scientific method, and scientific knowledge is reliable yet tentative. None of the studied NOS, concepts in this set of curriculum materials was described explicitly, and there was one instance where the reliable and tentative nature of scientific knowledge was portrayed inaccurately. The unit also had one implicit representation of the social and cultural context of science in Lesson14. This unit as with other kit-based curriculum materials reviewed, provided students with implicit representations. This Insights kit, however scored somewhat higher than Insights #1 in the aspects of creativity, and no universal scientific method. Across all units studied, Insights #2 had the second highest mean score for naturalistic methods and explanation, indicating that this message about the nature of science is consistent across the lesson in the unit.

Continued: Table 12. Findings for “Insights #2”

<table>
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<tr>
<td>Mean</td>
<td>0.57</td>
<td>0.50</td>
<td>0.93</td>
<td>0.93</td>
<td>1.00</td>
<td>0.07</td>
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</table>
This kit-based unit had consistent accurate implicit representations of contributions worldwide. A little more than half of the lessons had implicit representations of two NOS target aspects: science is creative and the reliable and
tentative nature of scientific knowledge. None of the target aspects in this set of instructional materials was explicit and there were eight lessons that conveyed an implicit misrepresentation of a specific NOS aspect. This set of materials overall scored lowest for some of the target NOS aspects. No universal scientific method received a negative mean score of -0.30 signifying that overall it implicitly misrepresented this NOS aspect – this misrepresentation occurred in four lessons, with only one lesson conveying an implicit and accurate message. Lessons in this unit were very teacher-directed and often students were led through a step-by-step process.

This set of materials also had a low mean score for naturalistic methods and explanations – an area that all other kit-based materials had a relatively higher implicit representation. What this means is that while all kits presented images of science relying upon naturalistic explanations in an implicit manner, this kit did not do so nearly as often – the message was sporadic, at best. In this kit, students were asked to imitate the balancing of objects and were instructed how to get an object to balance. Students had little opportunity to explore and collect evidence or conduct scientific investigations.
This kit-based unit had consistent, accurate, and implicit representations of NOS aspects: the reliable and tentative nature of scientific knowledge, explanations,
and contributions worldwide creativity, and naturalistic methods/explanations. About half of the lessons had implicit representations of the NOS target aspect: no universal scientific method. There were some implicit misrepresentations as there were times students were instructed step-by-step how to complete an investigation. The unit had one implicit representation of the social and cultural context of science in Lesson 14. This unit as with other kit-based curriculum materials reviewed provided students with implicit representations but scored higher than FOSS #1 in all the target NOS aspects. In lesson one of this unit, a mixed explicit and implicit message was conveyed regarding the naturalistic methods and explanations of science as it explicitly stated how scientists use their senses to investigate different states of matter. The suggested language provided students a narrow scope of how scientists collect evidence. It appears there are some implicit misrepresentations in both FOSS teaching guides, and there are some specific episodes of suggested teacher language that are a clear misaligned with nature of science aspects.
Fig 11: STC #1

Table 15. Findings for “STC #1”

<table>
<thead>
<tr>
<th></th>
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<td>Lesson 10</td>
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Mean 0.81 -0.06 1.00 1.00 1.00 0.06
This kit-based teaching guide was the most consistently accurate and implicit in its representation of creativity, and naturalistic methods/explanations. The lessons provided students with multiple opportunities to explore, observe, and the try to create explanations for their observations. The lessons also contained opportunities to revisit previous findings and make revisions based on new experiences, conveying an implicit message about the reliable and tentative nature of scientific knowledge. This set of lessons also received 2 negative scores for its representation of the various methods of investigation. In each case, an implicit but inaccurate message was conveyed regarding how science is conducted. Lesson 16 had an accurate yet implicit representation of the social and cultural context of science.

Teaching Guide 6: STC: Solids and Liquids, Grades K-1 (STC #2)
None of the NOS aspects examined in this set of curriculum materials was explicitly conveyed and in one instance, inaccurate messages regarding the reliable and tentative nature of scientific knowledge were conveyed. This kit-based unit had consistent, accurate, and implicit representations of two NOS aspects: contributions worldwide, and the reliable and tentative nature of scientific knowledge. About half of the lessons had accurate implicit representations of two NOS target aspects: creativity is vital to science, and naturalistic methods/explanation. The unit made no mention of the social and cultural context of science in any of the 16 lessons.

This unit, as with other kit-based curriculum materials reviewed, provided students with implicit representations but scored somewhat lower than STC #1 in all NOS aspects, except one: no universal scientific method. This unit had the second

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| Mean           | 0.81                 | 0.13           | 0.56       | 0.56         | 1.00            | 0.00                |
highest mean score for naturalistic methods and explanation, indicating that this message is reinforced throughout the unit, albeit with two instances of inaccurate portrayals.

*Teaching Guide 7: Scott Foresman, Chapters 8 and 9*

Since chapter eight and nine of this textbook based program had identical sets of data the findings will be represented and discussed within the same section.
Overall, these materials scored considerably lower when compared to the kit-based materials, with a majority of lessons receiving a score of zero. This indicates that NOS was largely absent from the unit. Messages about NOS were not implicit or explicit— they were simply not present for most of the unit. The zero scores can be attributed to the sole focus on content knowledge through the bulk of the chapter. Thus, students were not learning about science or scientists, nor were they acting like scientists by doing investigations and expected to pick up such messages implicitly. The teacher essentially provides students with opportunity to make minimal observation of photographs, and learn content knowledge, and related vocabulary.

This textbook’s emphasis on content is sandwiched by directed and guided inquiry experiences at the beginning and end of the unit that provides implicit representation of the targeted NOS aspects, with the exception of one NOS aspect that was not addressed at all; the cultural context of science. The lesson and the support material that students view in the textbook for the directed inquiry and guided inquiry represent an implicit message about the various methods of scientific investigations.
CHAPTER 5. SUMMARY AND DISCUSSION

Introduction

The findings of this study indicate that the explicit portrayal of the nature of science is not present in the curriculum materials reviewed for this study. What little NOS representations that were present were rated as implicitly accurate and in certain fewer instances implicitly inaccurate. To what extent does this absence of explicit instruction about science and scientists impact early childhood education teachers and students? What are the implications for the publishers of these curriculum materials, elementary teacher preparation programs, those who design continuous professional development for teachers, and most importantly the early childhood teacher? The teacher is the one that is at the frontline making the decisions and providing the instruction that has the potential of making such a critical impact on the student’s development of science literacy.

Discussion

Missed Opportunities

The findings of this study can be summarized in two words: Missed opportunities. The kit-based programs reviewed in this study provided students with many opportunities to “do” science, but often had implicit representations of the NOS aspects. The reviewed materials failed to provide students with the opportunity to explicitly learn what science is, how scientists work, how what they are doing in
class is similar to or different than what scientists do, and other important messages about the discipline. Both of these critical attributes were absent in the textbook instructional materials.

After reading all of these materials, so many opportunities existed to bring such messages to students’ attention. The kit-based programs, for example, consistently engaged students in “doing” activities and investigations, but the extent to which students associate such experiences with the behaviors of scientists is left to chance. In fact, one of the consistent findings from decades of research on students’ NOS learning is that implicit NOS does not help students develop an accurate understanding of the nature of science – “doing inquiry” does not mean that students transfer that knowledge to their conceptions of the scientific enterprise (Akerson & Volrich, 2006). Thus, while the kits were better than the textbook at having students “do” inquiry-based science, gains in their understanding of science are likely to remain unaffected.

The message of “missed opportunities” is most prevalent in the textbook series and in the “FOSS Balance and Motion” kit. Despite the claims of the Scott Foresman textbook publishers that the program is aligned with the standards, two major aspects of the standards are almost completely ignored: science through inquiry, and science as inquiry. Students do an activity at the beginning and the end of the unit, but such experiences are secondary to the major emphasis of the unit – learning vocabulary. The textbook series consistently provided students with vocabulary, description of science concepts, and reading comprehension strategies.
There were several instances where the focus of the lesson was more about “how to read about the content” than science itself. Once again literacy instruction moves front and center. The activities at the beginning and end of the chapter serve largely as verification exercises. These activities do little to promote an image of science as occurring through investigative processes; nor is the teaching of science occurring through inquiry as recommended by the National Science Education Standards (NRC, 1996).

In the “Balance and Motion” FOSS kit, science is portrayed to students as magic tricks – seeing how to get a cardboard crayfish shape to balance on one’s fingers. Students are simply shown the “trick” and asked to imitate it, and then try other ways. Not only are references to scientists missing, but also it is doubtful that students understand that they are participating in a science lesson. The experience could easily be mistaken for an art lesson or a game. Instead, students could be introduced to the lesson with a short story that sets the context for the lesson, describing a scientist struggling to solve a particular problem or understand how the objects comes balance. Students could then be given a similar problem and asked to solve it – trying multiple ways to do so. Students could then be directed to think about how they solved it, and learn how the scientist tried it – and explicit lessons about who does science, for what reasons, and the methods of science could be integrated in a way that students would find authentic and engaging. As written both sets of materials, are devoid of context.
Disproportionate NOS Aspects – for a reason?

Some aspects of NOS are more prevalent in curricular materials than others. Given the developmental concerns about NOS and young children, knowing what NOS concepts these students can learn is important. In this study, reliable and tentative nature of science, creativity, naturalistic methods/explanations, and contributions of science worldwide were far more likely to be addressed, albeit implicitly, than the social and cultural context, and no single scientific method. Perhaps, these NOS concepts are developmentally beyond early childhood students’ capabilities, or perhaps publishers are unaware of these NOS concepts or how they can be effectively taught to students. It is possible that these two NOS concepts are not a natural part of learning science through “inquiry” which is a major goal of each of the kit-based instructional materials reviewed.

It is possible to be explicit about certain NOS aspects that already exist implicitly in the kit-based materials. This makes perfect sense because if students are already participating in the process skills or actions of scientists. Why not draw their attention to how it is like or unlike what an actual scientist does? For example, students were often provided with opportunities to work with partners, small groups, and as a large group to process observations made before, during, and after their investigations. These opportunities to collaborate were scored as implicit because the teacher was never guided to make students aware of how collaborating or sharing findings is like the work of scientists. This again is a missed opportunity.
Science has a cultural context does not appear to be developmentally appropriate for this age group as they are more concerned with themselves and their immediate surroundings. Review of the literature demonstrates that early childhood students have naïve view of the NOS and are capable of developing a more accurate view if the instruction supports these concepts (e.g. Akerson & Volrich, 2006). The conversion of many of the implicit representations of NOS to explicit seems logical and authentic as we work to portray a more accurate image of science.

Potential Study Limitations

Teachers always interpret instructional materials (Langer & Applebee, 2007) based on multiple factors. However, given elementary teachers’ misconceptions about the nature of science and the lack of professional preparation that includes NOS as an explicit component, curricular materials are likely to heavily influence, if not define, NOS for teachers at the elementary grades. In many cases, inaccurate messages about NOS found in the curriculum materials are consistent with common misconceptions – such as the use of a step-by-step method to do investigations. Such messages are likely to reinforce teachers’ naïve NOS conceptions, and may be taught this way to students. Furthermore, it is highly unlikely that a teacher with NOS misconceptions would pick up on the implicit accurate NOS messages found in the kit-based programs. Because such messages are insufficient to change students’ NOS views (Lederman n.d.), they are also unlikely to change teachers’ views either. Since most elementary teachers hold significant misconceptions
regarding the NOS (Lederman, 1995), and the curriculum materials convey accurate messages only implicitly, and implicit instruction is insufficient to change views (e.g. Riley, 1979; Spears & Zollman, 1977; Trent, 1965) we can assume that teachers are unlikely to alter these materials to make them accurate and explicit with regard to the NOS.

A second issue that warrants discussion is related to the use of mean scores. In this study, units varied widely in the number of lessons, from 8 to 16. Means were calculated simply to aid in making comparisons across units that had different numbers of lessons. Higher means do not necessarily indicate more accurate NOS representations or a more explicit NOS representation (since all units ranged between 0 and 1), but do indicate a more consistent implicit NOS message. Thus means should be interpreted with caution and, when necessary, the individual lesson scores considered (Tables 11-17). Abd-El-Khalick (2008) faced the same problem of comparison across publishers in his study, and addressed it by collectively examining individual chapter scores for each NOS aspect – eventually deciding upon a single score to represent a NOS aspect across the entire text. His approach enables comparisons across publishers, but also loses the details that are captured in Tables 11-17. For this reason, the method used here was selected despite its limitations.

In the same manner as the Abd-El-Khalick study (2008), a subset of the available materials was selected for analysis due to the time-intensive nature of qualitative data analysis. Physical science units were selected for each of the
instructional materials reviewed in order to maintain a level of consistency. Perhaps life science or earth science materials contain NOS aspects in more accurate and consistent ways than what was seen here. Further research is required to make this determination.

**Implications**

This study is the first of its kind to determine how the nature of science is portrayed in early childhood curriculum materials since *National Science Education Standards* (NRC, 1996) made the nature of science an explicit desired outcome. While the examined instructional materials claim to be “aligned with the standards,” the standards with which they are aligned do not include the nature of science – students are not explicitly taught this information, nor are they assessed on these concepts. Clearly, the desired state as set forth in international reform documents is not reflected in these materials. This study has multiple implications for those that can improve the current state of early childhood science curriculum materials.

*Implications for Publishers*

Publishers play a key role in conveying NOS to both teachers and students. Given the implicit nature of NOS aspects in early childhood curriculum materials, an obvious recommendation is to make NOS more explicit throughout the materials so that students know they are learning about science and how it works. More is needed, however. Additionally, publishers should provide educative strands for nature of science concepts within and alongside individual lesson plans. These
educative elements should be placed in the margin of the lesson and meant as timely advice. This differs from the practice by most publishers to place background knowledge at the beginning of a unit or lesson. If teachers were given a lesson plan that was written as a vignette (Dietz & Davis, 2009), they could properly envision the lesson so they could see how the content and the NOS can be accurately and explicitly interwoven. For example, when teaching about how objects move, if the teacher reads a vignette that models the language and teaching moves made by the teacher the teacher, is more likely to grow professionally from the lesson. Specific educative sidebars need to be present that support the development of accurate views of NOS within instructional materials for teachers. These sidebars are can be short and focused to the lesson that is being implemented but will provide the teacher with the necessary support and rationale as to why a pedagogical decision is made within the lesson.

Because the nature of science is loaded with important subtleties (e.g. the distinction between “invent” and “discover,” informal uses of the word “theory”), timely, targeted nature of science teacher language scripting for the teacher should appear through vignettes embedded in the lesson. This does not mean that the lesson can or should be completely scripted, but such vignettes can be used as illustrative models for the teacher so that he or she learns important ways that the lesson could realistically (and accurately) unfold. Such vignettes are a part of the National Science Education Standards (NRC, 1996), but rarely appear where
teachers are likely to most use them – within the curriculum materials. Often they are placed in an additional resource, or the appendix of the teaching guide.

The benefit for educative curriculum materials became clearer and clearer after analysis of each lesson in a publisher’s teaching guide where several missed opportunities were present. While each of them had an educative element, all of them seemed to vary. Some of the units or lessons were preceded with educative text regarding content. Some had tidbits of management techniques off to the side of the lesson. None however had NOS pedagogical content knowledge embedded inside the lesson. The nature of science concepts should and need to be integrated into the PCK sidebars in order for the teacher to integrate this knowledge into their practice. It is also more timely to have it off to the side of the lesson as elementary teachers do not prepare for only one content area, and often do not have the time to search and read through instructional materials, to improve practice.

The integration of educative target nature of science aspects as the lesson unfolds could help early childhood teachers see how they can incorporate these aspects into practice. Then the educative aspect of the lesson becomes a scaffold for teachers to progressively improve their science instruction. Interestingly, the textbook series published by Scott Foresman was the only set of materials that explicitly referenced the nature of science inside the teacher materials. It was part of a pre-unit on what science is and how it works. While, some educative elements were incorporated regarding the nature of science in that pre-unit, unfortunately, the actual lessons that followed did not support these concepts. There were even
contradictions within the teacher’s manual – it explicitly addressed the idea that scientists do not follow a universal method but instead practice a variety of methods to learn about the natural world. But, the page students viewed had the traditional scientific method sequenced as it has been presented in a “traditional” sense. Educative curriculum materials would be one way to support early childhood teachers, and increase the likelihood that practices will improve.

Paralleling the need for educative curriculum, teachers could benefit from a scaffold of how and why to say, respond to, and conduct science conversations. This could be accomplished by providing a clear meaningful teacher’s role that would support the target NOS aspects. This could include sequenced questions, ways to respond to multiple possible student responses, and how to develop important NOS ideas within specific lesson plans. As lessons were reviewed, it was clear that if teachers had an idea of how to present NOS concepts or even draw attention to specific NOS aspects when they were implicitly present, an implicit representation could be changed into an explicit representation instead. Clearly it is evident that students are being asked to observe, collect evidence, and develop scientific ideas through the kit-based lessons. This teacher’s role could be something as simple as, “Scientists make observations to help them collect evidence about how things move.” Coupled with educative pedagogical content knowledge, the “why” would be provided, which over time could help teachers apply their learning into other science lessons.
While many of the publishers provided questions to some degree, none of them addressed any of the target NOS aspects addressed in this study and sometimes they even offered a misrepresentation of the a NOS aspect. Often they were prompts, directions, or statements that were missed opportunities. For example, a teacher would be suggested to say, “Use your senses as you observe.” Instead, they could have focused on the idea that “Scientists often will use their senses to learn more as they observe.” There were times when the suggested teacher language was, “What did you discover today?” offering a misrepresentation of the target aspect “naturalistic methods and explanations.” This could be stated as “Just like scientists, we need to use our observations to help us develop our ideas or explanations.”

Many of the kit-based lessons have an accurate implicit representation of specific target NOS aspects (e.g. Science is based on naturalistic methods and explanations, contributions to science can be made and have been made by people the world over, and scientific knowledge is simultaneously reliable and tentative) The publishers of these materials need to at the least take advantage of the missed opportunities. Doing so, would be the first step in aligning curriculum materials with reform documents. It seems practical that if students are already asked to behave in ways that align with “science through inquiry,” that the equally-important goal of “science as inquiry” could be accomplished by drawing students’ attention to how the behavior is like that of a real scientist.
It is critical that the publishers provide both the educative component as well as the meaningful and targeted vignettes, sample scripts, and a clear teacher’s role because one without the others has the great potential of misleading, misinforming, or even worse, being discarded by the teacher because they misunderstand the purpose behind the practice the materials wish to promote. It is important to note that I am not proposing teachers follow a script but instead are provided with the very targeted and timely vignette that supports both their development of a sophistication of their pedagogical content knowledge as well as how these NOS aspects unfold in practice in specific lessons. It is at that point that teachers could envision how NOS can be integrated consistently, accurately, and explicitly in a meaningful manner.

**Implications for Teacher Preparation Programs**

Teacher preparation programs are the first place in the professional continuum where teachers are explicitly taught how to teach science to children. As such, the content of these programs should reflect the emphases of the reform documents and have the responsibility to prepare teachers to teach in a manner that is consistent with that vision. Thus, it is crucial that teacher preparation programs integrate nature of science aspects into early childhood science coursework. In addition, they need to draw attention to teacher language and behaviors that promote an accurate and explicit message regarding NOS aspects.
Teacher preparations programs need to do more to prepare preservice teachers in regards to the nature of science. The curriculum materials reviewed in this study demonstrate the necessity of this need. Preservice teachers need to not only be made aware the nature of science concepts, but also how to weave them into the instruction they are going to provide. It is not enough to assume they will have quality materials; as we have seen in this study the materials did not meet the NOS standards of the reform documents. Teacher preparation programs owe it to their students to provide them with comprehensive preparation in science education. One science methods course is becoming more and more congested with inquiry-based instruction, instructional models, teaching behaviors, assessment strategies along with a variety of pedagogical content. It is important to remember we are always teaching the nature of science whether they know it or not (Clough, 2003). So, it is not acceptable for teacher preparation programs to allow future teachers to leave their program without an accurate understanding of the nature of science.

The structure of the coursework for preparing elementary teachers needs to be comprehensive and aligned. Both science content and science methods courses need to have common strands that carry a consistent and aligned message in regards to the reform documents. This does not mean one class dedicated to the nature of science but instead an interwoven approach that is integrated into pedagogical content knowledge and science content over the duration of several courses creating a longitudinal effect. This can be done with deliberate effort on the part of the faculty through the kinds of activities they model and demonstrate in their
science content and methods courses. It is in these contextualized activities that the course instructor can draw their students’ attention to aspects of the nature of science in an explicit manner and then prompt them to reflect on the importance of focusing their students on these ideas. Science content courses need to be active models of inquiry not episodes of lecture. These courses need to provide future teachers with a context as they work to develop an accurate understanding of NOS as well as the other goals we have for preservice teachers.

**Implications for Teacher Professional Development**

Teachers need professional development that supports science instruction. The data from the reviewed curriculum materials suggests that it would beneficial to provide teachers with support on how to explicitly teach important NOS concepts. This needs be continuous and interwoven into the daily workings of their practice. Teachers using a particular unit of study need to review the lessons and work together to revise and adjust the lessons so that they provide a consistent, accurate, and explicit message regarding the nature of science. In many cases this means making an implicit representation into a more explicit representation by drawing students’ attention to how this is similar to the ways science functions and works. This cannot be accomplished if teachers are not provided the opportunity to see how it translates into their actual practice, as often there is disconnection in teacher professional development opportunities. Teachers need to spend time studying, reflecting, and modifying lessons so that they align with nature of science aspects.
This could most easily take place in professional learning communities after some substantive educational opportunities regarding the NOS concepts and NOS pedagogical content knowledge for early childhood classrooms. Grade level teachers sitting around a table, collaborating and reflecting on specific lessons would provide practicing teachers continuous and ongoing support needed for substantive reform. Teachers who are part of a learning community develop a network of colleagues that they can support and depend on as they work to further develop the practice (Dufour et al., 2006).

*Implications for Early Childhood Teachers*

It has been said that teachers are the most critical piece within the classroom and it is for this reason that this thesis concludes with them. We know it is not the curriculum materials that make the difference. The teacher, in the end, decides what to do and what not to do. It is the teacher who decides what to say and what not to say. Early childhood educators need to challenge themselves to prepare to teach the science content in alignment with reform documents. This will provide them the insight they need to truly provide their students with the science education they need to develop true science literacy. The review of the literature for this study demonstrates that elementary teachers do not feel confident in their ability to teach science. If teachers cannot count on the instructional materials they have to support further development they must seek out ways to enhance and improve upon their instruction.
It is important that teachers become aware of the nature of science and how they are presenting it to their students. Establishing this baseline is a starting point to work from. Interestingly, as I worked on my research, colleagues inquired what I was working on. When I mentioned the nature of science they often asked, “What is that?” I need not say more. Teachers need to continue to monitor their science instruction to ensure it is aligned with an accurate portrayal of the nature of science. It is the teacher’s adjustments to lessons, the language that they use, the model they provide, and the questions they ask that will be most critical because they are the mediating factor between the instructional materials and the student.

Further Research

Further research needs to occur on how instructional materials can help to provide a scaffold for continuous teacher growth when it comes to the nature of science. The materials reviewed in this study did not include the educative element. We need to know how this support structure could provide an intervention for the teacher and what effects this structure would have on practice. We need to further investigate the views of NOS in early childhood students to determine what NOS concepts are developmentally inappropriate and those that are appropriate for this age group. I suspect that until we have this evidence; we will not be able to create the change that we so desperately need to begin to accurately teach NOS to our earliest students.
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<td>The lesson conveys: Implicit misrepresentation of the target NOS aspect.</td>
<td>The lesson conveys: Mixed explicit and/or implicit messages about the NOS aspect</td>
<td>The lesson conveys: Explicit, naïve representation of the target NOS aspect.</td>
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<td>• Scientists collect data</td>
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<td>• Scientists use evidence to explain their ideas.</td>
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<td>Contributions to science can be made and have been made by people the world over.</td>
<td>The lesson conveys: Explicit, informed, and consistent representation of the target NOS aspect.</td>
<td>The lesson conveys: Explicit, partially informed representation of the target NOS aspect.</td>
<td>The lesson conveys: Implicit, informed, and consistent representation of the target NOS aspect.</td>
<td>The target NOS aspect is not addressed in the lesson.</td>
<td>The lesson conveys: Implicit misrepresentation of the target NOS aspect.</td>
<td>The lesson conveys: Mixed explicit and/or implicit messages about the NOS aspect</td>
<td>The lesson conveys: Explicit, naïve representation of the target NOS aspect.</td>
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<td>• Scientists work together.</td>
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<td>• Scientists review and discuss findings with other scientists.</td>
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<td>Social and Cultural context of science.</td>
<td>The lesson conveys: Explicit, informed, and consistent representation of the target NOS aspect.</td>
<td>The lesson conveys: Explicit, partially informed representation of the target NOS aspect.</td>
<td>The lesson conveys: Implicit, informed, and consistent representation of the target NOS aspect.</td>
<td>The target NOS aspect is not addressed in the lesson.</td>
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<td>The lesson conveys: Mixed explicit and/or implicit messages about the NOS aspect</td>
<td>The lesson conveys: Explicit, naïve representation of the target NOS aspect.</td>
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<td>• Scientists are affected by their culture.</td>
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<td>• Scientists can help society.</td>
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