ENRICHING SCIENCE TRADE BOOKS WITH EXPLICIT-REFLECTIVE NATURE OF SCIENCE INSTRUCTION: IMPACTING ELEMENTARY TEACHERS' PRACTICE AND IMPROVING STUDENTS' LEARNING

BY

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DISSERTATION

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Abstract

The present study investigated the impact of elementary science trade books, which were modified to include explicit-reflective nature of science (NOS) references, on four variables: teachers' views of NOS, changes in teaching practices during a read-aloud of the trade book, students' interaction with the NOS concepts during the read-aloud, and teachers' perceptions of the materials. Including read-alouds during science instruction is a common practice in elementary teaching and draws on both the strengths of the teachers and the interdisciplinary nature of elementary teaching. To investigate these issues, eight participating teachers and their students underwent three hierarchical levels of intervention. Level I served as a control or baseline and consisted of a trade book that remained unmodified. Level II consisted of a trade book that had been modified to include explicit references to NOS. Level III consisted of a trade book that had been modified to include explicit references to NOS plus the inclusion of an educative teacher's guide. The educative teacher's guide included content aimed at supporting the teachers' development of more informed views of NOS, as well as guiding their pedagogical decisions during the read-aloud (e.g., by including specific reflective questions and potential student responses).

Multiple sources of data were examined in this study. To determine changes in teachers' views of NOS, teachers filled out the Views of Nature of Science Questionnaire Form CE (VNOS-CE) pre- and post-intervention. Audio recordings and field notes were obtained during the read-aloud sessions, allowing for the investigation of changes in teaching practice. Additionally, students completed free response tasks after each session to determine what, if any, ideas about NOS they took away from the sessions. Individual interviews of select students were used for a more in-depth analysis of students' views of NOS. Lastly, teachers participated in two interviews that focused on their views of NOS, as well as their perceptions of the curriculum materials.

Analyses showed that every participating teacher changed their views from less informed to more informed views on at least one of the NOS aspects. Consequently, they also changed their teaching practices between Level I and Level II, and between Level II and Level III of the intervention such that they included more explicitly references to NOS in the later levels. Additionally, teachers reported that the support from the teacher's guide in Level III led to them feeling more comfortable and prepared to lead discussions during Level III read-alouds. The students' free response data indicated minimal student involvement with the NOS content, however this may have been an artifact of the measure. In contrast, student interviews indicated every participating student changed from less informed to more informed views on at least one of the targeted aspects of NOS. Finally, teachers perceived the intervention materials in a generally favorable way, indicating that they would be likely to follow a similar intervention on their own. Additionally, this data provides ecological validity to the intervention.

Developing informed views of NOS in teachers and students has been a central goal of science education for several decades. Most previous research required lengthy professional development experiences, intensive researcher participation, or highly idealized teaching situations. The present study provides evidence that more minimal interventions that rely on practices that are already common in elementary teaching may be effective in reaching this goal. Such interventions are more easily scaled up to reach a wider number of teachers in a variety of teaching environments.

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Chapter I

Statement of the Problem

Developing informed conceptions of nature of science (NOS) has been a central goal of science education for several decades (Lederman, 1992; Lederman & Lederman, 2014). Incorporating NOS into science education is an important goal because it goes beyond teaching about science as a body of knowledge or set of processes to incorporate views of "science as a way of knowing" (Lederman, 1992, p. 331). Addressing NOS is a critical component of developing scientifically literate citizens (AAAS, 1990). Having informed[1] views of NOS will facilitate the understanding of the scientific enterprise, including how scientific knowledge is produced, as well as its strengths and limitations. At the K-12 level, the *Next Generation Science Standards* (NGSS Lead States, 2013) emphasize teaching about several aspects of NOS. These include, among other aspects, that scientific knowledge is "based on empirical evidence" and "open to revision in light of new evidence"; that science is a way of knowing that "addresses questions about the natural and material world," "uses a variety of methods," and "assumes an order and consistency in natural systems"; and that science is a human endeavor aimed at generating models, laws, mechanisms, and theories to explain natural phenomena (NGSS Lead States, 2013, Appendix H, p. 4).

Much research related to the teaching and learning of NOS has been conducted. This research consistently shows two things that are directly relevant to the present study: (a) most students and teachers hold less-than-informed views of NOS (i.e., naïve or partially informed), and (b) when NOS is taught in an explicit manner (i.e., treated as a specific instructional goal

[1] In this study, views that are in line with those supported by K-12 education reform documents (e.g., Next Generation Science Standards) are considered *informed*. In contrast, views that are not in line with the reform documents may be considered *naïve*. Because one's understanding of NOS is not a strict dichotomy, it is also possible to have *partially informed* views.

with activities aimed at improving NOS views) by teachers who hold informed views of NOS, students' views of NOS can be positively impacted (see Abd-El-Khalick & Lederman, 2000b; Lederman, 1992, 2014 for reviews). The latter impact is possible even among kindergarten students (Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Quigley, Pongsanon, & Akerson, 2010), indicating that teaching some aspects of NOS is a developmentally appropriate learning goal for elementary school children. However, there still remains the question of how best to scale-up the support for elementary teachers in a practical manner both to improve their (a) views of NOS to be consistent with current reform efforts in science education (e.g., NGSS Lead States, 2013), and (b) teaching practice to be in line with these informed views.

Improving Teachers' Naïve Views of NOS

Lederman (1992) identified four lines of education research on NOS: (a) assessment and improvement of student conceptions of NOS; (b) development of curricula to teach NOS; (c) assessment and improvement of teachers' conceptions of NOS; and (d) examining the relation among teachers' conceptions, classroom practice, and students' conceptions of NOS. Research along these four lines has been fruitful in that it has shown how instruction (or professional development) can improve students' and teachers' views of NOS. Specifically, a substantial body of research indicates that, to be effective, instruction in NOS should be explicit and reflective, as opposed to implicit (Khishfe & Abd-El-Khalick, 2002). However, most teachers who have not undergone interventions aimed at improving NOS conceptions hold naïve conceptions (Abd-El-Khalick & Lederman, 2000b; Lederman, 1992, 2014).

One line of research on improving teachers' conceptions of NOS utilizes interventions in preservice teachers' science methods courses (e.g., Abd-El-Khalick, 2001; Abd-El-Khalick &

Akerson, 2004, 2009; Akerson, Abd-El-Khalick, & Lederman, 2000). While it is desirable to address preservice teachers' views of NOS, there is limited research on the persistence of these changes, as the studies tend to end after one or two semesters. Indeed, in one study that employed a delayed measure of NOS views, the researchers found that, although participants improved their views of NOS during the semester in which the study occurred, several students' views reverted back to naïve views when measured five months later (Akerson, Morrison, & McDuffie, 2006). To this end, researchers have recommended that supports for teachers should extend beyond addressing NOS in preservice courses and include long-term, intensive interventions with practicing teachers (Akerson & Abd-El-Khalick, 2003). Indeed, Wahbeh and Abd-El-Khalick (2014) found that inservice science teachers retained or improved their NOS understandings 6 months after an intensive professional NOS development program coupled with work in participants' classrooms. In line with these recommendations, more substantial and lasting impacts in terms of improving NOS understandings were reported in research with practicing teachers involving long-term professional development interventions, some of which spanned multiple years (e.g., Akerson & Hanuscin, 2007; Lederman & Lederman, 2004). These interventions, nonetheless, are lengthy and resource-intensive. This is problematic, as it is unlikely that most practicing teachers will have the time, and teacher educators or schools would have the resources, to engage in this type of long-term professional development.

Elementary teachers represent a population that typically has different challenges in science teaching than most secondary science teachers. Unlike secondary science teachers, most elementary teachers are not science specialists and tend to specialize in language arts (Akerson, 2007). Thus, Deniz and Akerson (2013) specifically investigated improving teachers' views of NOS through integrating NOS with language arts instruction. Through the course of 5-day, 30-

hour professional development workshops, the researchers involved teachers in explicit reflective instruction revolving around reading fiction and nonfiction books related to NOS concepts and answering reflective prompts in science journals. The study had promising results showing that elementary teachers' views were more informed after the intervention, and that such positive impacts were accompanied by an increase in self-efficacy for teaching science. However, the study had major limitations. Most importantly, participating teachers held informed views of many aspects of NOS at the outset of the study, indicating that they are not representative of most elementary teachers, who tend to hold naïve views. NOS instruction, additionally, was not aimed at any specific content area (e.g., life cycles), but instead focused on decontextualized NOS instruction. This is problematic, as it is difficult for teachers to translate informed views of NOS into effective teaching unless given supports specific to the context in which it is taught (Wahbeh & Abd-El-Khalick, 2014). The latter issue will be further explored in the following section.

Translating NOS Views Into Practice

Early research on teaching NOS had adopted the assumption that teachers with informed conceptions of NOS would naturally translate their understanding into practice. However, while having an informed understanding of NOS is a necessary condition for teaching NOS, it is not sufficient (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000b; Lederman, 1999). For example, in a study of five high school biology teachers with informed views of NOS, Lederman (1999) found that only two approached teaching science in a way consistent with their views. However, these two teachers did not explicitly plan to teach NOS as a specific learning goal, instead focusing on affective outcomes and improving students' inquiry skills. Additionally, research has identified several factors that mediate the translation of teachers' NOS understanding into classroom practice over and above the depth of teachers' understanding of NOS. These include the need for novice teachers to prioritize classroom management issues (Lederman, 1999), the perceived priority to "cover" the tested science content instead of NOS, and teachers' beliefs about the relative importance of teaching NOS or students' ability to understand NOS concepts (Abd-El-Khalick et al., 1998; Akerson & Abd-El-Khalick, 2003; Lederman, 1999). However, even when teachers hold informed NOS views and perceive the teaching of NOS as an important instructional objective, they still struggle with translating their views into practice because of a lack of instructional resources aimed at teaching NOS in specific contexts.

Wahbeh and Abd-El-Khalick (2014) investigated the relative importance of factors that mediate the translation of science teachers' NOS views into practice in Palestinian schools. Performing this research in Palestine allowed for naturalistic "control" of many of the aforementioned reported factors due to a national curriculum that emphasized the teaching of NOS. This setting removed concerns of priority to cover the content and teachers' beliefs about the importance of teaching NOS. Additionally, only experienced teachers participated in the study, reducing the effect of "survival" issues that typically dominate the practice of novice teachers as it relates to teaching about NOS. This study found that, while several mediating factors still played into the translation of NOS understanding into practice, it was the teachers' understanding of NOS that was relatively more significant than any other factor. A second major and persistent factor was the availability of quality, NOS-related instructional resources that were *specific* to the science content at hand.

In particular, Wahbeh and Abd-El-Khalick (2104) found that teachers' understanding of NOS was closely related to the context in which it was learned, and teachers had difficulty transferring this knowledge to other contexts. These findings indicate the need to not only address teachers' content knowledge of NOS (i.e., if their views are informed or naïve), but also to address teachers' NOS pedagogical content knowledge (PCK). PCK is "subject matter knowledge *for teaching*" (emphasis in original; Shulman, 1986, p. 9) and is a distinct, but related, construct to content knowledge. PCK includes understanding the different ways of representing content knowledge, common misconceptions students may hold about the content, and ways in which these misconceptions may effectively be addressed. Successful NOS instruction was reported among teachers in studies where they were provided with instructional resources and associated supports for teaching NOS in specific content areas (e.g., Akerson & Abd-El-Khalick, 2003; Akerson, Cullen, & Hanson, 2009; Akerson & Hanuscin, 2007; Cullen, Akerson, & Hanson, 2010; Wahbeh & Abd-El-Khalick, 2014). These resources were manifested through intensive collaboration with the researchers, including workshops about NOS, release time to plan lessons that included NOS, researchers' teaching model lessons in participants' classrooms, and observations of participant teachers' classes followed by debriefing with the researchers about the effectiveness of the NOS instruction. In effect, these resources were aimed at increasing teachers' PCK for NOS in specific content areas.

Research on improving the teaching and learning of NOS thus far has provided the knowledge that teachers' NOS understandings can be improved, and that teachers can translate these understandings into their instructional practice. However, the resource and time intensive nature of the requisite long-term and substantial interventions is problematic, especially when viewed from the perspective of scaling-up to reach the wider population of elementary teachers. Akerson and Hanuscin (2007) suggested that curricula aimed specifically at teaching NOS might be one way in which elementary teachers could be supported in teaching NOS.

Use of Trade Books

Research shows that, in general, elementary teachers face difficulties with teaching science (Davis, Petish, & Smithey, 2006) due to low content knowledge (e.g., Abell & Roth, 1992; Rice & Roychoudhury, 2003; Sutton, Watson, Parke, & Thomson, 1993), low self-efficacy (e.g., Bleicher, & Lindgren, 2005; Palmer, 2001, 2006b), and insufficient support from administration or mentor teachers (e.g., Mullholland & Wallace, 2001; Spillane, Diamond, Walker, Halverson, & Jita, 2001; Tabachnick & Zeichner, 1999). The use of trade books (i.e., books that are marketed to the general public) is one way in which elementary teachers can, and often do, approach science teaching in a way that is interesting and accessible to young children (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; Daisey, 1994). Indeed, the use of good trade books is particularly encouraged for teaching science to young children (Rice, 2002). Such use also draws on the strengths of elementary teachers, the overwhelming majority of whom specialize in language arts teaching (Akerson, 2007). Capitalizing on teachers' strengths in language arts teaching likely will bolster their self-efficacy for teaching NOS (Deniz & Akerson, 2013).

While the use of trade books may be beneficial for teaching science content, there are some problems when it comes to using them for teaching about NOS. Specifically, trade books tend to include inaccurate representations of NOS (Abd-El-Khalick, 2002a; Brunner & Abd-El-Khalick, in process; Ford, 2006). Additionally, because trade books are intended for the general public and not specifically marketed for classroom use, they do not include any instructional guidance (e.g., a teacher's guide). As a consequence, teachers may not use trade books effectively in promoting the desired learning goals (Smolkin & Donovan, 2004). However, these problems may be overcome by modifying trade books to include explicit references to NOS and supplementing these books with materials aimed at improving teachers' views of NOS and developing their NOS PCK.

Educative Curriculum Materials

Educative curriculum materials are aimed not only at improving student learning, but also have the specific goal of supporting *teacher* learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). These materials are one way to improve practicing teachers' content knowledge, pedagogical knowledge, and pedagogical content knowledge in a subject area. Because research shows that teachers tend to rely on curriculum materials to address their own deficiencies in content knowledge (e.g., Abell & Roth, 1992), educative curriculum materials can potentially be quite impactful at meeting teacher needs and goals. Although at present there is limited empirical research on the effectiveness of educative curriculum materials, initial studies indicate that they can effect desired changes in teaching practice (Schneider & Krajcik, 2002) and may be effectively used to create changes in large groups of teachers (Davis & Krajcik, 2005) and in inquiry-based science contexts (Lin, Lieu, Chen, Huang, & Chang, 2012). Coupling rich educative materials with carefully revised science trade books may provide teachers with the scaffolding they need to better address NOS in their instruction. Additionally, this approach might be scalable when compared to the aforementioned resource and time-intensive NOS-related interventions.

Statement of the Problem

Research has demonstrated that young children *can* learn about significant aspects of NOS. Teaching NOS at the elementary level is developmentally appropriate and can achieve the desired learning outcomes (Akerson et al., 2011; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Quigley et al., 2010). However, achieving the requisite instruction has most often been demonstrated in highly idealized situations, such as, delivering instruction by a researcher-teacher who holds informed views of NOS, intends to teach NOS and understands how to teach NOS, and does not have to deal with pressures that may impact teaching NOS in regular formal elementary schooling (e.g., Saturday Science; Akerson & Donnelly, 2010; Quigley et al., 2010). Most elementary teachers are not likely to deliver such NOS instruction unless, as noted above, they are heavily scaffolded and supported. As such, there is need for research that addresses the issue of improving elementary students' conceptions of NOS in classrooms taught by regular inservice elementary teachers, who typically have limited science content knowledge and NOS understandings.

To improve, on a large scale, students' conceptions of NOS in regular classrooms with practicing teachers, researchers must address how to effectively and practically support teachers in this endeavor. Namely, researchers need to provide scalable interventions that improve teachers' understanding of NOS, situate learning of NOS in context-specific situations, and address teachers' limited PCK for teaching NOS. It is unlikely that practicing teachers will have access to lengthy NOS-related professional development opportunities given the realties of their practice and the prevalence of short-term, professional development modalities in the majority of schools. The use of educative curriculum materials may be one way to meet this objective. Taken together, these concerns call for research on ways in which elementary teachers may be supported in their teaching of NOS in manners that are accessible, practical, and context-specific, thereby increasing the chance to impact student learning of NOS.

Purpose

This study aims to examine the impact of modified science trade books, coupled with educative curriculum materials focused on NOS, on (a) participant elementary teachers' understanding of NOS, (b) the translation of these NOS understandings into their instructional practice related to NOS, and (c) student discourse related to NOS when teachers put these instructional resources into use. The combination of educative curriculum materials and trade books will support the teaching of NOS in three ways. First, the use of trade books draws on the strengths of elementary teachers, who tend to specialize in language arts and not science. Second, incorporating educative curriculum materials, which are focused on improving teachers' relevant NOS concepts and addressing issues related to teaching about NOS, will both help to change the teachers' views of NOS and develop their NOS PCK. Third, by modifying trade books to include explicit references and reflective prompts focused on NOS concepts, teachers will be supported in translating their NOS understandings into practice in the specific context of their lessons. The present study addresses the following specific research questions:

1. What is the impact, if any, of modified trade books and educative curriculum materials on teachers' understandings of NOS?
2. What effects do modified trade books and educative curriculum materials have on the observable instructional behaviors of teachers related to NOS?
3. What are teachers' perceptions of the efficacy of modified trade books and educative curriculum materials in supporting their understanding of, and teaching about, NOS?
4. In what ways do students interact with, and understand, the NOS concepts being addressed during the read-alouds of trade books?

Significance

Previous research on NOS has demonstrated both the need for increased instruction in NOS and ways in which the teaching of NOS can be supported through professional development without taking into account the realities of classroom teaching and practicing teachers. The present dissertation research distinguishes itself from previous research on NOS instruction at the elementary level, in that it examines ways in which practicing teachers with naïve views of NOS may increase their understanding of NOS through the use of modified trade books accompanied by educative curriculum materials. The significance of this research on teachers' views of NOS is three-fold. First, it addresses the unique needs of elementary teachers, unlike the majority of research that focuses on secondary science teachers. By using trade books in the intervention, improvement in elementary teachers' views of NOS and translation of these views into practice may be bolstered by drawing on the teachers' expertise in teaching language arts. This may help overcome the common problem of elementary teachers having low confidence about teaching science and lack of knowledge of science content.

Second, the use of educative curriculum materials is a resource-lean, and minimally invasive intervention compared with previous research interventions on teaching and learning NOS. The short amount of time required for the intervention allows for the possibility of easily scaling-up in future studies. It is also likely that teachers may be more willing to participate in a shorter intervention, rather than the more typical extensive ones, as teaching science is just one aspect of elementary teachers' responsibilities. As such, there may be more teacher "buy-in" for this type of intervention.

Third, through this research, the connection among three components of NOS learning is investigated: teachers' views of NOS, teachers' translation of views into practice, and students' interaction with NOS concepts. Paying attention to all three components paints a fuller picture of NOS instruction than previous research, which typically looks at only one component. Ultimately, understanding the complex interconnected nature of these components is necessary, as teachers mediate student learning through their practice, and improving students' views of NOS is the main goal of K-12 education.

Chapter II

Review of the Literature

The purpose of this chapter is to argue for research to support in-service elementary teachers' learning of NOS and translation of NOS views into practice in a manner that capitalizes on elementary teachers' strengths and may be implemented in a practical way. To frame this argument, the relevant literature on the learning and teaching of nature of science, the use of trade books in elementary science instruction, and the development of educative curriculum materials will be reviewed. The discussion will highlight issues with the sustainability of preparing elementary teachers for NOS instruction based on the current research and how the use of educative curriculum materials may potentially address these problems.

The Role of NOS in Science Education

Developing informed conceptions of NOS has been a major goal of science education for several decades (Lederman, 1992; Lederman & Lederman, 2014), as it is part of being a scientifically literate citizen. *Science for All Americans* (*SFAA*; AAAS, 1990) describes science literacy as

> being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (p. xvii)

As such, NOS has been a component of major science education reform documents over the past several decades. However, science education researchers and philosophers of science have debated over exactly what NOS entails. The following sections detail two sides of the debate and how reform documents have dealt with this debate and described NOS.

The contested definition of NOS. Although the importance of NOS in science education is generally agreed upon, there is still debate among philosophers of science and science education researchers on what NOS entails and what K-12 students should be expected to know about NOS. Alters (1997) compiled a list of 15 NOS tenets from the research and reform literature. He then surveyed 210 philosophers of science to determine what consensus, if any, there was about the statements. According to his interpretation of the data, he determined that there was no agreement about the statements and concluded that NOS, as it is presented in K-12 science education, is not adequately meeting the needs of our students. Furthermore, he argued that "many of the existing NOS tenets, which are commonly taken as factual, must be reconsidered in light of this study" (p. 48). However, this interpretation has been explicitly criticized by several scholars in the field (Smith, Lederman, Bell, McComas, & Clough, 1997). For example, Smith et al. (1997) point out that Alters specifically chose NOS statements about which philosophers of science would disagree. Additionally, they claim Alters skewed the presentation of the data in favor of his stance, such as by focusing on instances of disagreement while ignoring or downplaying several instances of agreement amongst the philosophers.

In contrast to Alters' view, some researchers argue that K-12 education should focus on the agreement amongst philosophers and researchers of science. Furthermore, although there is still high-level debate about NOS, this debate is not relevant for students (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), and that "at one point in time and at a certain level of generality, there is a shared wisdom (although no complete agreement) about NOS amongst philosophers, historians, and sociologists of science" (Abd-El-Khalick, 2012, p. 1045). This view will hereafter be called the shared-wisdom view. In addition to acknowledging the debate about the specific aspects of NOS, supporters of the shared wisdom view use the phrase *NOS* instead of *the NOS* to reflect that there is still debate about what the phrase means and that there is no one NOS (Abd-El-Khalick & Lederman, 2000a). Supporters of the shared wisdom view have put forth several aspects of NOS that are relatively unproblematic to promote in K-12 education. These include the empirical, creative, theory-laden, tentative, social and socio-cultural nature of scientific knowledge as well as the role of observation versus inference, difference between theories and laws, and the "myth of the scientific method." Of particular interest to this dissertation study are the empirical nature of science, the creative nature of science, and the role of observation versus inference, as these are the ones that are specifically manipulated and focused on throughout the intervention.

Furthermore, by promoting the shared-wisdom view of NOS, the researchers are not denying the importance of the debate about issues of NOS, but instead are remaining silent about the issues (Abd-El-Khalick, 2012). This allows NOS to be introduced to K-12 students at a level that is developmentally appropriate, as it provides young students with relatively simplistic, but still useful, representations of NOS while avoiding the more abstract philosophical arguments. Abd-El-Khalick (2012) has proposed that NOS aspects be taught as relatively unproblematic at elementary grades and then increase in the level of depth in later grades. In this way, students are still learning the desired conceptions of NOS from an early age, and are prepared to learn about the more debatable parts of NOS in later grades. It is necessary to address NOS at a young age because research shows that when NOS is not addressed in an informed way, students learn naïve views of NOS (Abd-El-Khalick & Lederman, 2000a; and Lederman, 1992, 2014). It is possible that this is due, as least in part, to the manner that typical science curriculum materials present NOS. For example, a survey of science textbooks shows that the first chapter often describes "The Scientific Method," promoting the naïve view that by following a simple set of actions, infallible scientific knowledge can be produced (Abd-El-Khalick, Waters, & Le, 2008). In contrast, an informed view would teach that there is no prescribed sequence of activities that all scientists follow. Additionally, science trade books that students may read outside of formal science instruction typically present NOS in a naïve manner or leave out any references to NOS at all (Brunner & Abd-El-Khalick, in process). As research shows that misconceptions about NOS are difficult to change (Clough, 2006), it is desirable to teach informed conceptions from the start of formal education.

NOS in science education reform documents. Although there may be some debate among philosophers and researchers about the definition of NOS, the way NOS has been addressed in recent U.S. reform documents has remained fairly consistent (i.e., from the 1990's to the present). It is helpful to think about the reform documents in three waves: Project 2061 documents, the *National Science Education Standards* (*NSES*; NRC, 1996), and the *Next Generation Science Standards* (*NGSS*; NGSS Lead States, 2013). Historically, all three waves of science education reform have largely paralleled the shared-wisdom view of NOS. Project 2061 began in 1985 with the purpose of improving science literacy for all American students, whether they entered into science as a profession or participated in science as a citizen (www.aaas.org/program/project2061). *Science for All American* (*SFAA*; AAAS, 1990) was the first of many documents published as part of Project 2061. *SFAA* was written to describe what students should know and be able to do in science by the time they graduated high school. In *SFAA*, the first three chapters are devoted to nature of science, math, and technology, or what it calls "collectively, the scientific endeavor" (p. xvii). NOS is addressed broadly in this document, and is divided into three principle subjects. The first, the scientific worldview, explains that science is a way to understand the world and describes the types of questions science can answer.

The second, scientific methods of inquiry, explains that although scientific inquiry shares some features, there are no fixed steps in science. It also highlights the use of logic and imagination in science. The third, the nature of the scientific enterprise, highlights the individual, social, and institutional dimensions of science. Other Project 2061 documents include the *Benchmarks for Science Literacy* (AAAS, 1993) and the *Atlas of Science Literacy* (AAAS, 2001, 2007). The *Benchmarks* specified a progression on how to achieve the level of science literacy recommended by *SFAA*. The first chapter of the *Benchmarks* is devoted to NOS and is consistent with the description of NOS in *SFAA*. The *Atlas of Science Literacy* consists of strand maps that are intended as tools to assist in designing science curriculum consistent with *SFAA* and the *Benchmarks.* These strand maps highlight the interconnectedness of NOS within the science content and inquiry skills, as NOS appears in several of the strand maps.

Following Project 2061, the *National Science Education Standards* (NRC, 1996) were developed. The *NSES* continued the push to create scientifically literate citizens by being intended as "science standards for all students" (p. 2) and included a standard on the History and Nature of Science. Although the Project 2061 documents were written to be references, and as such claimed not to ascribe importance to the location of content within the documents (AAAS, 1993) the *NSES* explicitly state that the order of content was intentionally arranged so that "each standard subsumes the knowledge and skills of other standards" (p. 104). As such, History and NOS, as the last standard in the document, are explicitly labeled as multidisciplinary content that should be integrated within the other content areas. The content of the History and NOS standards emphasizes science as a historical and social discipline by including instruction on the types of people who have done and are currently doing science. It also includes describes science as tentative, empirically-based, and well substantiated by evidence.

The most recent reform document in science education is the *Next Generation Science Standards* (NGSS Lead States, 2013), based on the *Framework for K-12 Science Education* (NRC, 2011). Like the *NSES*, the *NGSS* aim to describe what students should be learning at various grade bands throughout K-12 education. Unlike the *NSES*, which is written so that each standard subsumes the previous ones, the *NGSS* contains three dimensions: disciplinary core ideas, scientific and engineering practices, and cross-cutting concepts that should be addressed simultaneously.

NOS does not appear explicitly in any of the disciplinary core ideas, scientific and engineering practices, or cross-cutting concepts. *NGSS* describe NOS as "more than just a Practice" (p. 9), and "as a complement to the practices imbedded in investigations, field studies, and experiments" (p. 96). Appendix H of *NGSS*, "Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards" provides the most detailed description of NOS, with a matrix of eight understandings central to NOS across the K-12 grade levels. The first four are identified as being consistent with practices: scientific investigations use a variety of methods; scientific knowledge is based on empirical evidence; scientific knowledge is open to revision in light of new evidence; scientific models, laws, mechanisms, and theories explain natural phenomena. The second four identify with cross-cutting concepts: science is a way of knowing; scientific knowledge assumes an order and consistency in natural systems; science is a human endeavor; science addresses questions about the natural and material world (pp. 98-99).

Research on Teaching and Learning NOS

Despite NOS being a central goal for science education, research shows that most students and teachers have largely naïve views of NOS (Abd-El-Khalick & Lederman, 2000a; Lederman, 1992, 2014). This may be partly because incorrect conceptions of NOS are reinforced through textbooks and curriculum materials (Abd-El-Khalick, Waters, & Le, 2008) and even popular media (Aikenhead, 1988; Walls, 2012). Furthermore, although the reform documents present NOS clearly, they do not prescribe any curriculum for teaching NOS. However, there is clear evidence from research that NOS views can be changed with proper instruction.

NOS instructional approaches: Implicit vs. explicit-reflective. Abd-El-Khalick (2012) identified two perspectives on NOS: the lived perspective and the reflective perspective. According to the lived perspective, “NOS is the practice of science” (p. 1050). That is, NOS is equivalent to doing science. In contrast, according to the reflective perspective, “NOS derives from reflecting on science, it is about the practice of science” (p. 1050). These two perspectives of NOS call for different pedagogical approaches to teaching NOS, referred to the implicit or explicit approaches, respectively.

In the implicit approach, it is thought that students will come to understand NOS through participating in science. In their review of the literature, Abd-El-Khalick and Lederman (2000a) identified two assumptions that were common in research that employed an implicit approach. The first is that learning NOS is a by-product of engaging in scientific inquiry. The second is that NOS is an affective goal, and not a cognitive one. For example, in a year-long study of a fourth-grade teacher’s science instruction, Akerson and Abd-El-Khalick (2003) found that the teacher intended that students learn about the empirical NOS through supporting their conclusions with data during inquiry activities. However, she never explicitly encouraged the connection between the *act* of using data to support scientific conclusions and the reflection on *why* scientists do this. Further examples come from research in which students not only act like scientists in the classroom, but actually work with scientists in a student-scientist partnership (e.g., Moss, 2003). In research with elementary children, Akerson and Abd-El-Khalick (2005) examined the NOS views of fourth-grade students who participated in an inquiry-based science program led by a teacher with informed views of NOS. Although the teacher aimed to teach NOS implicitly through the use of inquiry, her students demonstrated naïve views at the end of the year of instruction, indicating that the implicit view was not effective at improving NOS conceptions.

In contrast, in the explicit-reflective approach, improving views of NOS is considered an instructional goal. As such, activities that target NOS aspects would be specifically planned for. One way in which this has been advocated for is by coupling NOS instruction with history of science, as using historical examples provides a context in which the enterprise of science may be addressed. For example, Abd-El-Khalick and Lederman (2000b) found that explicitly addressing NOS in the context of history of science courses improved college students' views of NOS more than just attending history of science courses alone. Whereas the implicit approach requires student participation in inquiry activities, it should be noted that the explicit approach does not deny the importance of inquiry activities and the benefits of inquiry activities in NOS instruction.

Few studies have supported the effectiveness of the implicit approach. In a direct comparison of the two approaches, Khishfe and Abd-El-Khalick (2002) found support for the explicit-reflective approach over the implicit approach. In this study, one group of sixth-grade students participated in inquiry activities while another group participated in the same activities followed by a reflective discussion of NOS. By the end of the intervention, 2.5 months later, the group that participated in explicit-reflective discussions held more informed views of NOS, compared to the inquiry-only group. Further support for the effectiveness of the explicit-reflective approach comes from research with primary students (Akerson & Abd-El-Khalick, 2005; Akerson et al, 2014; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Akerson & Volrich, 2006; Conley et al., 2004; Lederman & Lederman, 2004; Quigley et al., 2011), secondary students and post-secondary students (e.g., Abd-El-Khalick & Lederman, 2000b; Khishfe & Lederman, 2007), and both preservice and in-service teachers (e.g., Abd-El-Khalick, 2001; Abd-El-Khalick & Akerson, 2004; Akerson, 2004; Lederman & Lederman, 2004).

Different studies on the explicit-reflective approach have used a variety of activities to improve NOS views, including inquiry activities, class discussions, journaling, and reading of trade books. Additionally, connecting the history of science with NOS is an effective way to teach NOS to older students (Abd-El-Khalick & Lederman, 2000b), although concerns about the appropriateness of the historical approach with young students have been voiced (AAAS, 1993). Additionally, the NGSS provide suggestions for incorporating NOS into science instruction including both the use of reflection on the connection between practices of science and NOS and the use of history of science. Most studies have used some combination of these activities. For example, Akerson and colleagues incorporate the use of inquiry activities, class discussions, journaling, and connecting with children's literature to teach NOS in several of their studies (Akerson & Donnelly, 2010; Akerson & Volrich, 2006; Quigley et al., 2011). However, to date none have specifically looked at the effects of one activity over the others.

In addition to learning gains in NOS, Quigley et al. (2011) described the added benefit of the explicit-reflective approach allowing the teacher to monitor students' understandings and modify their teaching to meet the students' needs better. Indeed, Akerson et al. (2014) showed that different methods of instruction within the explicit-reflective approach had differential effects on students of differing NOS achievement levels. The low-achieving student benefitted from group discussions and direct questioning about how various activities connected with specific aspects of NOS, but the science notebook was not a useful tool in changing his views of NOS. In contrast, the science notebook was a significant tool for the mid-achieving student because it allowed her a space to reflect on her conceptions and explore meanings in her own words. The science notebook was also an effective tool for the high-achieving student, as it allowed him to draw connection across aspects of NOS. This student also described relations to NOS in the children's stories found in the classroom.

Contextualization of NOS activities. Clough (2006) described the additional dimension of contextualization in which NOS is taught. In contextualized instruction, the learning of NOS is embedded in the science content. In contrast, decontextualized instruction is not tied with any specific science content but instead focuses solely on the targeted NOS aspects. It is possible to combine the two approaches to teaching NOS within one unit of study. For example, Akerson et al. (2011) described a NOS unit for third-grade students. This unit began with 10 days of instruction on decontextualized NOS content to introduce the students to the ideas. One activity the researchers used was a classic example of a decontextualized NOS activity, "Tricky Tracks" (Lederman & Abd-El-Khalick, 1998). This is considered a decontextualized activity because it does not depend on students' prior knowledge of science content. Twenty days of contextualized NOS instruction followed, in which the concepts that were already introduced were expanded upon. Students' views of NOS were measured before instruction, after decontextualized instruction, and after contextualized instruction. Students made initial gains after the decontextualized instruction and further gains after the contextualized. Additionally, research during a Saturday Science program also used a combination of a contextualized and contextualized approach (Akerson & Donnelly, 2010; Quigley et al., 2011). Students made gains in learning NOS during both of these studies. Akerson et al. (2011) call this the "NOS Teaching Cycle," in which NOS aspects were introduced without context, embedded in context, and then reinforced. Taken together, these results demonstrate that both contextualized and decontextualized instruction may be used to effectively teach NOS content effectively.

However, it is important that NOS not be addressed *only* through decontextualized instruction because the use of decontextualized instruction by itself may promote the view of NOS as a separate content area, instead of being interwoven within the traditional science content. Incorporating NOS within the science content is important to address science as a human enterprise (Clough, 2006). Akerson and Donnelly (2010) claim,

> by carefully juxtaposing decontextualized instruction that highlights NOS aspects with contextualized instruction illustrating these NOS aspects in multiple specific science contexts, a teacher can provide opportunities for students to become aware of their existing ideas in explicit ways, modify them within specific contexts, and reflect on these changes. (pp. 5-6)

Translating teachers' views of NOS into instructional practice. Although research has shown that both students and teachers can learn NOS and has provided evidence of some relatively more effective ways with which to change views of NOS, there still remains a disconnect between what practices research has shown to be effective and actually implementing these practices in classrooms with teachers. This can be considered a problem of translating a teacher's views of NOS into instructional practice. The issue of translation ties together two important areas of teacher knowledge: NOS content knowledge (NOS CK) and NOS pedagogical content knowledge (NOS PCK). Shulman (1986) described three different areas of teacher knowledge: content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK). Content knowledge refers to a teacher's understanding of the material being taught. Pedagogical knowledge is a general understanding of teaching, including classroom management, use of praise, and general questioning strategies. Pedagogical content knowledge refers to a teacher's understanding of how to teach the specific content. It includes, for example, knowledge of students' thinking about the content (e.g., common student misconceptions), specific activities to support instruction of the content, and useful analogies or representations of relevant ideas.

All effective teachers should have high PK, regardless of the specific content. However, to teach NOS effectively, teachers should also have high NOS CK and NOS PCK. NOS CK refers to a teacher's understanding of NOS as a subject. It is desirable that teachers have informed views of NOS (i.e., hold views in line with those of the reform documents), indicating high NOS CK. Having high NOS CK is a necessary condition for effective teaching of NOS. However, it is not sufficient, as research shows that teachers with high NOS CK do not always teach in line with their views (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000; Lederman, 1999). For example, Abd-El-Khalick, Bell, and Lederman (1998) analyzed the teaching practices of 14 preservice teachers during their student teaching assignments, all of whom had adequate views of NOS and who intended to teach NOS. Despite these intentions, the student teachers rarely incorporated explicit NOS instruction into their teaching plans. Similarly, Lederman (1999) found that experienced high school teachers did not always translate their informed NOS views into practice. Of the five teacher participants, only two effectively addressed some NOS in their teaching practices.

These results indicate that while having NOS CK may facilitate teaching NOS (as with the two practicing teachers in Lederman's [1999] study), research must also focus on improving NOS PCK. NOS PCK refers to a teacher's understanding of how to teach NOS. This may include knowledge of effective teaching strategies or analogies as well as an understanding of common student preconceptions or misconceptions. Some research has investigated the effects of improving instruction of NOS through improving NOS PCK (Akerson & Abd-El-Khalick, 2003; Akerson, Cullen, & Hanson, 2009; Akerson & Hanuscin, 2007; Cullen, Akerson, & Hanson, 2010).

One particularly intensive example of professional development comes from Akerson and Abd-El-Khalick's (2003) investigation of a fourth-grade teacher's NOS instruction. They determined what individual supports an experienced elementary teacher with informed views of NOS needed to teach NOS explicitly in her classroom. The researchers worked closely with the participant teacher throughout the year, observing lessons in person once a week and video recording all other science lessons. To implement changes in the participants' teaching practices, the researchers relied on heavy supports. These included teaching of model lessons in the participant's classroom by the primary researcher, debriefing of observed lessons, and elucidating content-specific NOS ideas (i.e., assisting her in taking her context-independent understandings and applying them to specific science content).

Akerson and Abd-El-Khalick's (2003) findings clarified the need for continued support of translating NOS views into practice beyond the preservice years. Improving NOS PCK in practicing teachers is important for at least two reasons. First, there is a large population of teachers who are already practicing. By providing them with support for improving NOS PCK, larger scale change in NOS teaching may be seen than by simply targeting preservice teachers alone. Second, the practicing teachers who effectively teach NOS on their own may act in turn as supports for preservice or new teachers. This may be true particularly for elementary teachers. Research has shown that new elementary teachers frequently begin their teaching careers with low self-efficacy for teaching science (e.g., Bleicher & Lindgren, 2005; Cantrell, Young, & Moore, 2003; Palmer, 2006a, 2006b). Teachers who are not comfortable teaching science may avoid science instruction altogether (Appleton & Kindt, 2002), including NOS because it is an area that is not often emphasized in science teaching. However, when new teachers are surrounded by a culture that values science instruction, for example by associating with teachers who are comfortable and supportive of teaching science, they are more likely to adapt to that culture (Abell & Roth, 1992). There is additional support for this mentoring effect from NOS research. In research on preservice elementary teachers' translation of NOS views into practice, Akerson, Buzzelli, and Donnelly (2010) found that most preservice teacher participants began student teaching with similar profiles in terms of level of NOS understanding and concerns about teaching NOS. However, those with cooperating teachers who were aware of the importance of NOS and emphasized NOS in their own instructional practices were more likely to plan for and teach NOS on their own successfully.

Although teachers with high NOS CK and NOS PCK may be more likely to teach NOS explicitly in their classrooms, there are several other mediating factors that inhibit the effective teaching of NOS, including the need for novice teachers to prioritize classroom management issues (Lederman, 1999), the perceived priority to "cover" the tested science content instead of NOS, and teachers' beliefs about the relative importance of teaching NOS or students' ability to understand NOS concepts (Akerson & Abd-El-Khalick, 2003; Lederman, 1999). One of the most predominant mediating factors, however, is the availability of resources for effectively supporting the teaching of NOS (Wahbeh & Abd-El-Khalick, 2014). While preservice teachers may learn NOS in a decontextualized manner or in the limited number of contexts that come up in methods classes, it is not possible to prepare them during their preservice years to teach NOS in every context in which they may be expected. As such, accessing resources for supporting contextualized NOS instruction may facilitate teaching by teachers with adequate NOS views.

Special concerns with research on young students' views of NOS. Much of the research that has been done on teaching and learning of NOS with K-12 students has focused on students in secondary schools. The relative dearth of research on elementary students learning NOS may be in part due to two reasons: (a) the difficulty with effectively and efficiently evaluating young students' views of NOS, and (b) questions about the developmental appropriateness of teaching NOS to young students. These issues will be examined more fully in the following sections.

Evaluating young students' views of NOS. Throughout the history of research on learning NOS, many instruments have been developed to measure NOS views. Abd-El-Khalick (2014) identified 32 unique NOS instruments, starting with those developed in the 1950's. These instruments can be grouped according to the type of response they elicit: forced-choice or open-ended (e.g., Abd-El-Khalick & Lederman, 2000; Nott & Wellington, 1995). The forced-choice instruments include responses such as agree/disagree (Swan, 1966; Welch, 1966; Wilson, 1954), multiple-choice (e.g., Aikenhead et al., 1987; Billeh & Hasan, 1975; Cooley & Klopfer, 1961), or Likert scale (e.g., Chen, 2006; Kimball, 1967-68; Rubba, 1976). Abd-El-Khalick further documents the trend in instrument use from the predominant use of forced-choice measures in early NOS research to the use of open-ended assessments in more recent studies.

This trend toward the use of open-ended assessments is important to note because it reflects the concern with the effectiveness of forced-choice instruments in accurately measuring views of NOS. Aikenhead (1988) points out a major flaw in forced-choice instruments, namely that "they all assume that both the student and the assessor perceive the *same* meaning in the items" (p. 608, emphasis in the original). Furthermore, although students may choose the same response, the forced-choice instrument does not provide a reason for why the student made the choice. In this way, the forced-choice instruments limit access to important information about student understandings. In his comparison of four response methods (i.e., Likert-type, written paragraph, interview, and multiple choice), Aikenhead (1988) found that although the Likert-type responses were the most efficient (i.e., they required the least amount of effort on the part of the researcher), they were the least valuable in the type of information they provided. In comparison, the written paragraphs and interviews provided the clearest insight into student responses. The trade-off, of course, is in the amount of effort required by the researcher, as many more resources are needed to administer and score open-ended written instruments or interviews than are needed for Likert-type instruments.

With dissatisfaction with forced-choice instruments rising, the need for effective open-ended instruments became apparent. In particular, research showed an obvious benefit of the combination of open-ended written responses and interviews in generating accurate profiles of NOS views (Lederman & O'Malley, 1990). The development of the Views of Nature of Science (VNOS) Questionnaire capitalizes on the effectiveness of the combined responses. The instrument, in its many forms (i.e., Form A [Lederman & O'Malley, 1990], Form B [Abd-El-

Khalick, et al., 1998], Form C [Abd-E-Khalick & Lederman, 2000], Form D [Lederman & Khishfe, 2002], and Form E [Lederman & Ko, 2004]), has become the most widely used instrument assessing NOS views (Abd-El-Khalick, 2014). In addition to demonstrating effectiveness in determining views of NOS, the instrument is one of the few to have established construct validity (Bell, 1999).

In addition to general issues with the types of instruments used in evaluating views of NOS, multiple researchers have identified methodological concerns with administering assessments to young children in particular (Lederman & Lederman, 2004; Walls, 2012). Specifically, young children's ability to read and write limit the effectiveness of instruments that rely on open-ended written responses. Lederman and Lederman (2004) speculate about the limited number of studies on elementary students, saying, "Perhaps, a valid approach to assessing the understandings of students too young to read and write presented too much of an obstacle for such data to be collected" (p. 18). Alternative to the written response, they proposed the method of administering the VNOS-E orally to small groups. However, when using small group interviews, it is difficult—if not impossible—to track changes in individuals' views.

Developmental appropriateness of teaching NOS. Questions have been posed as to the developmental appropriateness of teaching NOS to young children (Akerson & Donnelly, 2010). These questions can be addressed through analysis of the research on gains in elementary students' understanding of NOS. A search of the published literature resulted in 10 studies on elementary students' conceptions of NOS (Akerson & Abd-El-Khalick, 2005; Akerson et al., 2011; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Akerson et al., 2014; Akerson & Volrich, 2006; Conley, Pintrich, Vekiri, & Harrison, 2004; Lederman & Lederman, 2004; Quigley, Pongsanon, & Akerson, 2010; Walls, 2012). Across the studies, researchers attempted to improve students' views of the tentative, creative, empirical, and theory-laden nature of science, as well as the difference between observation and inference. However, the success at this goal varied. For example, understanding the empirical nature of science and the difference between observation and inferences seemed to be more accessible to students of all ages, as gains were made in students from kindergarten to fourth grade. However, there was still variability, as some studies found students held informed views before the intervention (Akerson et al., 2011) while others found that "the empirical NOS seemed to be an aspect a bit more difficult to attain, despite the continued emphasis on this aspect throughout the program activities" (Akerson & Donnelly, 2010, p. 23). Despite the differences in effectiveness across studies, the combined results demonstrate evidence of success in teaching each aspect of NOS to elementary student, indicating that it is developmentally appropriate to teach NOS to young students.

Although it is possible to claim the developmental appropriateness of teaching NOS, it must be emphasized that direct comparisons cannot be made across studies as they differed significantly in their implementations, including involving teachers with different comfort levels of NOS, interventions that lasted different lengths of time, and different intervention techniques. Despite these limitations, some initial conclusions about the developmental appropriateness of teaching NOS to elementary students can be drawn. For example, closer inspection of the literature shows inconsistent results for teaching the various aspects of NOS across grade levels. One illustration of this is that Akerson and Hanuscin (2007) found changes in kindergarten students' conceptions of the empirical nature of science, but Akerson and Donnelly (2010) found the empirical NOS to be one of the more difficult aspects for their students to change.

One of the more consistent findings across the studies was that an adequate understanding of the theory-laden nature of science was more difficult for younger elementary students to attain (Akerson et al., 2011; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007). Additionally, when comparing three third-grade students of different achievement levels, only the highest-achieving student achieved an adequate understanding of the theory-laden NOS (Akerson et al., 2014). Akerson et al. (2014) speculated that the theory-laden nature of science is more abstract than the other aspects, making it more difficult for young students to understand. However, there is still some inconsistency in the findings, as Lederman and Lederman (2004) found that the first grade students in their study had large gains in understanding the theory-laden nature of science and claim that young students are capable of understanding abstract concepts if given proper support in the learning environment.

Because the developmental appropriateness depends not just on the content, but supports in the learning environment in which the content is taught, it is difficult to determine which aspects are easier to attain at younger grade levels. For example, the teacher is arguably the most important support in the learning environment. However, the level of the teacher's understanding of nature of science and comfort in teaching NOS differed across studies from teachers with developing conceptions and low comfort in teaching NOS (Lederman & Lederman, 2004) to teachers with informed views and experience teaching NOS (Akerson & Volrich, 2006), to researchers whose focus is on teaching and learning of NOS (Akerson & Donnelly, 2004; Quigley et al., 2011). Indeed, Lederman and Lederman note that the greatest gains in the students' understandings were in the theory-laden, empirical, and inferential aspects of NOS. These were also the aspects in which the teacher held informed views.

Use of Trade Books in Science Teaching

Elementary teachers tend not to be specialists in science (Davis, Petish, & Smithey, 2006). Research consistently shows that elementary teachers struggle to teach science because of low self-efficacy (e.g., Bleicher & Lindgren, 2005; Cantrell, Young, & Moore, 2003; Palmer, 2006a, 2006b), low content knowledge (e.g., Abell & Roth, 1992; Rice & Roychoudhury, 2003), and low motivation to teach science (Appleton & Kindt, 2002). In upper grades, one tactic that teachers may use to combat issues that deter them from teaching science is to rely on the students' textbook as a way to improve content knowledge. However, many elementary science programs do not use a textbook. Indeed, the use of science textbooks at the elementary level can be problematic, as these texts are often difficult to read. Halliday (1993) compared the lexical density of written texts to scientific text. Most written texts have a density of 4 to 6 lexical items per clause. In contrast, scientific texts have a lexical density of 10 to 13 items per clause. As such, teachers may turn to other types of informational texts to support their teaching of science. One type of text that is frequently used is the trade book, or books that are marketed to the general public and are not specifically intended to be used in instruction.

What types of text are used in science instruction? Texts used in science instruction include textbooks, reference books, and trade books and fall under the general category of informational texts. A number of terms may be used to discuss texts that convey information about reality, including nonfiction, information(al), and expository texts. In actuality, many researchers do not explicitly define the terms they use (Williams, 2009) and actually point out the difficulty in defining the terms (Kiefer & Wilson, 2011). Additionally, some researchers separate out biographies from other nonfiction text (Kiefer, 2010). This distinction is not made in the current dissertation study, and although I acknowledge the importance of attending to definitional issues, I have chosen simply to use the term informational text, as it aligns with the terms used in both the Next Generation Science Standards and Common Core Standards for English-Language Arts. However, as Dreher and Voelker (2004) stress "that all nonfiction is not alike and that it is important to afford children opportunities to experience all these types" (p. 262) and different types of texts may be used for different purposes, it is important to distinguish the types of texts students are reading and for teachers to choose texts appropriate to the tasks they complete with the students.

The category of informational texts can be further broken down into narrative and non-narrative informational texts (Donovan & Smolkin, 2002). Both narrative and non-narrative informational texts are primarily used to inform the reader. However, they differ in how they do this. Narrative informational texts use time sequences or processes to present a particular phenomenon. Smolkin and Donovan (2004b) exemplify the narrative informational text with Gail Gibbons' (1991) *From Seed to Plant*. This book follows a sequence of events including the travels of a seed and ending with the seed being eaten. Although the book includes much factual information, it is told through a narrative style, using sequencing words like "then" to progress through the information.

In contrast, non-narrative informational texts tend to present a topic, followed by its attributes, using "timeless" language. Smolkin and Donovan (2004b) describe Gail Gibbons' (1990) *Weather Words and What They Mean* as an example of non-narrative informational text. The main topic is *weather words* and subtopics include *temperature*, *air pressure*, *moisture*, *wind*, and *areas of weather*. Within each of these subtopics, specific information is included.

Some books present factual information embedded within a storyline. Because these books are written both to inform and entertain, they are called dual-purpose texts (Donovan & Smolkin, 2001), or alternatively hybrid texts (Pappas, 2006; Williams, 2009). One popular example of this genre is *The Magic School Bus* series by Joanna Cole. Much research has been done on this particular series of hybrid books (e.g., Leal & Kearny, 1997; Maria & Junge, 1994; Smolkin & Donovan, 2004a).

Benefits of trade books in science instruction. The use of trade books in science instruction is advocated for by both standards documents and research. Using trade books is in line with recent recommendations for both science instruction and language arts instruction, as recently adopted standards advocate for literacy skills to be developed across the curriculum and not just in an English Language Arts class. The Common Core State Standards (CCSS) for English Language Arts encourages an interdisciplinary approach to literacy, with instruction occurring across the subjects (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Additionally, Appendix M of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) acknowledges that "literacy skills are critical to building knowledge in science" (p. 1), and as such, the NGSS were written to be consistent with the Common Core State Standards.

Research also supports the use of trade books in science instruction. In the following sections, research from two areas will be reviewed: (a) making science approachable as a subject, and (b) meeting science learning goals.

Making science approachable. In addition to Dreher and Voelker's (2004) recommendation to incorporate multiple types of informational text into the science classroom to familiarize students with the different purposes of texts, there are other reasons to use a wide variety of texts in science learning. Although much of science learning incorporates a textbook, using one text per grade level limits the amount of differentiation that can be done at a grade level (Donovan & Smolkin, 2001). This is particularly problematic with young children, as they are still learning how to read and may have widely varying levels of proficiency. However, through the use of a variety of informational texts, written at different reading levels, students may more easily access the information and get productive practice at reading in the content area.

Contrary to the belief held by some teachers that students are not capable or interested in reading nonfiction texts (Donovan & Smolkin, 2001), research shows that young children are able to understand them. For example, in one study 20 students were read an informational text out loud (Moss, 1997). After the reading, the first graders were asked the draw a picture about the book and retell the information in the book. The researcher found that the students were able to summarize the information and make inferences about the text, indicating that they understood the content of the text. She concluded by saying that "children may be far more capable of comprehending expository text than previously thought" (p. 12). Indeed, without exposure to these types of texts, students will not have the ability to develop their skills in reading and comprehending informational texts.

Additionally, some research shows that scientists are depicted more realistically in trade books (Dagher & Ford, 2005; Sharkawy, 2013). Sharkawy (2013) analyzed 15 biographies of scientists (both historical and contemporary), aimed at elementary-aged children. She looked for depictions of scientists that may affect how young children see science: superior scientific intelligence, early aptitude for science, and overcoming challenges significant challenges. She found that only four of the biographies depicted the scientists as having superior intelligence, and further noted that all four of these were historical biographies (i.e., Galileo, Einstein, Curie, and Newton). Contemporary scientists and those from minority groups were depicted as achieving success through hard work and not superior intelligence. Additionally, the contemporary biographies did not stress the scientists as having an early aptitude at science (although it is important to note that Dagher and Ford [2005] found conflicting results about this characteristic of trade books). One drawback of the biographies was that it did not stress the cognitive difficulties the scientists may have had with science, as they focusing very little on the scientists' effort. However, the biographies did tend to focus on scientists overcoming personal struggles, such as poverty.

In addition to representing scientists and science in general more accurately, trade books can be used to highlight traditionally marginalized populations. Representations of males as scientists tend to dominate science textbooks (Elgar, 2004; Kahveci, 2010). In contrast, women are presented more positively in trade books than in textbooks, as are minorities (Daisey, 1994; Rice, 2002). Whereas the lack of representation of diverse people in textbooks may alienate many students from participating in science as a career, trade books may be purposefully selected to highlight the inclusion of all people in science activities (Daisey, 1994).

Science learning gains. Incorporating the use of informational texts in science classes helps increase students' understanding of science content knowledge, science processes, and science vocabulary. Rice and Snipes (1997) read science books out loud to elementary students and compared students' knowledge on the subject before and after the books were read. Students answered questions on the post-test more in line with information from the books than on the pre-test, indicating that they were retaining science information that was read to them. Varelas and colleagues (Varelas & Pappas, 2006; Varelas, Pappas & Rice, 2006) examined learning gains that second-grade students made while studying three science units that incorporated informational text read-alouds and hands-on science activities. Analyses of discussion in the second-grade classroom during both the read-aloud session and the activity debriefings showed that the children developed major scientific concepts through the use of the informational texts combined with the hands-on activities. Additionally, in both classrooms, students' scientific talk increased throughout the unit as they made connections with the hands-on activities, read-alouds, and their personal experiences (Varelas & Pappas, 2006).

Some researchers caution about the increasing use of scientific talk in an elementary classroom because it might constrain students' connection with the science concepts, especially in the physical sciences (Kurth, Kidd, Gardner, & Smith, 2002). However, Varelas and Pappas (2006) claim that the use of both everyday language and scientific language is beneficial for students as it assists them in their own science content understanding and allows them to feel connected to the scientific community. Additionally, Varelas et al. (2006) used this as an indicator of students' progressing understanding of science as a process, as it showed that students were making connections between theory and data.

Additionally, Morrow, Pressley, Smith, and Smith (1997) found that children who were taught science through activities and literature made larger gains in both vocabulary and science content than those students who learned through either literature or activities alone. Similarly, Brabham, Boyd, and Edgington (2000) found that second, third, and fourth grade students made gains in vocabulary after being read an informational storybook out loud. Of note in this study is the fact that the independent reading level of the book was at the fifth-grade level, indicating that read aloud activities are one possible way in which young students can access the science content even through difficult texts.

Challenges with using informational texts. Although using informational texts, in particular trade books, can be beneficial for elementary students' science learning, there are also challenges that must be addressed. The following sections will detail the challenges that the texts themselves pose, and the challenges that teachers have with picking appropriate texts and utilizing these texts in the elementary science classroom.

Poor or misleading texts. Atkinson, Matusevich, and Huber (2009) caution that, "although the advantages of trade books offer are numerous, not all trade books are equal in quality" (p. 2). In particular, because they are marketed for the public, trade books may not be subject to the scrutiny that textbooks are. Indeed, it may not even be the author's intent that the book be used as a teaching tool and so the author may knowingly include inaccurate science content, in favor of making the book more aesthetically appealing. Donovan and Smolkin (2001) point out that such is the case with *The Very Hungry Caterpillar* by Eric Carle (1969), in which he chooses to have his "very unusual" caterpillar emerge from a cocoon instead of a chrysalis and eat lollipops and ice cream (www.eric-carle.com/q-cocoon.html).

Additionally, hybrid books—those that contain elements of both story and informational genres—pose particular problems. These books may contain little scientific information and the information that they do contain may be incorrect or misleading. Rice and Rainsford (1996) found that in a sample of 300 trade books, story books tended to have the most misconceptions or incorrect information. Similarly, in a content analysis of 23 trade books, Donovan and Smolkin (2001) found a large range of informational ideas per page, from a minimum of .25 to a maximum of 11.5, with stories tending to have fewer ideas per page compared to non-stories.

In Mayer's (1995) study, students were read *Dear Mr. Blueberry* (James, 1991) out loud. This book contains scientific information in the form of letters written between characters. In particular, one character directly addresses misconceptions held by the second character and contrasts it with correct information. After students were read the book, the researcher tested children's knowledge of information from the book, under the assumption that the direct contrast of information and misinformation would promote learning. Surprisingly, the children remembered many of the misconceptions that were addressed in the book instead of the correct information. In an extension of this study, Rice and Snipes (1997) administered both a pre-test and post-test of content knowledge before reading five science books to students, allowing them to determine which conceptions children had before reading the book and how the content of the book changed those conceptions. They found that, although children changed answers only infrequently from pre-test to post-test, when the children did change answers on the post-test the revised ones were consistent with the information from the book, regardless of whether the book's information was correct or incorrect. These studies support the idea that children learn from texts, whether they present correct information or not, thus highlighting the need to include books with correct information in science instruction.

Even when texts are selected that contain correct information, the use of hybrid texts may be confusing to students in terms of the goals for reading, as hybrid texts may be read for either the storyline or for the informational content. In a comparison of children's responses to different types of texts, Shine and Roser (1999) found that children tended to focus on the narrative elements of all books, including the hybrid books. When Tower (2002) replicated this study using informational texts that explicitly did not include narrative features, however, children did not create a narrative of the text. This indicates that children in the first study were not attending to the information in the hybrid book, but focused on the narrative features instead. Jetton (2006) and Maria and Junge (1994) found that even when students were cued to pay attention to informational content during a read-aloud of a hybrid text, students did not recall the content. Instead, they remembered the narrative elements of the story. Combined, these four studies show that although students are not inclined to create narratives in non-hybrid informational texts (as shown in Tower, 2002), they are drawn to the narrative structure in hybrid texts over the informational content. This has implications for science instruction. If teachers choose hybrid books to teach content, they must be aware that the narrative structure can impede students' learning of content.

However, there may be a developmental trend with children's ability to distinguish factual elements in hybrid texts. In a study of second-, third-, and fourth-grade students, Brabham and colleagues (2000) found that there was an increase in the ability to differentiate between fact and fiction from second to third grade. Children in the second grade were more likely to confuse fact and fiction, believing that fictional elements of the story such as anthropomorphizing were true. It is interesting to note that there was no difference, however, between grade levels for vocabulary gains. This may indicate that, if teachers have a goal of increasing vocabulary, hybrid books may be an appropriate tool through which to do that, as long as teachers are aware of the limitations in students' ability to distinguish between fact and fiction.

Teachers' selection of appropriate texts. Fortunately, even though the appropriateness of texts for use in elementary science classes varies widely depending on the book, teachers have the ability to choose books that are well suited to their classroom needs. However, research has shown that this is not always a simple task. Donovan and Smolkin (2001) provided elementary teachers with 23 books about Life Cycles and Properties of Matter, both common topics covered in elementary science classes. The teachers were instructed to choose books for use in their science instruction. Teachers considered the science content (including accuracy), reading level, and visual features when choosing books. Teachers were not always successful in making appropriate choices based on these considerations. For example, one fifth-grade teacher chose

Eric Carle's *The Tiny Seed* (1987) and *The Very Hungry Caterpillar* (1969) as good sources of information, but both of these stories only contain .25 informational ideas per page. Of further concern, Donovan and Smolkin note that teachers did not take into consideration the important issue of genre, as indicated in the example above in which a teacher selected a storybook as a source of information. This indicates that teachers are either not aware of, or do not consider important, the influence that the type of text has on learning.

Compounding this issue is the assumption that children either do not enjoy reading informational texts or that children do not enjoy reading about science (Donovan & Smolkin, 2001) and the use of stories must be incorporated into classrooms to help overcome these obstacles. However, as described above, children both enjoy reading informational texts and are capable of understanding the information in them (Rice & Snipes, 1996; Varelas & Pappas, 2006). As such, these assumptions are ones that are not supported by research. It is important that teachers are aware of these faulty assumptions so that they do not act on them when choosing books for science instruction.

Teachers may consider using recommended book lists or rubrics to assist them in making appropriate choices for which informational books to use in their classes (Broemmel & Reardon, 2006). Donovan and Smolkin (2002) and Rice (2002) recommend that when using these lists that teachers pay attention to genre, content, and visual features of the books. Of particular importance, science trade books should have substantial science content, be scientifically accurate, and be current (Donovan & Smolkin, 2002). However, it is important that teachers do not assume the creators of the recommended book lists judge the books based on the same features that are recommended by researchers. Atkinson and colleagues (2009) created a rubric for analyzing science trade books based on the three features that were highlighted by previous researchers. Atkinson et al. found that when the rubric was used to score books on recommended lists, the recommended books were not always high quality.

The rubric was trialed with 28 books recommended by a textbook publisher, 15 of which were on other recommended lists (e.g., National Science Teacher's Association's [NSTA] Outstanding Science Trade Books for Students K-12 [www.nsta.org/publications/ostb/]). On average, 80% of the books were not recommended for use based on their scores on the rubric. Only nine books recommended by the publisher and NSTA were supported for use in the elementary classroom by the rubric. The excluded books were not written at appropriate grade levels, did not contain significant amounts of science information, or were not widely available. These results indicate some problems with relying solely on recommended book lists. However, when the rubric was tested with preservice teachers, the teachers paid attention to the features highlighted in the rubric and successfully chose books appropriate for science instruction. Furthermore, the teachers appreciated the guidelines that the rubric provided as a useful tool in selecting books for the science classroom. This shows that even teachers with limited experience can successfully choose books that are appropriate for use in the elementary science classroom when given appropriate tools.

Utilizing texts. Even after choosing appropriate texts to use in science instruction, teachers still have to determine how to utilize them effectively for teaching science. Much of the research on using trade books in elementary science classes presented the books during read-alouds, indicating this was an effective way to teach science content (e.g., Brabham, Boyd, & Edgington, 2000; Jetton, 2006; Varelas & Pappas, 2006; Varelas et al., 2006). Elementary teachers tend to choose narrative nonfiction and hybrid books as books to read aloud over information books (Donovan & Smolkin, 2001; Jacobs, Morrison, & Swinyard, 2000). This is problematic, as teachers may not focus on the science information in the books, choosing to focus on the storyline instead. Smolkin and Donovan (2004a) analyzed how elementary teachers approached reading *The Magic School Bus Inside the Earth* (Cole, 1987) to their students. All of the teachers focused on the running text, which contained the storyline, in the book. However, this text contained only 11.4% of the informational ideas. The remaining information was conveyed through examples of student reports, picture labels, diagrams, speech balloons, and author notes. Teachers varied in their approach to presenting this information, from reading almost everything in print to reading only the storyline. Smolkin and Donovan warn that teachers must inspect books that present information in such a complex way and devise a plan for approaching the information before reading to the class. In this way, they can more effectively use the hybrid books in the classroom.

Even when teachers have a plan of action for using narrative nonfiction or hybrid books in read-alouds, hybrid books are still potentially problematic, as these types of books do not always have appropriate science content and are sometimes confusing for children. In contrast, information books were consistently indicated as good resources for children's individual research projects or classroom science interest centers. However, relegating these books to individual use removes the teachers' impact on learning. Interactions between students and teachers during read-alouds of informational texts increase children's understanding of the text, scaffolds their learning of content knowledge, and adds to thinking in scientific ways (Smolkin & Donovan, 2001).

Educative Curriculum Materials

It has been noted earlier in this chapter that there are three major problems with effectively teaching NOS at the elementary level: (a) most teachers typically do not have high

NOS CK, (b) most teachers typically do not have high NOS PCK, and (c) there is a lack of instructional resources aimed at teaching NOS in the variety of contexts required in elementary science education. The development and use of educative curriculum materials may be one way to address all three issues effectively. Recall that unlike traditional curriculum materials (e.g., textbooks or workbooks), educative curriculum materials are aimed at improving not only student learning, but also have the specific goal of supporting *teacher* learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). As such, they may be used to impact the teaching practices and content knowledge of inservice teachers.

Ball and Cohen (1996) describe five areas to consider when developing educative curriculum materials. Specifically, they recommend that educative curriculum materials (a) describe common student misconceptions or beliefs, (b) improve teachers' understanding of the content, (c) explain the rationale for designing the unit in the way it is designed (i.e., explaining why a given activity is important), (d) describe how the unit fits into the bigger pictures of the curriculum, and (e) allow for teachers to use the curriculum flexibly to fit their specific teaching conditions. Davis and Krajcik (2005) used these five "high-level guidelines" (p. 5) to create a design heuristic for educative curriculum materials. The heuristic revolves around improving teachers' content knowledge, PCK for topics, and PCK for disciplinary practices (specifically, scientific inquiry).

The use of educative curriculum materials is relatively new, and as such there is limited research on its effectiveness. However, the research that is available is promising, as it shows that teachers are able to improve CK and this affects teaching practices. One area in which this has been shown to be true is the teaching of NOS through inquiry activities. In their development of educative curriculum materials for teaching NOS in an inquiry unit, Lin, Lieu, Chen, Huang, and Chang (2012) created a framework for supporting NOS PCK. This framework has three criteria, each accompanied by a rationale and implementation guidance. The first, supporting teachers' understanding of NOS concepts and NOS curriculum guidance, includes rationales for why teaching NOS is important, and provides guidance both for implementing NOS instruction in a given context and understanding student alternative conceptions. This criterion is in line with Davis et al.'s (2005) general recommendations that educative curriculum materials include content supporting teacher learning. The second, supporting teachers' engagement of students in the context of formulating knowledge, is accompanied by the rationale for why NOS discussion is important for learning and the guidance for asking questions during a NOS discussion. This criterion is in line with Davis et al.'s (2005) general recommendations that educative curriculum materials provide possible discourse moves or discussion questions supports teachers in facilitating student learning. The third, supporting teachers' assessment of students' understanding of NOS, is accompanied by a rationale for why assessment is a necessary part of NOS instruction and guidance for assessing students' views of NOS.

To test their framework empirically, Lin et al. designed an *educative teacher's guide* that included materials aimed at the three framework criteria. Two sets of teachers—one with high NOS CK and the other with lower NOS CK—used the educative teacher's guide during an inquiry science unit. While it may be expected that the teachers with the lower NOS CK would not address NOS issues as effectively as those with high NOS CK, the results showed that teachers in both groups taught in similar manners. Furthermore, these teaching practices positively impacted student learning of NOS. This indicates that the educative curriculum materials were beneficial for supporting teachers with low NOS CK to teach in a manner similar to those with higher NOS CK.

Discussion

The available body of research on the teaching and learning of NOS has provided several insights into both the importance of teaching NOS and effective methods for implementing NOS instruction. However, although many questions have been answered by the research, the current status of teachers' and students' knowledge of NOS has changed little, indicating the need for a research program that is more focused on implementing changes in a practical way. By practical, I refer to the need for interventions that meet the following four criteria: (a) they address the development of teachers' NOS CK and NOS PCK, (b) they support NOS instruction that is contextualized within specific science units, (e) they are aimed at practicing teachers, and (d) they do not require lengthy or resource-intensive professional development. By addressing these four criteria, it may be possible first to change teachers' views of NOS from naïve to more informed while also supporting the teachers' translation of these views into effective instructional practice. Subsequently, these changes may impact student understanding of NOS.

Although current research has been effective at changing teachers' views of NOS, it has done so with lengthy professional development requirements. Furthermore, once these professional development opportunities are completed, teachers are unlikely to translate their newly changed views into practice as they teach in different contexts than those that were the focus of the professional development. The combined use of trade books and educative curriculum materials provides a promising method through which to support teachers' development of informed NOS views and translation of these views into practice in a variety of contexts. Additionally, because elementary teachers tend not to be specialists in science, the use of trade books draws on the strengths of the elementary teachers. Because the trade books are curricular tools that are commonly used in elementary science instruction, the addition of the educative curriculum materials is a much less intrusive intervention than those commonly employed in NOS research.

Chapter III

Method

The purpose of this study was to investigate the effect that modified trade books coupled with supportive educative curriculum materials have on the teaching and learning of NOS in an elementary school setting. The trade books were modified to include explicit references and reflective prompts related to NOS. Specifically, the study examined (a) the impact of modified trade books and educative curriculum materials on teachers' understandings of NOS, (b) the effect of modified trade books and educative curriculum materials on teachers' observable instructional behaviors related to teaching NOS, (c) teachers' perceptions of the modified trade books and educative curriculum materials in supporting their understandings of NOS, and (d) student interaction with, and understandings of, target NOS concepts. In the remainder of this chapter, I will present an overview of the study's design, the study's context, procedures, and analyses.

Design

Participant teachers read science trade books aloud to their elementary students, and coupled those readings with discussions of the content of the books. The approach was aligned with the practice of reading text and using oral language in elementary classrooms. Three levels of intervention were created through modifying the trade books. Level I served as a control or baseline and consisted of a trade book, which was adopted as is, unmodified. Level II consisted of a trade book that was modified to include explicit references to, and reflective prompts about, some aspects of NOS. Level III consisted of a Level II modified trade book in addition to the inclusion of an educative teacher's guide that aimed to bolster teachers' understanding of the target aspects of NOS and guide their NOS instruction. Outcome variables that were measured in this study included teacher understanding of NOS, teacher instructional behaviors related to the target aspects of NOS, classroom dialogue as it pertained to NOS, teacher perceptions of modified educative materials, and student understandings of NOS.

Participating teachers were observed teaching during three different science lessons. Each read-aloud session consisted of the teacher reading a trade book aloud to the students and the accompanying class discussion around each trade book. In each session, each participant teacher read to students a different trade book at each level of intervention (unmodified, modified, and modified plus educative materials). After each class discussion, students completed a free response to determine what ideas persisted from the reading and discussion.

Pilot data were gathered during the fourth quarter of the 2014-2015 school year (May-March, 2015). Data for the main study were gathered during the first semester of the 2015-2016 school year (September-December, 2015). All participant teachers taught the intervention lessons in the order described by the study. Because the levels of intervention were ordered such that higher levels included more intense interventions, each of the participants progressed through the levels in the same order: the first session aligned with Level I, the second session aligned with Level II, and the third session aligned with Level III. This allowed for fidelity of conditions, such that each teacher only had access to the modified materials in the desired sequence. The sequence of data collection and types of data gathered are described in Figure 1.

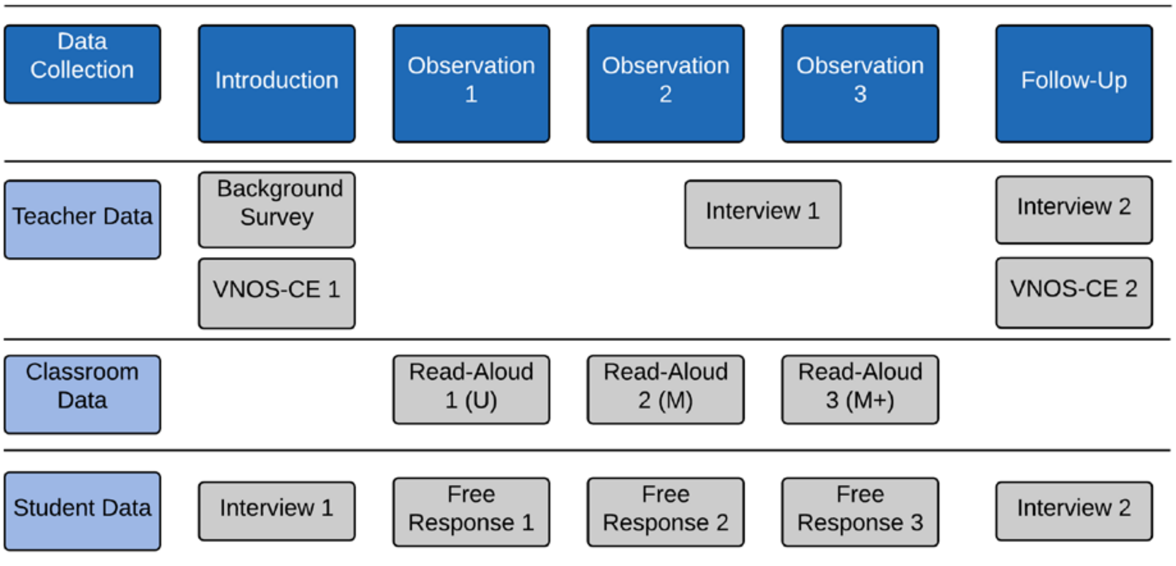

Figure 1. Sequence of data collection activities for each participant teacher.

All participating teachers read aloud three different trade books. Because the books differ in terms of genre and specific content, it was important to be able to determine if any differences among results were due to the intervention or are confounded by the specific books used, or the order in which the books are read. As such, participating teachers read different books in different conditions. While each teacher progressed in her three observed sessions in order from Levels I to III, the order of the specific trade books used across teachers was different. For example, Teacher 1 read *I, Galileo* during Level I, followed by *Come See the Earth Turn: The Story of Leon Foucault* during Level II, and *Galaxies, Galaxies!* during Level III whereas Teacher 4 read the books in the reverse order (while keeping to the progression from Level I to III). Table 1 presents the six permutations of book order, which were undertaken to help control for the possible impact of the text itself and the order in which books were read.

Table 1

Permutations of Book Orders

Teacher	Books and conditions		
	Level I	Level II	Level III
1	*I, Galileo*	*Come See the Earth Turn*	*Galaxies, Galaxies!*
2	*Galaxies, Galaxies!*	*I, Galileo*	*Come See the Earth Turn*
3	*Come See the Earth Turn*	*Galaxies, Galaxies!*	*I, Galileo*
4	*Galaxies, Galaxies!*	*Come See the Earth Turn*	*I, Galileo*
5	*Come See the Earth Turn*	*I, Galileo*	*Galaxies, Galaxies!*
6	*I, Galileo*	*Galaxies, Galaxies!*	*Come See the Earth Turn*

This study focused on three aspects of NOS: the empirical, inferential (i.e., differences and relationship between observation and inference), and creative NOS. The empirical NOS refers to scientific claims relying on evidence obtained through the senses or extensions of the senses. This aspect is related to the distinction between observation and inference. Observations are descriptions of natural events about which observers can reach consensus with relative ease. In comparison, inferences are conclusions that are consistent with, but go beyond, observations; they are not directly observable. For example, while scientists may not be able to directly observe gravity, they can infer its existence by observing the effect it has when objects fall toward the centers of massive objects, such as the earth (e.g., objects fall to the ground). The creative NOS refers to the need for scientists to use their creativity and imagination in generating ideas, explanations and theories. These three aspects were highlighted in this study because while there is no clear consensus about which aspects are more developmentally appropriate for younger students, there is support from research that meaningful changes in these aspects can be attained by elementary-aged children (Akerson & Abd-El-Khalick, 2005; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Akerson et al., 2014; Akerson & Volrich, 2006; Lederman & Lederman, 2004; Quigley, Pongsanon, & Akerson, 2010).

Study Context

Data collection occurred in classrooms from three elementary school districts that service a Midwestern micro-urban city and neighboring towns. Participants for the study were recruited from fourth- and fifth-grade classes. Fourth and fifth graders were chosen for two reasons. First, I was attempting to balance the need for an understanding of how teaching and learning of NOS occurs at the elementary level with a need for collecting reliable data. Students in the fourth and fifth grades would be more articulate than their younger counterparts. This difference facilitated the collection of richer data, as fourth and fifth graders were able to respond to interview questions and complete written assessments in more articulate and reliable manners. Second, because formal teacher preparation requirements do not differ for teachers across the elementary grades, the fourth- and fifth-grade teachers should have similar strengths and face similar challenges as teachers in other elementary grade levels. Consequently, the results from teacher participants in this study could inform the questions under study in other grade levels.

Participants

Eight teachers from four elementary schools were conveniently selected to participate in this study. The teachers worked in three districts near a large Midwestern university. Background information for each teacher was gathered. These data were used to describe the individual teachers and provide context for the teaching environment (see Appendix A for the teacher background survey). For example, comfort level with science was important to consider because it plays into a teachers' ability to incorporate new materials into their teaching (Davis & Krajcik, 2005). I attempted to capture as much variety in teachers' backgrounds as possible by not targeting any specific teachers based on their background. However, the teachers who showed interest in the study had similar backgrounds (see Table 2). All teachers were veteran teachers, with 6 to 29 years' experience. Additionally, none of the teachers had specialized in science, which is typical of elementary teachers (Davis, Petish, & Smithey, 2006). Finally, seven of the eight teachers had Master's degrees in education. The one teacher who did not have an advanced degree, Ms. Gerber[2], was currently working towards her Master's degree in Curriculum and Instruction.

Table 2

Teacher Background Information

Teacher name	District	Grade level	Teaching experience	Highest degree	Area of specialization	Comfort level with science[a]
Edwards	1	4	6 years	Master's	Special Education, Math	4
Gerber	2	4	21 years	Bachelor's	None	2
Maloney	2	4	13 years	Master's	None	3
McKinley	2	5	9 years	Master's	None	2
Crawford	2	5	29 years	Master's	Social Studies	2
Jenkins	3	4	10 years	Master's	Reading, Math	3
Smith	3	4	11 years	Master's	Language Arts, Social Studies	4
Green	3	4	22 years	Master's	Social Studies	3

[a] Comfort level was rated from "very comfortable" (4) to "very uncomfortable" (1).

In addition to teacher participants, I invited all students from their classrooms to participate in the study. Data about individual students were collected. Teachers provided data about students' race, gender, free and reduced lunch status (as a proxy for SES), and achievement in science and language arts (see Appendix B for the student demographic survey). Student data was aggregated across classrooms and is presented in Table 3 to provide the context for each classroom.

[2] All teacher and student names are pseudonyms.

Table 3

Student Demographics

Teacher	N	Gender		Race			Free/Reduced lunch	ELL Status
		F	M	W	B	O		
Gerber	26	10	16	25	0	1	0	0
Maloney	25	11	14	23	0	2	0	0
McKinley	26	12	14	24	0	2	0	0
Crawford	27	14	13	27	0	0	0	0
Edwards	18	7	11	2	16	0	18	2
Jenkins	21	14	7	8	9	4	21	0
Smith	21	10	11	13	7	1	21	0
Green	20	10	10	7	9	4	20	0

Additional data were gathered from all students in the form of audio recordings from classroom read-alouds and a NOS-related free response task. Three select students from each classroom participated in pre- and post-intervention interviews. The students were purposively selected by the teachers to represent a wide range of reading levels (i.e., above grade level, at grade level, and below grade level).

Procedure

The intervention. In this section I detail three issues relevant to the design of the intervention materials: Selection of trade books, modification of trade book text, and creation of the accompanying educative curriculum materials.

Selection of trade books. Three trade books were selected for use in this study: *Come See the Earth Turn: The Story of Leon Foucault* by Lori Mortensen (2010); *I, Galileo* by Bonnie Christensen (2012); and *Galaxies, Galaxies!* by Gail Gibbons (2007). Each book met the following set of criteria, which are detailed in the sections below: (a) the content was aligned with the unit of interest (i.e., Earth and space science), (b) it was highly recommended, and (c) it was written at an appropriate interest level. Table 4 provides relevant details about each book. By consulting with teachers in the pilot phase of the study, I ensured that the books were representative of those typically used in the elementary science classroom. Additionally, all three books were available from the local public library, a resource on which many elementary teachers rely to supplement their own teaching. As such, these trade books may be considered "mainstream," as it is likely they would be found in other elementary classrooms.

Table 4

Relevant Trade Book Information

Book title	Genre[a]	Interest level	Unmodified reading level	Modified reading level
I, Galileo	Narrative information	3-5	7.3	7.6
Galaxies, Galaxies!	Nonnarrative information	3-5	6.8	7.1
Come See The World Turn!	Narrative information	3-5	6.5	6.9

[a] Classification of genre was based on Donovan and Smolkin's (2002) distinction between storybooks, nonnarrative information books, and narrative information books.

The first criterion was meant to contextualize the learning of NOS within the wider science context. Effectively teaching NOS within a variety of contexts is one of the predominant problems science teachers face, as they often are able to replicate specific NOS activities from professional development opportunities or methods classes, but struggle with translating these practices to new contexts (Akerson & Abd-El-Khalick, 2003; Wahbeh & Abd-El-Khalick, 2014). The second criterion, that the books were highly recommended, helped to ensure that teachers and students could learn from the books and were engaged with the books' content because they contained accurate information and were written in an engaging manner. Equally important, this criterion ensured that the books are highly regarded by elementary educators and likely to be mainstream exemplars of the sorts of trade books used in elementary classrooms. The pilot district incorporated many trade books in the science curriculum. To determine which books met this criterion, I referenced books from the pilot district's curriculum and the National Science Teacher Association's (NSTA) list of Outstanding Trade Books. This list was created through a partnership between NSTA and the Children's Book Council and targeted books that can "build literacy skills while learning science content" (www.nsta.org/publications/ostb). Finally, I relied on teacher recommendations, by choosing a book that one teacher used while teaching an elementary space unit (i.e., *Galaxies, Galaxies!)*. Other books by Gail Gibbons have been included multiple times in previous NSTA Outstanding Trade Books list (i.e., 1996, 1998, 1999, 2000, 2003, 2009, 2016) and have been included in research on science trade books (Broemmel & Reardon, 2006; Smolkin & Donovan, 2004).

The third criterion, that books are of an appropriate grade level, helped to ensure that the content of the trade books were developmentally appropriate for the fourth- and fifth-grade students both in terms of interest and readability. Interest level was gleaned from either the NSTA website (*I, Galileo* and *Come See the Earth Turn*) or the publisher's website (*Galaxies, Galaxies!*). It is important to note that the interest level and reading level of trade books did not coincide. Scientific texts are typically more difficult to read than other written texts (Halliday, 1993). However, during read-alouds the teacher is able to mediate the difficulties student may have with the more advanced language and so it is recommended that books used in read-alouds are at a higher reading level than those students would read on their own (Duke & Bennett-Armistad, 2003). As such, the books were chosen for an elementary interest level, but a higher reading level.

Modification of trade books. When considering the layout of a page in a trade book, it is helpful to consider it in three parts: running text, sidebars, and pictures. Donovan and Smolkin (2004) examined how teachers performed read-alouds from *The Magic School Bus*, a hybrid text that contains the storyline in the running text and other information in sidebars in the form of "student reports" and in pictures in the form of speech bubbles and labels. They found that out of the 12 teachers in their study, 11 of them read the complete running text while significantly fewer read the content of the sidebars and pictures. However, support for adding text in the sidebars comes from research on science textbooks. Students are knowledgeable about the structure of a textbook and they learn that important information is often placed in the sidebar (Walpole, 1998). Isolating important information in the sidebar is one cue that students use in comprehending textbook information and may also be used by teachers, as they are also skilled readers of textbooks. Additionally, in Level III of the intervention, certain educative features (described later) were used to highlight the content of the sidebars and provided suggestions on how to incorporate this content into class discussion.

Based on these considerations, I modified and added to existing text in both the main text of the trade books and the sidebars to include explicit references to NOS concepts[3]. First, I read through the trade books and coded for existing references to NOS aspects, both explicit and implicit (Abd-El-Khalick, 2002). Additionally, I identified "missed opportunities," that is, times in which NOS aspects could have been incorporated in the text but were not. Based on the analysis of the existing book, I modified the main text in two ways: minor modifications and major modifications. Minor modifications consisted of changing the main text such that implicit references were made more explicit. These modifications were written to flow seamlessly with the rest of the text and were in the same character as the original text (i.e., they maintained the

[3] As the trade books were copyrighted materials, an analysis of fair use was conducted to determine if publishers' permissions were needed to perform modification. Several factors led to the determination that permissions were not needed and the modification and use of trade books fell under fair use. However, to protect the authors' original work, only excerpts of the modified texts were included in this dissertation. Additionally, the excerpts have been cropped to exclude illustrations when possible. When illustrations were included, the quality of the image was reduced so as to protect the artists' original work.

storyline for a narrative or natural flow of information for an expository text). They were considered minor because they did not significantly change the content of the trade book, but simply made the language more accurately and explicitly reflect NOS. On the other hand, major modifications entailed the addition of new information that was not originally found in the text. These modifications related the original text specifically to NOS in an explicit manner. Additionally, I modified or added text in the sidebars in the form of reflective prompts, as this is typically where this type of information is located in informational texts (Walpole, 1998). These prompts were titled “Think About It,” to highlight their interactive nature. (See Table 6 for examples of modifications.)

Each modification was coded as major or minor, and according to the NOS aspect to which it was related (i.e., empirical, inferential, or creative). While it was not possible to control for the amount of minor modifications across trade books, as they rely on the book containing “missed opportunities,” which differed by book, I kept the number of major modifications consistent across books. Additionally, the number of major modifications for each aspect remained the same across books to ensure teachers had equal opportunities to address each aspect equally, even though they might be reading different books in different conditions. Each trade book contained three major modifications for each of the three target NOS aspects, for a total of nine major modifications.

Several measures were taken to ensure that the modifications did not significantly change the readability of each book. First, the readability of both the unmodified and modified versions were compared using the Flesch-Kincaid grade level measure (Kincaid, Fishburne, Rogers, & Chissom, 1975) to verify the modifications did not significantly change the reading level (Table 5). Second, a graduate student and former reading coach from the district in which the pilot study took place read through each modified text to ensure that the writing style of the modified text flowed smoothly with the original text. Finally, I sought the assistance of an advanced undergraduate student in design to digitally alter the texts so that the modifications were not obvious and did not disrupt the flow of reading. Figure 2 shows an example of the difference between the original and modified texts after being digitally altered.

Table 5

Examples of Modifications from Galaxies, Galaxies

Type of modification	Original text	Modified text[a]
Major—observation vs. inference	GRAVITY is an invisible force that pulls objects together.	GRAVITY is an invisible force that pulls objects together. **Scientists cannot directly observe gravity, but they infer it is there because they see its effect.**
Minor—empirical NOS	Soon it was determined that there were billions and billions of galaxies. The known universe was getting bigger and bigger.	Soon it was **thought** that there were billions and billions of galaxies. The**re was evidence that the** known universe was **bigger than they originally thought.**
Reflective prompt		**Think About It: Why are sky maps useful in understanding the night sky?**

[a] Modifications are marked in bold.

Then, one day, Léon made a startling discovery in his laboratory. He had clamped a steel rod into a lathe, a machine that allowed him to spin and shape objects. In moving around the machine, Léon accidentally twanged the tip of the rod, setting it wiggling from side to side. Léon slowly turned the machine's crank to start the rod spinning. To his amazement, he saw that even though the rod began to spin, the tip kept wiggling side to side, independently from the spinning motion.

At that moment, Léon unddrstood how to answer a question that had baffle scientists for centuries: how can science prove that the earth spins on its axis?

Figure 2a. Example of unmodified text from *Come See the Earth Turn.* Modifications are outlined.

Then, one day, Léon made a startling discovery in his laboratory. He had clamped a steel rod into a lathe, a machine that allowed him to spin and shape objects. In moving around the machine, Léon accidentally twanged the tip of the rod, setting it wiggling from side to side. Léon slowly turned the machine's crank to start the rod spinning. To his amazement, he observed that even though the rod began to spin, the tip kept wiggling side to side, independently from the spinning motion. Based on these observations, he inferred that this was similar to how the Earth spins on its axis.

At that moment, Léon understood how to answer a question that had baffled scientists for centuries: how can science provide evidence that the earth spins on its axis?

Figure 2b. Example of modified text from *Come See the Earth Turn.* Modifications are outlined.

Development of educative curriculum materials. Although the main focus of this study was the educative curriculum materials, it is important to acknowledge that these materials are not equivalent to the curriculum. The curriculum, as it is enacted in the classroom, is dependent on both relevant instructional materials and the teachers' role in implementing it (Ball & Cohen, 1996). As such, it is important to design materials that teachers are willing to use. That is, there must be teacher buy-in. The success of educative curriculum materials depends on the presence of high quality base materials (Davis & Krajcik, 2005). As most trade books typically do not address NOS concepts adequately (Abd-El-Khalick, 2002; Brunner & Abd-El-Khalick, accepted), they would not be considered high quality in terms of facilitating learning about NOS, and therefore they were modified to include explicit informed references and reflective prompts. After the existing materials were analyzed, I developed new educative curriculum materials to support the teaching and learning of NOS through the use of the modified materials. These educative materials were included in a separate document from the trade book, similar to a teacher's guide.

Davis and Krajcik (2005) described three components of successful educative curriculum materials: base materials, teacher's guides, and educative features (see Figure 3). The base materials are those materials with which the students interact and are frequently realized as textbooks or worksheets. In this study, the trade books were the base materials, as they were what students actually saw during the lesson. As the trade books have already been described in the previous section, they will not be described further here.

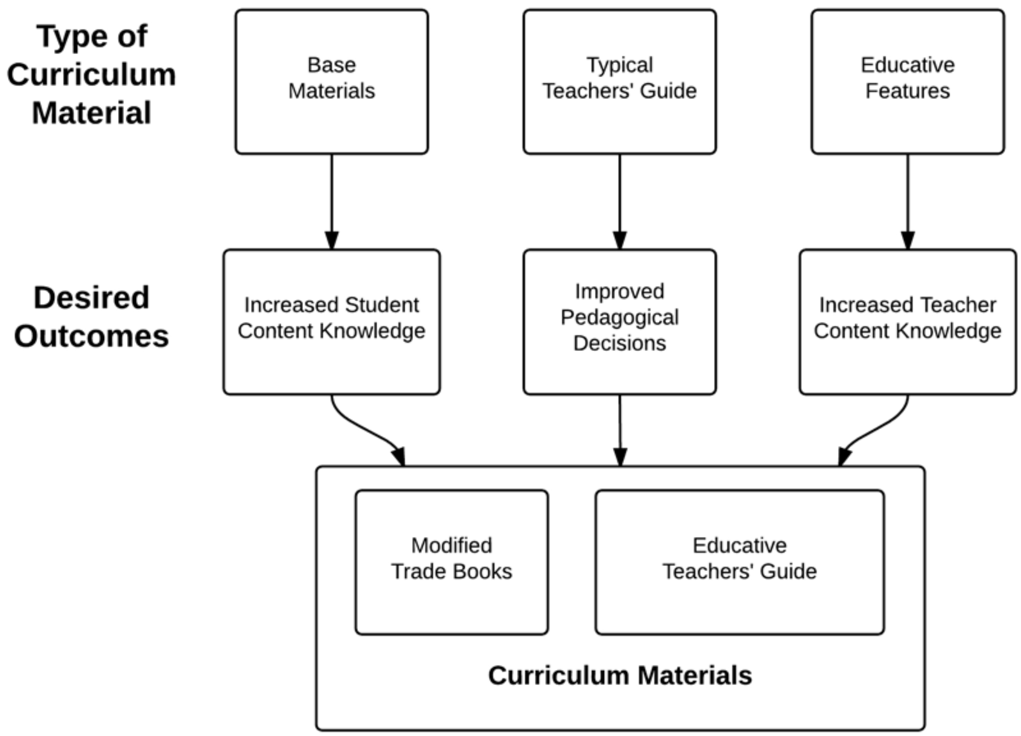

Figure 3. Components of educative curriculum materials.

Teacher’s guides are used to inform pedagogical decisions and typically include descriptions of the learning activities (e.g., step-by-step procedures for a demonstration), guiding prompts for class discussions, and common student naïve conceptions. Educative features are aimed at improving teacher understanding of concepts and are typically not included in most curriculum materials. In previous studies, these have been incorporated with the typical teacher’s guides in one document (Davis et al., 2014; Krajcik & Schneider, 2002). In this study I followed the latter model and created a separate document, hereafter referred to as the “educative teacher’s guide” (Lin et al., 2012), which included both pedagogical and educative material to guide pedagogical decisions and improve teacher understanding of NOS content. Davis et al. (2014) suggested five lenses around which educative materials can be viewed (i.e., science content, scientific practices, literacy practices, participation structures, and assessment). This study focused on the lenses of supporting science content and literacy practices in science instruction. Literacy practices included reading text, writing text, using oral language, and engaging in scientific discourse (explanation, argumentation, etc.).

The first step in the design process was analyzing the curriculum units for educative features. This step occurred in phase one of the modification. Trade books are not specifically intended for use in instruction and do not come with separate teacher's guides, and so I did not find any existing educative features, as expected. After the existing materials were analyzed, I developed an educative teacher's guide that contains new educative curriculum features to support the teaching and learning of NOS. Unlike most traditional teacher's guides, which are aimed only at guiding instruction, this document also contained material aimed at improving teachers' understanding of NOS concepts. As such, this guide aimed to improve both NOS content knowledge (CK) and pedagogical content knowledge (PCK) for NOS (Abd-El-Khalick & Lederman, 2000).

The educative teacher's guide consisted of two parts: an introduction and a teaching section. The teaching section contained reduced trade book pages surrounded by large margins, in which the educative features were placed. Development of the educative teacher's guide was informed by previous research. Davis et al. (2014) suggested features for providing content support and supporting literacy practices. The features for content support both help teach and contextualize the content within an overarching framework for the unit (i.e., provide coherence from lesson to lesson). Specific features that were used in this study are content storylines and content boxes. Content storylines indicated how the lesson relates to other material in the unit and were placed in the introduction of the teacher's guide. Content boxes highlighted important content as it occurred and was interspersed throughout the learning section of the teacher's guide and set in the margins.

Additionally, in a study on the effectiveness of an educative teacher's guide for teaching NOS in an inquiry unit, Lin et al. (2012) found several specific features of the guide to be particularly useful for improvement of teachers' NOS CK and PCK for NOS. These included extensive learning supports for concepts and keywords, specific teaching practices, and the rationales for specific teaching practices. These general features were specifically realized as descriptions of the targeted aspects of NOS (i.e., the role of observation and inference, and the empirical and creative NOS) in the introduction; connections between NOS and the NGSS in the introduction; discussion questions and sample student responses in the margins of the learning pages; and rationales for the discussion questions as footnotes to the learning pages. Table 6 provides an outline of each educative feature, including its purpose, description, and the location in the modified materials. Figure 4 represents how these features were actually represented in the text.

Table 6

Types of Educative Features

Educative feature	Purpose	Description	Location
Content storyline	General PCK	A short description of how this lesson fits within the overall unit to help teachers contextualize the specific lesson and provide coherence.	Introduction
Content boxes	NOS-CK	Highlight of important NOS content in the trade books	Margins of the learning section

(continued)

Table 6 (continued)

Educative feature	Purpose	Description	Location
Description of the relevant aspects of NOS	NOS-CK	Description of the role of the empirical, inferential, and creative NOS as these pertain both in science in general and to the content of the trade book.	Introduction
Connections between NOS and the NGSS	PCK for NOS	Description of NOS in the NGSS and how this pertains to the content of the trade book.	Introduction
Discussion questions & possible student answers	PCK for NOS	Questions meant to relate NOS content in the trade books to students' experiences. These questions also provide opportunities for students to reflect on the NOS content	Margins of the learning section
Rationales for discussion questions	PCK for NOS	Connecting discussion questions (i.e., pedagogical moves) with specific rationales to improve learning	Footnotes of the learning section

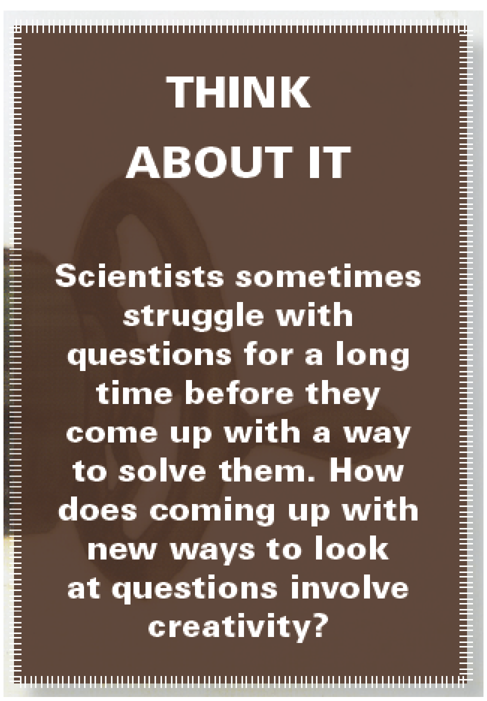

Figure 4a. Example of educative features—reflective "Think About It" questions.

Come See The Earth Turn

Lori Mortensen

Content Storyline

The book *Come See The Earth Turn* introduces students to the work of Leon Foucault. Through careful measurements, Foucault was able to provide evidence that the earth spun on its axis, even though people were not able to directly witness this phenomenon.

Space and Nature of Science

Nature of science is an important part of science education that is concerned with understanding the enterprise of science – that is, how scientists work and why they do the things they do. Knowing about nature of science is an important component of being a scientifically literate person. There are many things that go into understanding the nature of science. This book focuses on three: Scientific knowledge is based on empirical evidence, Scientists make inferences based on observations, and Science is a creative activity.

Scientific Knowledge is Based on Empirical Evidence
Scientific knowledge is based on empirical evidence. Empirical evidence is based on observations. Scientists use a variety of tools to gather evidence or to make measurements and then look for patterns in the empirical evidence as a way to understand the world. For example, astronomers use telescopes to gather information about objects in space. Whenever scientists make a claim, they must ask themselves if the evidence supports it.

Scientists Make Inferences Based on Observations
Scientists engage in the activities of making observations and inferences. Observations are descriptions of what happens in the natural world. Scientists rely on their five senses when making observations. In contrast, inferences are statements about the natural world that cannot be directly accessed by the senses. For example, scientists can make the observation that dropped objects fall to the ground, but they must infer that it is gravity that causes the object to fall because gravity is not visible. When learning about space, it is important that students distinguish between observations and inferences, as much of what is studied is not directly accessible to our senses.

Sometimes scientists create technology to help them make observations. A telescope helps astronomers look farther into space. Scientists must test these technologies to make sure the observations are not just an artifact of the technology. For example, they must be sure that a visible spot is actually an object in space and not a mark on one of the lenses. This is true of other types of technology too, like machine rovers or probes that visit planets that are not accessible to us.

Science is a Creative Activity
Although science is based upon empirical evidence, it depends upon the creativity of scientists. Creativity in science is seen in the way scientists interpret empirical evidence and generate explanations that are consistent with the evidence. Creativity is also seen in the ingenuity of scientists in developing new technologies. One example of this is the creativity scientists exhibited in developing the modern telescopes. These technological advances influence the progress of science.

Figure 4b. Example of educative features—content storyline and descriptions of targeted aspects of NOS.

Connecting with the Next Generation Science Standards

The Next Generation Science Standards focus on students understanding the nature of science as part of being scientifically literate. The three components of nature of science that are focused on in this book come from two nature of science standards: Science is based on empirical evidence and Science is a human endeavor. By the time students finish 5th grade, they should know the following things.

Scientific knowledge is Based on Empirical Evidence	Science is a Human Endeavor
• Scientific findings are based on recognizing • patterns. • Scientists use tools and technologies to make accurate measurements and observations	• Science affects everyday life • Creativity and imagination are important to science

Connecting with the Common Core State Standards

One focus of the Common Core State Standards is on reading and understanding informational text. By engaging students in a read-aloud and discussion of this book, you are connecting with the following Common Core State Standards. The numbers below align with the College and Career Readiness Anchor Standards.

Key Ideas and Details	Craft and Structure	Integration of Knowledge and Ideas
1. Read closely to determine what the text says explicitly and to make logical inferences from it. 2. Determine central ideas or themes of a text and analyze their development.	4. Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone.	7. Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words. 8. Delineate and evaluate the argument and specific claims in a text.

Figure 4c. Example of educative features—connections between NOS, NGSS, and CCSS-ELA.

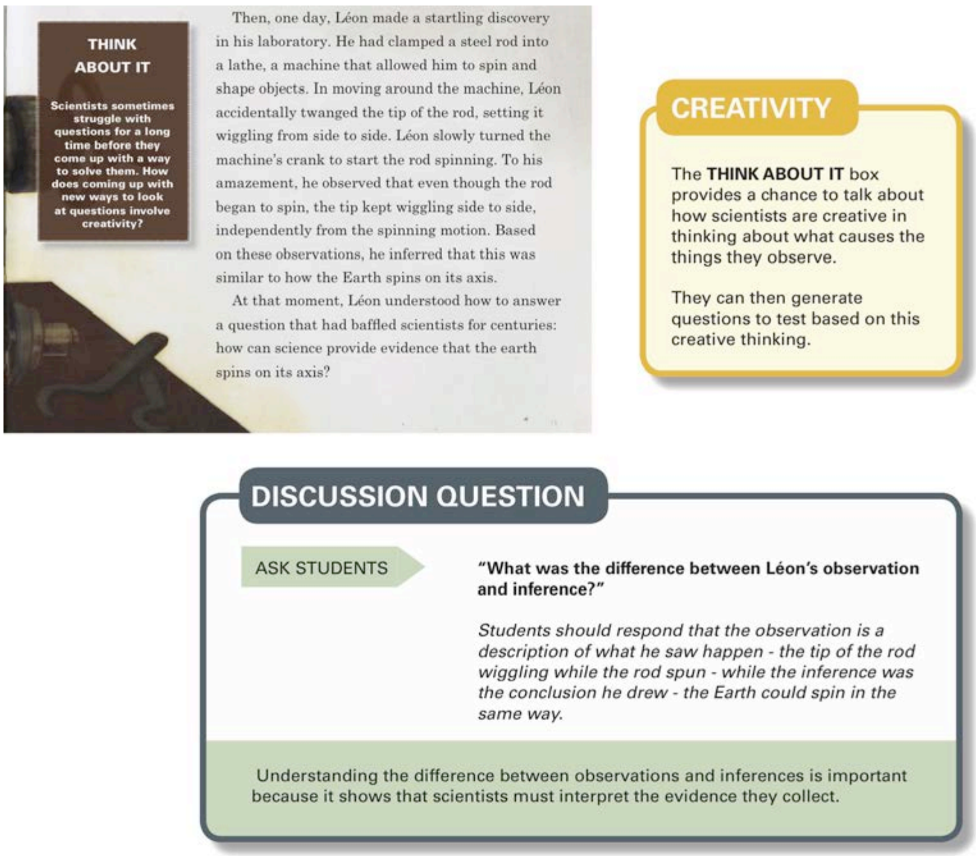

Figure 4d. Examples of educative features—content boxes and discussion questions with rationales.

Two graduate students in Science Education, with expertise in NOS, provided support throughout the process of modification of trade books and development of the educative curriculum materials. These students assisted in both phases of modification and development, thus, ensuring that the modifications were done in a manner that both effectively addressed the relevant NOS aspects and was not disruptive to the flow of the text.

Pilot testing and final revisions. The modified materials were pilot-tested at a school in District 1, described above. The teacher, Ms. Edwards was provided with the appropriate materials for each level of intervention before the planned class read-aloud sessions to allow time to familiarize herself with the materials. I followed the same procedure as the main study, including interviewing the teacher before the intervention and between the second and third read-aloud. Additionally, during the second interview I asked Ms. Edwards about each trade book to determine her perception of the changes to the trade books, as well as to pilot and refine the interview protocol. Questions focused on (a) flow of the text, (b) perceived helpfulness of supportive NOS content, and (c) perceived helpfulness of guiding questions/discourse moves. Based on the teacher's feedback, no modifications were necessary. As such, data from this classroom was folded into the data from the remainder of the study and included in all analyses.

Data collection. This study utilized multiple data sources to answer the four research questions. Each data source was aligned with one or more research question, as outlined in Figure 5. The following sections detail the relevance of each data source to the study and the methods of collection.

Teacher survey. At the beginning of the study, teachers were given a survey to gather data on teacher variables that may impact NOS teaching and general demographic variables. Survey questions are available in Appendix A. Although research shows that individual teacher variables (e.g., teaching experience and comfort with science) may affect a teacher's ability to translate informed views of NOS into classroom practice (Akerson & Abd-El-Khalick, 2003; Lederman, 1999; Wahbeh & Abd-El-Khalick, 2014) and utilize educative curriculum materials (Davis & Krajcik, 2005), there was not much variability in teachers' background data. As such, these variables could not inform specific analyses in substantial ways. However, information about teachers' background was used to better capture the classroom environment in which the instruction took place (i.e., age, race, gender). Teacher demographics were presented in Table 2 above.

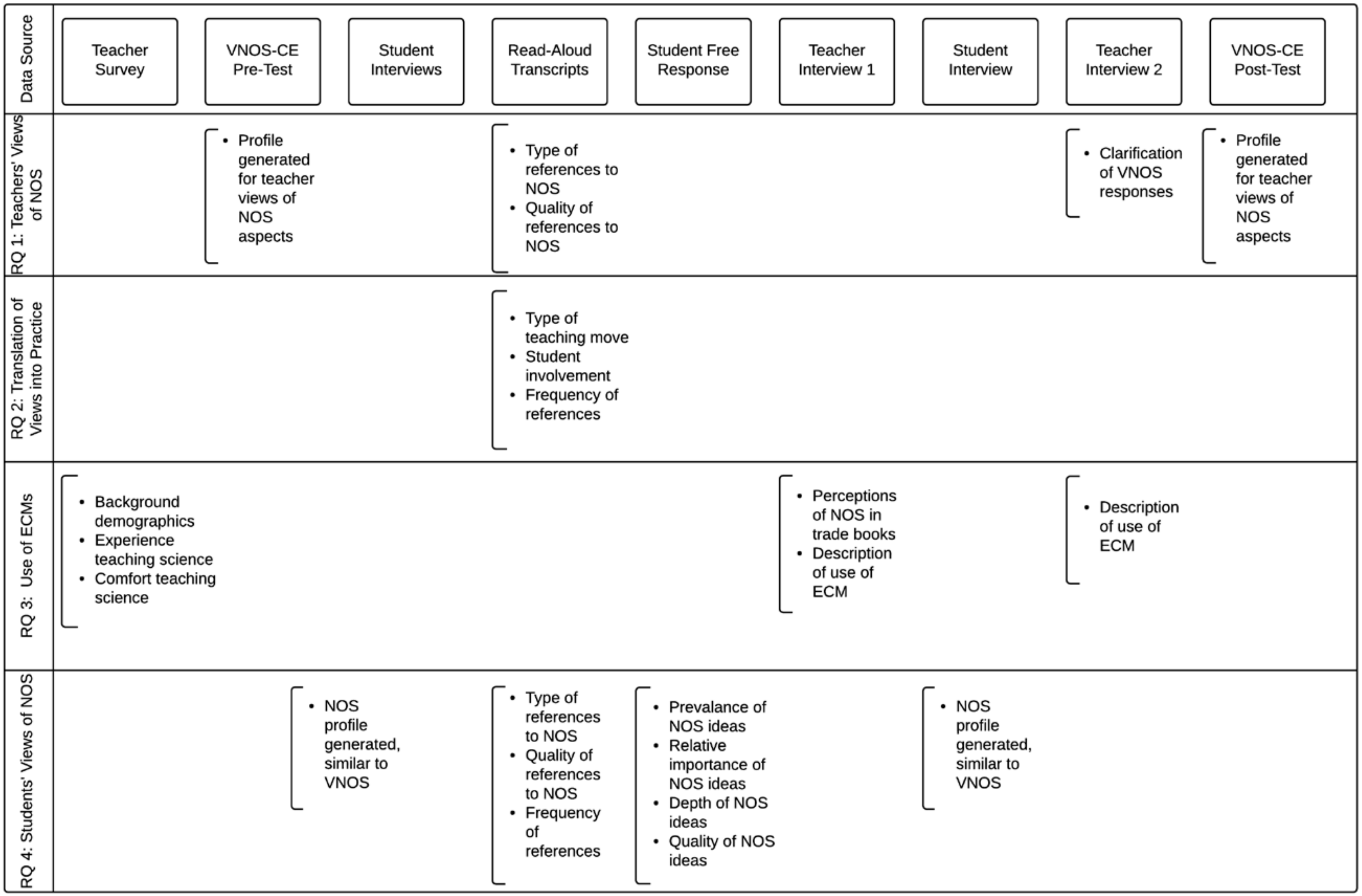

Figure 5. Alignment of data sources with research questions.

Student demographics. Data on individual student variables were collected. These demographic variables (i.e., gender, race, SES) were used to characterize the classroom setting. To protect student privacy, teachers were asked to provide all demographic information for participating students. SES was approximated by whether students qualified for the free/reduced lunch program. These data were not available for students in District 2. To estimate student achievement in science and language arts, I asked teachers to determine if the student was above grade level, at grade level, or below grade level in each subject. Data from each classroom were provided in Table 3. A complete copy of the student demographic survey is available in Appendix B.

Teacher views of NOS. One of the main goals of this study was to determine what effects, if any, the modified trade books and educative curriculum materials had on teachers' views of NOS (RQ 1). To determine changes in views, it was necessary to have both a baseline measure of teachers' views and a measure after the teachers have interacted with the intervention materials. As such, pre- and post-assessments of teacher views of NOS were administered. Teachers were given the Views of Nature of Science Questionnaire Form-CE (VNOS-CE; Abd-El-Khalick, 1998, 2014b) to determine their views of NOS. (Questions from the VNOS-CE are available in Appendix C.) The VNOS-CE was based on the more commonly used VNOS-C. The VNOS-C form consists of 10 open-ended questions. The VNOS-CE questionnaire contains all 10 original questions, but also has two additional questions that ask about the generation of scientific knowledge and how and why scientists participate in conferences and publications. Questions on the VNOS-CE are aimed at elucidating participants' views of several aspects of NOS. Although the focus of this study is only on empirical, inferential, and creative NOS, the entire questionnaire was administered to teachers for two reasons. First, the questionnaire is not intended to have a one-to-one correspondence between questions and aspects of NOS (Lederman et al., 2002). As such, it is possible that participants' views of these aspects of NOS may be inferred from their responses to more than one question. Second, because several aspects of NOS are interrelated (Abd-El-Khalick et al., 2013), it is important to have a comprehensive understanding of the participants' views of all aspects. For example, although the study focuses on the empirical NOS, this aspect is also related to the theory-laden NOS. By asking questions that target both aspects, it is possible to more fully understand the possibly complex views that participants may have about NOS.

Administration of the VNOS-CE usually consists of administering the questionnaire and a follow-up interview to clarify participant responses. However, as the interview itself may serve as an intervention to change participants' views of NOS because it provides an opportunity for participants to critically reflect on their responses, I did not include an interview pre-intervention, and instead only interviewed teachers between the Level II and III sessions and after the intervention, as described in a later section.

Student NOS interviews. Three students from each participating class were interviewed at the beginning and end of data collection in District 2 and 3 to determine any changes to their views of NOS (RQ 4). The three students who were interviewed pre-intervention in Ms. Edwards' class in District 1 participated in the initial interview but were not available for a second interview. Focusing on three students from each class allowed a more in-depth analysis of student learning than the broad measures that were gathered at the classroom level (i.e., classroom discourse data and student free response data). A student from each of the three levels of language arts achievement identified by the teacher (i.e., above grade level, at grade level, and below grade level) were purposely selected to participate in the two sets of interviews so as to provide a broad view of all students.

Although some studies have used a modified version of the VNOS to measure views of NOS with students as young as kindergarten or first grade (e.g., Akerson & Hanuscin, 2007; Akerson & Volrich, 2006), others have cited the use of interviews as a more valid measure of young students' views (e.g., Lederman & Lederman, 2004). The most commonly used written assessment for young students is the VNOS, Form D (VNOS-D; Lederman & Khishfe, 2002), which was based on questions from the Perspectives of Scientific Epistemology questionnaire (POSE; Abd-El-Khalick, 2002b) and designed to measure middle- and high-school students' views of NOS. Although the VNOS-D has been used with young students, the reading level is measured at a Flesch-Kincade grade level of 8.3, a level that would prove difficult for students in the fourth grade to understand because the ability to effectively answer items on an open-ended questionnaire depends on students' language abilities.

There was a high level of variability in participant students' language ability, based on the schools' Illinois Standard Achievement Test (ISAT) reading scores. Students in the pilot classroom were all below grade level, while other classes had a spectrum of abilities. The decision to use interviews in lieu of the open-ended questionnaire helped overcome the difficulty students might have faced with reading and writing. Questions for student interviews were modified from the VNOS-D and the POSE questionnaires and focused on the role of the empirical, inferential, and creative NOS. Interview questions are available in Appendix D.

Classroom observations. In this study, teachers demonstrated their ability to translate NOS views to practice (RQ 2) through trade book read-alouds. To document changes in practice across educative conditions, I observed each lesson in which the teacher incorporated the identified trade books. Each teacher was observed three times to align with the three levels of intervention. Classroom observations generated two sources of data: audio recordings of classroom dialogue and field notes. The audio recorders were positioned such that they captured both the teacher's voice and as much student dialogue as possible. One recorder was placed next to the teacher and a second was placed in the middle of the classroom. Additionally, throughout the observations I recorded field notes. The field notes focused on describing nonverbal classroom interactions. For example, I captured in the field notes when the teacher gestured to a particular part of the page to draw attention to it. Additionally, because the student voices were only captured on the audio recording, the field notes were used to determine which students were speaking. These notes were useful for determining if any students interacted substantially with the NOS concepts in a verbal manner and allowed for connection to other student data points, such as the free recall tasks described next.

Student free recall task. To determine if silent students were attending to the NOS content, all students completed a free recall task to measure reactions and thoughts related to each trade book. The free recall task was chosen as one way with which to gain insight into students' views of NOS for those students who remain silent during the classroom discourse (RQ 4). After each read-aloud session, students were given a sheet of paper asking them to record what they were thinking about, remembered, or wondered during the reading or class discussion. Although it is necessary to be sensitive to the limitations of a written measure with young students, and especially those who may have below-average language abilities, the written measure allowed for an efficient way to elicit responses from a whole class of students. To avoid confounding writing ability with the measure of views of NOS, the free recall task data were used in conjunction with other measures of student views (i.e., student participation in discourse and student interviews). A sample of the free recall task sheet is available in Appendix E.

Teacher interviews. Each participating teacher was interviewed twice during the study. The first interview occurred before the third classroom observation. The purposes of this interview was to determine (a) how teachers typically prepared for read-aloud sessions during science instruction, (b) teachers' perceptions of the educative curriculum materials, and (c) teachers' perceptions of NOS concepts in the trade books (RQ 3). Interviewing teachers before the third observation had two additional benefits. First, interviewing teachers after they had received the modified materials but before they taught the lesson ensured that they had at least read through the materials in preparation for the lesson, thus providing additional assurance that the educative conditions were being enacted with fidelity. Second, changing one's views of NOS is facilitated through reflection. Providing teachers with the opportunity to talk about the NOS content in the read-aloud books also provided them with a chance for reflection and thus, hopefully facilitated learning of NOS content as well.

The second teacher interview occurred after all three lessons had been taught. The purpose of this interview was to determine (a) teacher perceptions of the effectiveness of the educative curriculum materials in preparing them to deliver lessons, and (b) perceptions of students' learning of NOS concepts. This second interview also was used to measure changes in teachers' views of NOS, in conjunction with the second administration of the VNOS-CE. This interview followed a modified version of the protocol described by Abd-El-Khalick (2004). The modification included providing teachers' with both their initial and final VNOS-CE questionnaires so that they might be questioned about changes in their responses. Examples of questions for Teacher Interview 1 and 2 are available in Appendix F and G.

Data Analysis

This section details the analyses for the data collected over the course of the study. Multiple data sources were used to answer each research question. A detailed description of data analysis procedures is provided below.

RQ 1: Changes in teachers' views of NOS. The initial administration of the VNOS-CE was used to determine teachers' initial views of NOS. The questionnaires were analyzed holistically, as described in Lederman et al. (2002), because there is not a one-to-one alignment of question to NOS aspects. Based on questionnaire responses, a profile was generated for each teacher. Analysis of the initial VNOS-CE questionnaire provided a way to establish a baseline for each teacher's pre-intervention views of NOS. As such, teacher views of each aspect were characterized as informed, partially informed, or naïve, although particular attention was paid to the three targeted NOS aspects.

Once the teachers' initial views of NOS were characterized, I determined changes in their views based on data from final administration of the VNOS-CE and its accompanying interview. The final administration of the VNOS-CE was analyzed in the same manner as the initial questionnaire. Both direct comparison with the initial responses and comparison of overall profiles were used to determine changes in views of NOS. Teacher responses to the second interview were used as evidence to support conclusions of changes in NOS views from the questionnaires. Changes across conditions from naïve to informed were considered as evidence of desired changes in NOS views.

A graduate student in science education with an expertise in NOS coded two pre-intervention and two post-intervention questionnaires to establish reliability of the coding scheme (i.e., 25% of the data). Interrater reliability was 89%.

RQ 2: Teachers' use of educative curriculum materials for teaching NOS. The way in which teachers make use of the modified trade books and educative curriculum materials for teaching NOS sheds light on translating their views of NOS into teaching practice. As such, the main data source for determining changes in teachers' practices came from the observational data during read-aloud sessions. The audio recordings were transcribed verbatim and the transcripts were analyzed for evidence of changes in views of NOS and instructional practices related to addressing the target NOS aspects that occurred throughout the study.

These transcripts were coded in four ways: level of intervention (i.e., Level I, II, or III), type of NOS reference (i.e., implicit, explicit, or explicit-reflective), and quality of NOS reference (i.e., naïve, informed). Previous research has only been concerned with the quality of references as being naïve or informed. A graduate student in science education with an expertise in NOS coded five transcripts (20%) to determine the validity of the coding scheme. The two coders reached 85% agreement.

Evidence that teachers changed from less to more desirable instructional moves and discussion of NOS ideas during read-aloud discussions across the three conditions support the effectiveness of the educative curriculum materials in translating NOS views into practice. Additionally, the frequency of informed NOS references was explored. An increase in the number of NOS references per discussion was evidence that the modified materials support the translation of NOS views into practice, as the level of support provided by the material increases with each observation.

RQ 3: Teachers' perceptions of educative curriculum materials. Teacher interview data were used to determine perceptions of the educative curriculum materials. Because teachers are unlikely to use materials that they do not deem to be valuable, it was important to elicit their views of the intervention materials. Responses were categorized according to perceptions of how the materials supported teachers in changing their views and instructional practices, supported changes in students' views, and aligned with typical teaching practices. Additionally, any concerns that teachers had with the materials were coded.

RQ 4: Student interaction with, and understandings of, target NOS concepts. Data for this research question came from transcripts of classroom discourse, student free recall responses, and student interviews. The transcripts were coded and analyzed for student participation in a similar manner to the teachers. They were coded in three ways: type of references to NOS (implicit or explicit), quality of references to NOS (naïve or informed), and frequency of references to NOS. Improvement in students' interaction with NOS concepts were indicated by a change from implicit to explicit type of references, naïve to more informed quality of references, and a larger number of references across educative conditions.

Student responses to the free recall task were investigated for references to the targeted NOS aspects. Each student response sheet was coded as either including references for each of the targeted aspects or not. As such, each student response sheet received three codes: one each for the empirical, inferential, and creative NOS. Additionally a second level of coding was used to describe the quality of the references. In addition to the informed and naïve, an additional code of "unknown" was used. The latter code was used in the rare case when students indicated some sort of connection with the material but it was not possible to determine what exactly the connection was. For example, one student just wrote the word "creative." A graduate student in science education with expertise in NOS coded responses from five read-aloud sessions (20% of the data) to determine reliability of the coding scheme. The two coders reached a high level of agreement on (95%) on the codes.

Interview transcripts with select students were used to garner a more in-depth view of students' views of NOS. Student interviews were used to generate profiles of student views of NOS, in a similar manner to the analysis of the teachers' VNOS-CE questionnaires. That is, interviews were transcribed and transcriptions were read through holistically. Specific references to the targeted NOS aspects were identified and coded as being naïve or informed. All of the codes for the same aspect were gathered and used to form a profile. A graduate student in science education read through five of the transcripts and generated profiles for the students to determine reliability of the coding scheme. Interrater reliability reached 87% and was deemed acceptable.

Interviews and free recall responses were used to qualitatively determine changes in understandings of NOS concepts. Additionally, when possible transcripts from whole-class discussion were considered. In this way, it was possible to track targeted students' interaction with NOS at three points: at pre-intervention, based on their initial interview; during the intervention, based on their participation in classroom discussions; and at post-intervention, based on their final interview.

Chapter IV

Results

This chapter is organized in four main sections, which correspond with the four research questions (RQs). The first section describes changes in the teachers' views of NOS, based on responses to the pre- and post-intervention administration of the VNOS-CE questionnaires (RQ1). The second section focuses on how teachers translated their changing views of NOS into practice while leading their students through the read-aloud discussions (RQ2). The third section reports on teachers' perceptions of the books, based on interview responses (RQ3). Finally, the fourth section describes how students interacted with the NOS content, as gleaned from student free response data, student participation in read-aloud discussions, and interviews with select students (RQ4).

Changes in Teachers' Views of NOS

In this section, I describe changes in teachers' views of NOS from pre-intervention to post-intervention. Table 7 provides a summary of changes made in teachers' views of each NOS aspect. Each teachers' pre- and post-intervention profile is provided in the "Pre" and "Post" columns of the table. Additionally, changes towards more informed views are coded with light shaded cells, whereas changes towards less-informed views are coded with dark shaded cells. In the following sections I describe teachers' pre-intervention views of NOS, highlighting common misconceptions. Then I describe changes in both the targeted aspects of NOS (i.e., the empirical, inferential, and creative NOS), as well as non-targeted aspects of NOS, which emerged in the course of the study. Although it may be assumed that all changes were based on the intervention because teachers did not engage in any other planned NOS instruction, when possible, specific sources of change are described (e.g., references to specific portions of trade books).

Table 7

NOS Profiles of Teachers Pre- and Post-Intervention

	Gerber		Maloney		McKinley		Crawford		Edwards		Jenkins		Smith		Green	
NOS	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Empirical	I	I	P	P	I	I	P	I	I	I	N	P	P	I	I	I
Inferential	P	I	N	P	P	P	P	P	S	S	S	P	P	I	P	P
Creative	I	I	P	P	P	I	P	P	P	P	P	P	P	P	P	P
Tentative	P	P	P	P	P	P	P	P	N	P	N	N	P	P	N	N
Theories/Laws	N	N	N	N	P	P	N	N	N	N	N	N	P	P	N	N
MSM	N	I	N	N	P	P	N	I	P	P	N	P	P	I	P	N
Theory-Laden	P	I	S	S	S	P	S	P	P	P	S	N	S	I	S	P
Sociocultural	I	I	N	I	S	S	P	P	N	S	N	P	P	P	P	I
Social	P	P	N	N	P	P	P	I	N	N	N	P	P	P	P	I

Note. I = Informed, P = Partially Informed, N = Naïve, S = Silent. Light shading indicates gains from pre- to post-intervention; Dark shading indicates losses.

Pre-intervention views of NOS. Teachers' baseline views of NOS were determined based on their responses to the VNOS-CE questionnaire that was administered prior to the intervention. Profiles of each teacher's views were generated (Table 7) and indicated that there was significant variability in teachers' understanding of NOS. No teacher had completely informed views, however three teachers had informed views about specific aspects: Ms. Gerber was informed about the empirical and sociocultural NOS and both Ms. McKinley and Ms. Green were informed about the empirical NOS. Likewise, no teacher was completely naïve. As such, most of the teachers' profiles describe a range of naïve to informed views, with most holding partially informed views on several aspects of NOS. It is important to keep in mind that the partially informed views were caused by two distinct reasons: teachers either made conflicting statements about a single aspect (e.g., scientific knowledge changes but laws are proven or absolute) or they made informed but incomplete statements (e.g., a teacher may state that scientists are creative in generating new methods to investigate science questions but she does not address creativity in coming up with theories that explain the data). Teacher responses described several "myths" about NOS that had been previously identified in the literature (e.g., McComas, 1996). Descriptions of specific views for each aspect are provided below.

Empirical NOS. All teachers except one were either informed or partially informed about the empirical NOS. Their replies included references to the need for data or observations to support scientific claims. Ms. Gerber, Ms. McKinley, Ms. Edwards, and Ms. Green held fully informed views of the empirical NOS because their statements consistently indicated that scientific claims must be supported by observational evidence. For example, when responding to how science differs from other ways of knowing, such as religion or philosophy, Ms. McKinley stated, "Science is based on data, not on beliefs or opinions." This view was expanded in other responses as she went on to state that scientific knowledge is developed "through records of observations and experiments, scientists record trends, observations, and data." Ms. Gerber and Ms. Green made similarly informed comments.

Teachers that held partially informed views made a mixture of informed and naïve comments about the empirical NOS. Ms. Maloney exemplified this. When asked about the difference between science and other ways of knowing, she stated:

> Science includes observations, experiments, and data. People are trying to understand the natural world. . . . With science, you can still experiment and test the ideas now. There are still observations people can make about the scientific ideal; it's hard to make an observation on something religious that happened thousands of years ago.

This statement would be considered informed because it not only specifies that scientific claims are based on observational data, but also that these claims differ from other forms of knowing, such as religion. However, in a later response to a question that asks if scientific theories ever change, Ms. Maloney stated:

> I honestly don't know. I could see both sides. The world is constantly evolving so I could say yes, the theories would evolve and change as well, but then these theories are so old and there's hardly a way to really prove something from thousands of years ago. *It's all based on philosophy.* [My emphasis.]

This indicates a naïve view that theories are not well-substantiated by empirical evidence. This mixture of informed and naïve views led to Ms. Maloney's views of the empirical NOS being classified as partially informed.

Ms. Jenkins was the one teacher with naïve views of the empirical NOS. In response to questions that typically elicit answers related to this aspect, Ms. Jenkins generally had short and uninformative responses. Indeed, not only did she have the shortest responses of any teacher, but several of Ms. Jenkins' responses were answered without any information useful to understanding her views of NOS. For example, one questions asked "What specific evidence **do**

you think scientists used to determine what an atom looks like?" [emphasis in original], providing an opportunity to expand upon the empirical NOS. However, Ms. Jenkins simply responded with "No idea—that's what I have been taught." The only explicit reference to the empirical NOS was in response to the question asking about what specific evidence scientists use to determine species. Ms. Jenkins replied, "They can only make groupings and speculations—they can only make generalizations and then further inspect the species." This was coded as a naïve view of the empirical NOS because the reference to speculations and generalizations implies that she does not view scientific classification as being rooted in empirical evidence.

Inferential NOS. None of the teachers were fully informed about the inferential NOS; however, five of the teachers held partially informed views. Of the remaining three teachers, one held naïve views and the other two did not respond in a way that allowed their views to be coded, and so they were categorized as being silent.

Ms. Gerber, Ms. McKinley, Ms. Crawford, Ms. Smith, and Ms. Green all had partially informed views of the inferential NOS. Participants were coded as partially informed when they made informed but incomplete references to this aspect. For example, in her only reference to the role and status of inferences, Ms. Crawford stated, "Even though the same data is presented [for understanding how dinosaurs became extinct], different interpretation to a conclusion is possible." This statement indicates that she understands that inferences must be in line with the empirical evidence, but does not address the idea that scientists do not have direct observational access to the events that caused the extinction. As such, it is an incomplete reference.

Teachers were also considered partially informed if their responses implicitly addressed the inferential NOS. For example, Ms. McKinley made two references to the inferential NOS, both implicit. When responding to how scientists determine what an atom looks like, she stated, "After many, many years of looking at the makeup of objects, this combination would be somewhat true to conclude that all three [protons, neutrons, and electrons] must be present in an atom." This was coded as an implicit informed reference to the NOS because, although she did not directly state that scientists cannot see subatomic particles, she implied that they must understand the nature of these particles through how they interact to make up other objects.

Ms. Maloney was the only teacher with a naïve view of the inferential NOS. She only made one reference to the role of inferences in science, when addressing how scientists could come up with different conclusions for the extinction of dinosaurs. She stated, "At times, data can be skewed to look the way you want it. This happened 65 million years ago, so it is very hard to have exact concrete data to prove the theory." In this statement, she implies that it is impossible to make scientific claims without "exact concrete data," which ignores the idea that scientists can make claims consistent with incomplete evidence. Furthermore, by describing the possibility of skewing data, she implies that scientists are not relying on the available evidence, but instead are manipulating data to come up with their desired conclusions.

Creative NOS. Ms. Gerber held informed views of the creative NOS, while all the other teachers held partially informed views. They were coded in this way for two distinct reasons: either they made informed but incomplete references to the role of creativity in science or they made a mixture of informed and naïve references.

Ms. Maloney, McKinley, Crawford, Edwards, Jenkins, and Smith all had incomplete views of the creative NOS. Ms. Maloney demonstrated this when she stated,

> They [scientists] have to be imaginative and creative when coming up with a problem to test and designing that test. I believe they also have to be creative after their data collection. They need to present their findings in a creative easy to understand format for the "normal" person.

Similarly, Ms. Crawford stated, “I would think scientists would have to be creative and imaginative to think outside the box to prove different reasons for how things work.” This view exemplifies the idea of scientific ingenuity. That is, scientists must come up with unique ideas for solving problems. Indeed, ingenuity does involve creativity. However, by simply focusing on this aspect of creativity, the teachers did not consider how creativity must be used in developing scientific explanations, an important aspect of the development of scientific knowledge.

Similar to the other partially informed teachers, Ms. Green stated that creativity is important in planning and designing scientific investigations. However, Ms. Green explicitly stated that creativity must not be used when analyzing data. She stated, “I feel that at the plan/design stage imagination and creativity are at the forefront of what motivates the science community. Creativity and imagination must then take a back seat to data and actual facts that have been discovered.” This was coded as partially informed view of the creative NOS since it combined some informed elements (i.e., there is creativity in planning) and some naïve elements (i.e., creativity must not be used when interpreting the data).

Ms. Gerber was the only teacher who displayed a fully informed view of the creative NOS. She was coded as having informed views because she addressed the role of creativity in all stages of the development of scientific knowledge. She explicitly stated, “I think you can see creativity and imagination at all stages.” She expanded upon the role of creativity in developing scientific explanations, stating:

> I think scientists have to use their own creativity and imagination. That is how new ideas and theories come about. A lot of scientific findings are accidental or because people can look at and interpret differently or they are the person that looks at information differently or “goes where nobody else has.”

She explicitly addressed how interpretation of scientific evidence is a creative process, an important idea that was left out of other teachers’ responses.

Tentative NOS. Most teachers held partially informed views of the tentative NOS prior to the intervention. These teachers all include a mixture of informed and naïve references to the tentative NOS. Informed references revolved around the idea that, although well-substantiated, the discovery of new information may lead to changes in scientific knowledge. When explaining how scientific theories change, Ms. Smith stated, "I believe that scientific theories can and do change. This is due to repeated experimentation, new data, and related inquiries." This additive view of the tentative NOS was echoed in responses from Ms. Gerber, Ms. Maloney, Ms. McKinley, and Ms. Crawford, who cite variations such as "more and more methods of testing" or "the use of technology" as ways to add to known scientific information.

Simply discussing how science changes as new information is gathered is an incomplete view of the development of scientific knowledge and is missing the critical component of reinterpreting existing information and the development of new theories or explanations. Many teachers expressed a naïve view of this concept by referring to "proving scientific facts." As both the words "prove" and "fact" imply an unchanging nature, they are antithetical to the idea of the tentative NOS. This is exemplified in Ms. Crawford's response that "without data or observation the scientific knowledge is not proven." Her response implies that having evidence that supports scientific knowledge makes that knowledge a certainty, ignoring the idea that the evidence may be reinterpreted. As such, a fully informed view of the tentative nature of science requires an understanding that both the process of discovering new information and reinterpreting existing information leads to changes in scientific knowledge.

Three teachers held naïve views of the tentative NOS: Ms. Edwards, Ms. Jenkins, and Ms. Green. Both Ms. Edwards and Ms. Green held the idea that some forms of scientific knowledge—i.e., theories—change because they are not "proven true." While statements such as these claim that scientific knowledge changes, they miss the important idea that even though it changes it is quite reliable and durable. Ms. Edwards claimed, “Scientific theories do change because they are not proven true” while Ms. Green stated, “A theory is just that a theory it is not set in stone.”

In contrast, Ms. Jenkins was classified as naïve because she made statements indicating a view that scientific knowledge does not change. When specifically referring to if scientific theories change, she claimed, “Not the basis of the theory—there was obviously some part of the theory that was true hence why it was proven the first time.” This indicated a naïve view of the tentative nature of science because the evidence “proving” the theory was so durable the theory could not be changed. Interestingly, Ms. Jenkins later stated that certain types of science (i.e., the cause of the extinction of the dinosaurs) cannot be proven at all because “only God knows.” This is also considered a naïve reference to the tentative NOS because it relies on faith-based claims instead of scientific claims.

Nature of and relation between theories and laws. No teacher held informed understanding of the nature of and relation between laws and theories. Only two teachers had a partially informed understanding (i.e., Ms. McKinley and Ms. Smith), while the rest had naïve understandings. Ms. McKinley’s had partially informed understandings about the nature of theories. She knew that they were highly substantiated (i.e., a theory has “data or observations to support it”) and that they are generative in that they “guide us in our quest for further studies and better, more developed theories.” However, she also had a hierarchical view of the relation between theories and laws, in that theories become laws once there is enough evidence: “Laws are developed over time as multiple accounts of a theory prove to be true.”

Ms. Smith had a more sophisticated view of the relation between theories and laws. She stated, “A theory of law explains how something works. A scientific law describes what happens in certain conditions. For example, the law of gravity vs. the theory of evolution.” This statement captures some of the difference between the nature of theories and laws and avoids the common misconception that theories become laws. However, she did not describe several important aspects of theories, such that they can be used to predict future discoveries and are based on indirect evidence.

The rest of the teachers held explicitly naïve views of the nature of and relation between theories and laws. Many of these echoed Ms. McKinley’s naïve view that theories become laws but did not include any indication of alternative informed views. A similar misconception, held by Ms. Green, was that “a theory is more of an educated guess where [a] law is absolute and can’t/shouldn’t be changed.” Although she does not specifically state that a theory becomes a law, she holds a similar idea that scientific laws are a higher status of knowledge than scientific theories. This mirrors the colloquial use of the term “theory” and is a common misconception (McComas, 1996). Ms. Edwards described a slight modification of the idea:

> Scientific theory is an idea that has a great deal of evidence behind it such as evolution. Scientific laws are facts. While I strongly believe in evolution, it is still a theory. We do not know for sure. Scientific law is something that is proven such as gravity.

This modification allows that theories are supported by a significant amount of evidence, but adds on that laws go beyond this evidence to be proven.

Finally, some teachers held naïve views of theories but failed to make any references pertaining to the nature of laws or the relation between laws and theories. For example, Ms. Jenkins, as described above, indicated naively that theories do not change and simply wrote “?” when asked if there is a difference between a scientific theory and a scientific law. Similarly, Ms.

McKinley looked up the definition of a law and theory in a textbook and copied that response into her questionnaire:

> A **scientific law** is a statement based on repeated experimental observations that describes some aspects of the universe. A **scientific law** always applies under the same conditions, and implies that there is a causal relationship involving the elements. A **scientific theory** is a well-substantiated explanation of some aspect of the natural world that is acquired through the **scientific method** and repeatedly tested and confirmed through observation and experimentation.

She expanded upon her response with the statement, "They don't sound different to me."

The "myth" of the scientific method. None of the teachers had fully informed views regarding the "myth" of the scientific method, however Ms. McKinley, Ms. Edwards, Ms. Smith, and Ms. Green had partially informed views due to making mixed references to informed and naïve views. For example, when describing what science is, Ms. Edwards stated, "Science tests hypothesis to determine facts about the world around us," indicating that tests are necessary for developing scientific knowledge. However when directly asked if experiments are necessary for developing this knowledge, she explained that it does not and provides the example, "Jane Goodall may have done some experiments, but much of her work was based on observations." In this way, she demonstrates that some scientists use different methods for understanding the natural world beyond following the specified steps of the scientific method. Similarly, Ms. Smith states that, "Observation is a powerful tool that gives information to scientists. Experimentation is not always available to scientists."

The other teachers described a reliance on the scientific method to develop scientific knowledge. Ms. Jenkins directly referenced "the scientific method" twice in her VNOS-CE. In response to how science is different from other ways of knowing she stated, "Explaining things by using testable methods. Scientific method. Science can be tested and put through experiments and labs to prove." She followed this up by describing an experiment as "going through the scientific method—creating hypothesis and testing a theory. Repeating multiple times." This demonstrates a clear view that "the scientific method" describes one way—and the only way—that scientific knowledge can be produced.

Another way that this was naïve view was described was through the privileging of experimental discoveries at the expense of other ways of examining evidence. Ms. Maloney provided evidence to this view throughout her VNOS-CE questionnaire. For example, when describing how science is different from other ways of knowing, she referenced that science can still be experimented and tested, unlike "something religious that happened thousands of years ago." This view is naïve to the role of areas of science that depend upon historical evidence, such as paleontology, or are not directly testable, such as much of astronomy. She continued to state that the development of scientific knowledge required experiments because "there needs to be a question posed and then an activity/experiment to support finding the answer to that question."

Theory-laden NOS. The majority of teachers' responses did not include any indication to their views of the theory-laden NOS, and as such they were classified as being silent on this aspect. Two teachers, Ms. Gerber and Ms. Edwards, held partially informed views. Ms. Gerber acknowledged that, "Scientists are able to look at information in different ways" and furthermore that "how the information is interpreted can show differences and brainstorming sessions can lead to different conclusions." These responses indicate an understanding that individual scientists bring differences to interpreting scientific data. Similarly, Ms. Edwards added that different scientists are "giving different weight to pieces of evidence," but does not explicitly state why they would do this. As such, both responses indicated some understanding that individuals' backgrounds may influence their interpretation of data, but neither explicitly stated that these differences are due to theoretical or disciplinary commitments and therefore are partially informed views.

Sociocultural NOS. One teacher held informed views of the sociocultural NOS, three held partially informed, and three held naïve views. Ms. McKinley did not reference the sociocultural NOS at all. Ms. Gerber indicated an informed view by describing twice in her questionnaire how funding and religion impact what may be explored in science. She later extends this idea by stating that, "I believe it [science] reflects social and cultural norms. When funding is needed the scientist will have added influences on their research. Funding may come with 'strings attached.'"

Ms. Smith, Ms. Crawford, and Ms. Green held partially informed views because their answers were incomplete. For example, Ms. Smith stated that, "I believe that what is important to people reflects the scientific focuses within that social group" and Ms. Crawford similarly stated, "I would think [science] transcends national and cultural, but I don't have specific examples." These responses do not indicate how these commitments (i.e., funding or national commitments) influences science and so it they were classified as incomplete.

Ms. Maloney, Edwards, and Jenkins held naïve views of the sociocultural NOS, in that they indicated social and cultural values do not influence science. Ms. Maloney exemplified this response, "I guess I'd say science is universal. I'd say experiments, observations, investigations should give the same results no matter where they are conducted. They should not be influenced by social, political, or philosophical values." This response does not attend to the role that society has in determining which scientific questions are pursued due to its involvement in determining ethical and funding decisions about scientific exploration.

Social NOS. None of the teachers held informed views of the social NOS, however five of them held partially informed views. Ms. Gerber, Ms. McKinley, Ms. Crawford, Ms. Smith, and Ms. Green all gave some indication of adequately understanding the role that other scientists have in negotiating scientific knowledge, although this view was incomplete. Responses revolved around the role of scientific conferences and publications as venues for critiquing or evaluating scientific findings. For example, when describing the role of conferences and publications in science, Ms. McKinley wrote that researchers publish to share ideas with "researchers, colleagues, colleges, people/groups that have funding." A conference, she continued, "would be a place where reputable sources [i.e., scientists] gather that can understand and analyze the evidence or data to determine if it is worth publishing." Ms. Green held the idea that "preapproval is needed to present any findings at a conference or meeting" and Ms. Gerber stated conferences are a place where "other scientists that can review" information. None of the participants indicated an understanding that peer review helps to filter out individual biases of scientists, however, and so their responses were deemed incomplete.

The remaining three teachers held naïve views of the social nature of science. Two common misconceptions were present. The first was that conferences are important for sharing results. Ms. Maloney stated that scientists present at conferences to "spread the word of their findings" while Ms. Jenkins stated conferences were "for other people to look at their theories." Neither of these responses indicate an understanding of the socially negotiated view of scientific knowledge. The other naïve view of the social NOS is that scientists are merely seeking accolades for their work. Ms. Edwards stated, "They submit their research because the institutions they work for receive additional prestige and funding when they have more published findings." While this may be an accurate statement, the funding of work is not provided *through* publications but publications are generally a *result of* adequate funding.

Post-intervention changes in NOS views.

Changes in targeted aspects. Every teacher except one made desired changes in the targeted aspects of NOS. Four teachers changed their views of the empirical and inferential NOS, while one changed her view of the creative NOS. The following sections describe changes made by specific teachers for each of the targeted aspects.

Empirical NOS. Three teachers changed their views of the empirical NOS: two teachers moved from partially informed to informed views and one teacher moved from naïve to partially informed views. It is important to note that four teachers had already started with informed views of the empirical NOS at the outset of the study. As such, seven teachers ended the study with informed views of the empirical NOS. Ms. Crawford, Ms. Edwards, and Ms. Smith moved from partially informed to fully informed views. Any naïve reference to the empirical NOS was absent from their second VNOS-CE. Instead, their responses were all in line with reform documents, similar to those described above.

Ms. Jenkins changed from a naïve to a partially informed view of the empirical NOS. In her pre-intervention VNOS-CE, Ms. Jenkins made one naïve reference to this NOS aspect. However, after the intervention, she stated, "Scientific knowledge doesn't require experiments but does require proof or evidence behind it." This indicates a more mature understanding that scientific claims are based on empirical evidence.

Ms. Edwards presented an interesting change in her post-intervention references to the empirical NOS. Although she had informed views prior to the intervention, these views were not prevalent throughout her VNOS-CE responses. Whereas in her initial questionnaire, she stated, “Science is the study of the world around us,” in the post-intervention questionnaire she stated, “Science is looking at what you observe to figure out things about the world around you.” This presented a more complete picture of science as being empirically based. However, at times she used the word observe in a manner that was not naïve but was not necessarily indicative of a complete understanding. For example, in her post-intervention questionnaire, she described scientists understanding of the atom as originating because “Scientists have observed, used their creativity, and designed experiments to test their theory.” This is a more complete answer than her initial response of “No idea,” however it is still rather vague.

In the post-intervention interview, I asked her to explain more about this process of making observations and using creativity. She responded with, “I was just trying to use the nature of science thing.” She continued to state that she remembered reading about it, but then finished with, “I really have no idea about it.” This example points out an important issue with the educative curriculum materials: they support teachers in developing more informed views of NOS within the context of their targeted topic. This understanding may not be easily transferred to other topics. For Ms. Edwards’ responses, she was able to provide general understanding of how NOS applied, but was not able to provide details for particular science topics, such as the development of the atomic model. These findings mirror the issue as discussed by Clough (2006) and the need to contextualize NOS, as well as the broader problem with transfer in learning in general, which is well-documented in the educational psychology literature (e.g., Bransford & Schwartz, 1999).

Inferential NOS. None of the teachers began the study with informed views of the inferential NOS. However, four teachers changed their views during the study: two began with partially informed views and ended with informed views while another two began with naïve views or made no references to the inferential NOS (i.e., were coded as being silent) and ended with partially informed views. Indeed, the inferential NOS was the targeted aspect with the most gains.

Ms. Gerber and Ms. Smith both moved from partially informed to informed views. Prior to the intervention both teachers understood that scientists have to interpret information. Ms. Gerber stated in her pre-intervention VNOS-CE that scientists can draw different conclusions based on the same evidence because of “how the scientists look at the information. Both events could show the same kind of effects on the earth. Critical thinking can be different for each person. How the information is interpreted can show differences.” In this way they were demonstrating an implicit understanding that the inferences drawn from the observable evidence are different than the evidence itself. However, in the post-intervention questionnaire, both indicated additional understanding that there are some things in science that cannot be observed. For example, Ms. Smith stated, “I believe wavelengths are used to determine the structure” of the atom. Similarly, Ms. Gerber described how “other scientist have done their own experiments or have redone experiments to observe and prove and to give enough information to be able to make inferences to fill in the gaps” to understand the structure of the atom. In her interview she further expanded on the process of “filling in the gaps” to discuss how not everything can be seen, and so scientists must “make guesses based on what they can see.” Both Ms. Smith and Ms. Gerber acknowledged that the subatomic particles themselves could not be viewed, but instead scientists learned about their interactions through indirect evidence.

Ms. Maloney changed to partially informed views of the inferential NOS from a naïve view. Ms. Maloney’s responses are interesting in that she maintained all of her naïve references to the inferential NOS from her initial survey, but added informed references to the inferential

NOS in responses to other questions. That is, she maintained that scientists cannot know about events that happened in the past (e.g., the extinction of the dinosaurs) because they cannot see these events. However, in her overall description of science, she wrote, “People take what they learn from observations and experiments and make an inference as to how something within the natural [world] works.” It is not surprising that she would make incongruent statements about NOS, which is well documented in the literature (Abd-El-Khalick, 2004). Indeed, this has been described in several participants’ surveys for other aspects of NOS already. It is possible that these incongruities are capturing the developing nature of participants’ views.

It was not possible to determine Ms. Jenkin’s view at the beginning of the study because she did not make any statements addressing the inferential NOS; however, at the end of the study her interview responses indicated a partially informed view. I asked how she thought scientists learn about black holes. She responded that inferences must play a part if they cannot see a black hole. Specifically, they use “things they already know about it to help them make sense of what they’re seeing or what they’re looking at.” This indicates that while scientists may not be able to learn about the black holes by observing them directly, they may be able to understand something about them by what they do see. That is, their inferences about what is happening must be consistent with their observations.

Creative NOS. Only one teacher made changes in her views of the creative NOS, Ms. McKinley, although it is important to note that Ms. Gerber began the study with informed views and so it was not possible for her views to change. In the pre-intervention VNOS-CE, Ms. McKinley indicated that creativity was needed in designing an investigation and sharing the results with other. This view remained in her post-intervention questionnaire, but she added that, “Interpretation is a form of creativity as people use their imaginations to make connections between ideas." This statement extends her previous response by considering the creativity involved in understanding data and imagining what they could mean.

Although the other teachers did not change in the assigned qualitative code for the creative NOS, it does not mean that they made no changes in their understanding of related ideas. As an example, Ms. Crawford initially only mentioned the use of creativity in science when explicitly asked about it and at that point stated an incomplete understanding, to the effect that creativity was used to "think outside the box" in science. However, in her post-intervention response, she included creativity when discussing what science was. She stated that students should be "creative in science or with their knowledge." Although this was a desired change in her understanding of creativity in science, it was not indicative of a fully informed understanding because it did not include the role of creativity in generating conclusions from data or explanations for phenomena.

Ms. Edwards once again presented as an interesting case of how changes in responses may be indicative of the type of learning that occurs. She initially stated that creativity was "involved in formulating the question and designing experiments" and in developing tools. In her post-intervention questionnaire, she added that "Scientists observe, use their creativity, and design experiments" as a response for both the question about how scientists develop their understanding of the atom and for how scientists present their findings at a conference. Ms. Edwards' change in use of the word *creativity* mirrors the change in the word *observe*. However, similar to her understanding of the role of observations in science, she understood that scientists were creative in science, but not how that creativity was manifested in specific instances.

Changes in other aspects. In addition to the targeted aspects, all of the teachers made changes in at least one other NOS aspect. This is perhaps unsurprising due to the nature of the books read-aloud. Although the intention of the study was to specifically target just three aspects, other aspects were still addressed in the chosen books. For example, *I, Galileo* describes how Galileo was imprisoned for heresy against the church by saying that the sun is the center of the universe. As such, the book addressed how powerful religion has been historically in informing what claims scientists could or could not make—that is, it described the sociocultural nature of science. Additionally, views of non-targeted aspects may have changed because the individual aspects are interrelated, and so a change in one may support a change in another. For example, when developing a more informed understanding of the creative NOS, a teacher may also change her view of the role of "the scientific method" in science because being creative in science may mean using multiple or novel methods for developing scientific knowledge instead of just one pre-determined steps. Of the non-targeted aspects, three deserve to be highlighted for unique patterns of change: the theory-laden NOS, the myth of the scientific method, and the role of and relation between theories and laws.

Theory-laden NOS. The most teachers made desired changes in their views of this aspect than out of any other aspect—including the targeted ones. In total, five teachers changed their views[4]. This is possibly due to the fact that prior to the intervention, most teachers were silent as to their understanding of the theory-laden NOS: six teachers were coded as silent while two were partially informed. Ms. Gerber, the only teacher who held partially informed views pre-intervention, and Ms. Jenkins ended the study with informed views. Ms. Gerber exemplified the informed view in her statement [formatting maintained from original]:

> They are looking at the data for different answers,
> scientist may not be trying to prove the same hypothesis or theory,
> scientist are not looking for the same answers,

[4] Please note that Ms. Jenkins was initially coded as being silent on the theory-laden NOS, and subsequently coded as having a naïve view post-intervention. Although this is a change in observable responses, it was not coded as an undesired change as it is possible that she held naïve views initially.

scientist are inferring differently,
different background knowledge and experience,
scientist are trying to come up with as many explanations as they can

This statement addresses the inferential NOS by describing how scientists' backgrounds influence their choice of problems (i.e., looking to "prove" the same hypothesis or theory), how they view the data (i.e., looking for "different answers") and the types of conclusions they draw (i.e., "inferring differently").

The other teachers developed a partially informed view of the theory-laden NOS. In particular, there was evidence that they understood that the role of scientists' background beliefs influenced how their viewed evidence. This mainly was apparent when they explained how scientists with the same data could create different explanations for the extinction of the dinosaurs. For example, Ms. McKinley stated, "This works in the same way as even with the same set of evidence, interpretation is always subjective to personality, experiences, beliefs, and therefore, conclusions." Unlike Ms. Gerber or Ms. Smith, none of the teachers with partially informed views explicitly stated that, more than personal beliefs, it was scientists' training and theoretical commitments that caused these differences and that the differences extended beyond interpreting evidence to even influencing the types of questions scientists explore.

The "myth" of the scientific method. Changes in participants' views of the role of the scientific method in developing knowledge were unique in that this is the only aspect that showed *undesired* changes in one participant's views. Although four participants changed their views in the desired manner, there was evidence that one participant made undesired changes. Changes in the desired manner involved removing naïve references to the scientific method in favor of informed references. For example, Ms. Crawford initially claimed that the development of scientific knowledge required experimentation. However, after the intervention she described that observations in the absence of experiments could be used to create scientific knowledge. Changes of this type were not surprising, as they often could be traced back to particular references in the trade books. For example, Ms. Crawford referenced an incidental observation Foucault made in *Come See The Earth Turn* as resulting in his understanding that the Earth spun on its axis.

In contrast to the desired changes, Ms. Green ended with a more naïve view of the myth of the scientific method. In her initial questionnaire, Ms. Green made an informed statement that the development of scientific knowledge does not require experiments and elaborated with the example that it is possible to "learn about space and gain knowledge about planets, stars, the galaxy without having to do an experiment." Other statements modifying this one implied the need for experimental data, "There has to be a hypothesis and data collection along with a presentation of your analysis." Indeed, these types of changes are present in her final questionnaire as well. However, the statement about being able to develop knowledge without experiments has been altered in her second questionnaire to address learning as a student, not the development of new knowledge. She wrote, "I do not believe it requires experiments. Experiments can help to prove or alter your thoughts but they aren't needed to acquire knowledge. I can read a book on animals and migration and learn about them without doing an experiment." In light of this response, Ms. Green's view of the role of the scientific method was deemed to be naïve.

Once again, this result is not surprising, given the prevalence of the "myth" of the scientific method in general science education. Three teachers had posters detailing the steps of the scientific method up in their classroom and at some point every teacher made a naïve reference to it. In fact, Ms. Jenkins was adamant that scientists must follow the scientific method.

During her interview, I asked if all scientists follow it and she emphatically replied, “I hope so!” She went on to state that the scientists described in the books followed it, but did not provide evidence of how. This is particularly interesting, as the books never explicitly mentioned the scientific method and in fact provided several descriptions of how scientists deviated from it. For example, even the unmodified version of *I, Galileo*, the version that Ms. Jenkins read, detailed how Galileo deviated from the scientific method by utilizing simple observation with a telescope to discover that the moon was not smooth, but instead contained peaks and valleys. Indeed, this speaks to the level of entrenchment that the scientific method has in science education.

Nature of and relation between theories and laws. The last aspect that deserves special attention is the nature of and relation between scientific theories and laws. These findings were unique in that they were the only ones that indicated no changes in views. All teachers remained either naïve or partially informed about theories and laws. This is perhaps due to the relative isolation of these aspects compared to the other NOS aspects. Although it is possible to see the relevance between other aspects and this one, it is not as intertwined as the other aspects are with each other. For example, it is easy to see how having an informed view of the tentative nature of science may influence your understanding of theories (i.e., that they are durable and well-supported by evidence instead of “just an idea”), but it not as easy to see how an understanding of theories or laws in turn influences the other aspects.

Translating Changing Views Into Practice

In this section, I describe how teachers translated their changing views of NOS into practice as they led the read-aloud sessions. I begin by describing the differences in the length of discussions across levels of interaction as a rough proxy for the depth of discussion. I then dig deeper into the content of the discussion by reporting on the number, quality, and type of NOS references. I include in this section illustrative examples of classroom discourse for several common misconceptions, and exemplars of effective teaching, about NOS. I conclude the section by describing the pervasiveness of literature and literacy instruction throughout the read-alouds as an important component of integrating science with literature and literacy instruction.

Length of discussions. I calculated the length of discussion as a rough proxy for the depth of discussion around the trade books. The length of discussion is an important measure in a classroom, as much of the learning in the elementary classroom occurs verbally (Cazden, 2001). I determined that the beginning of the discussion started when the teacher began either an introduction to, or in one case in which there was no introduction, the reading of the trade books. The end of the discussion was when the teacher instructed the students to begin the free response task.

Additionally, the length of discussion was compared across books, as it is possible the differences in the books (e.g., length or reading level) could impact the length of the discussion. Discussions ranged from 17 min 45 s, led by Ms. Edwards, to 51 min 28 s, led by Mrs. Gerber. Across teachers, the average discussion took 31 min 13 s. Table 8 provides the length of time of every read-aloud session, as well as the average time per teacher and per book. It is important to note that although most teachers specifically scheduled read-aloud sessions when they would have large blocks of time in the classroom, this was not always possible. In some cases, the amount of time teachers could spend on a read-aloud was constrained by their schedule. For example, Mrs. Maloney's first read-aloud was constrained by her students attending gym immediately after the book was finished. Similarly, Ms. Crawford's last read aloud was constrained by an early dismissal. The following analyses were run both with constrained times

Table 8

Length of Discussions by Teacher and Book

Teacher	Come See the Earth Turn			Galaxies, Galaxies!			I, Galileo			Teacher Average (*SD*)
	Level I	Level II	Level III	Level I	Level II	Level III	Level I	Level II	Level III	
Gerber	22min 32 s				43 min 20 s				51 min 28 s	32 min 17 s (*6 min 54 s*)
Maloney			29 min 43 s	23 min 52 s				26 min 53 s		26 min 49 s (*2 min 56 s*)
McKinley		31 min 30 s		29 min 0 s					31 min 28 s	30 min 39 s (*1 min 26 s*)
Crawford			26 min 41 s		40 min 19 s		38 min 39 s			37 min 6 s (*8 min 34 s*)
Edwards	27 min 26 s					43 min 46 s		40 min 6 s		35 min 13 s (*7 min 26 s*)
Jenkins		18 min 50 s				27 min 52 s	29 min 57 s			38 min 7 s (*14 min 36 s*)
Smith	23 min 9 s					30 min 10 s		26 min 42 s		22 min 13 s (*4 min 56 s*)
Green	17 min 45 s				34 min 20 s				36 min 40 s	29 min 37 s (*10 min 20 s*)
Level Average	22 min 43 s	25 min 10 s	28 min 12 s	26 min 26 s	28 min 1 s	33 min 56 s	34 min 18 s	31 min 14 s	39 min 52 s	
Book Average (*SD*)	25 min 22 s (*2 min 45 s*)			29 min 28 s (*3 min 57 s*)			35 min 8 s (*4 min 23 s*)			

and without. Results did not differ substantially, and so results from the entire data set are presented here.

The length of discussion varied substantially from teacher to teacher. Ms. Gerber on average held the longest discussions and Ms. Smith on average held the shortest. However, a plot of the length of discussions by teacher indicated a similar trend across participants (Figure 6). Indeed, every teacher spent longer on Level III book discussions than she did on the Level I discussion, with the exception of Ms. Crawford, who was constrained by her class schedule. It is possible that had she not had this constraint she would have followed a similar trend as the other teachers.

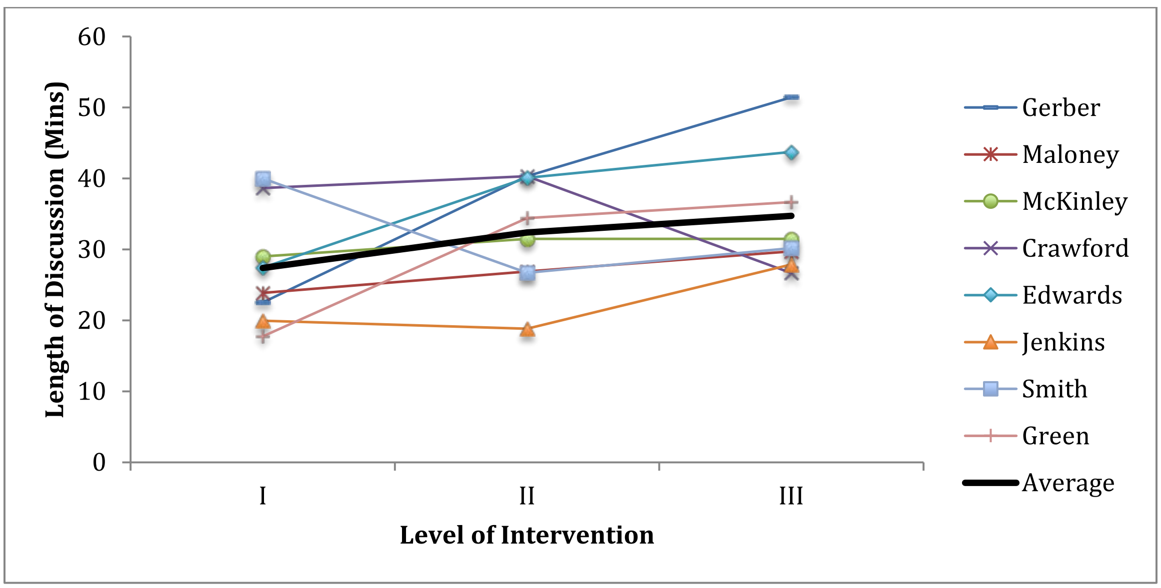

Figure 6. Length of read-aloud discussions.

To more closely examine this trend, I analyzed the average length of discussion per book. Due to differences in genre, length of book, and readability, it is possible that books acted differently in different conditions. I calculated the averages in two ways (see Table 8). First, I calculated the average time spent reading each book in each condition. This revealed that participants spent longer times reading *Come See the Earth Turn* and *Galaxies, Galaxies!* in each subsequent level. *I, Galileo* did not follow this trend, as the Level II read-alouds were shorter than the Level I read-alouds. However, it is important to keep in mind that Ms. Maloney and Ms. Smith read *I, Galileo* as their Level II book and that they were the two teachers with the shortest average read-alouds and as such their contributions may have caused the results to act in this way. After calculating the average for each level, I calculated the average time spent reading each book, regardless of level (see Figure 7). These results indicated that a difference across books, such that teachers spent less time reading *Come See the Earth Turn* than *Galaxies, Galaxies!* and the most time reading *I, Galileo.*

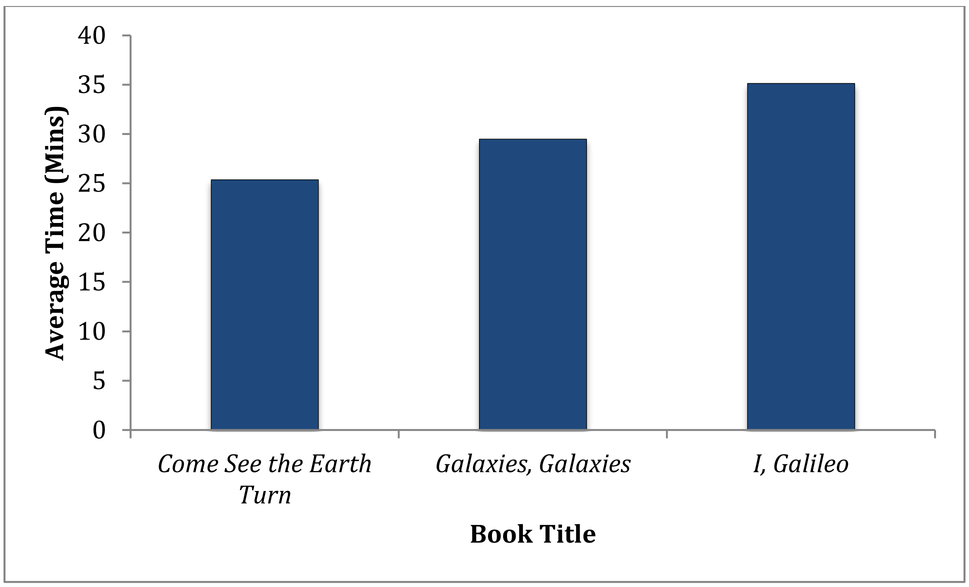

Figure 7. Average length of discussion per book.

Number, quality, and type of references for targeted NOS aspects. The length of discussion served as a rough measure of the quality of discussion that occurred at each level of read-aloud. Each read-aloud was more closely inspected to identify specific types of prompts that the teachers made to engage students with the NOS content in the books. I first explored the origin of references. I then took a broader view of the data to consider some of the trends across levels of intervention and a holistic analysis of the quality of references across levels.

Origin of references. Before the differences in discussions between books or levels of interventions can be explored, it is important to consider the origin of references. I determined the origin of the references: the teacher or the book. That is, when teachers were reading directly from the text, I attributed the reference to the book. All other references were attributed to the teacher. Because the unmodified books were predominantly silent regarding the targeted NOS aspects, there were very few naïve references in the unmodified texts. Specifically, *Come See the Earth Turn* only had one naïve inferential reference; *I, Galileo* had four naïve inferential references; and *Galaxies, Galaxies!* had no naïve references (see Table 9). Additionally, as a result of the intervention design, all naïve references to NOS were altered in the modified texts read in Levels II and III. As such, all naïve references in these levels came from the teachers.

Table 9

Number of Informed NOS References in Modified and Unmodified Books

	Come See the Earth Turn			*Galaxies, Galaxies*			*I, Galileo*		
	Unmodified		Modified	Unmodified		Modified	Unmodified		Modified
Reference	I	N	Informed	I	N	Informed	I	N	Informed
Empirical	2	0	5	1	0	11	2	0	5
Inferential	1	1	3	0	0	5	1	4	3
Creative	0	0	3	0	0	4	1	0	4

Note. I = Informed; N = Naïve.

The unmodified books had very few informed references to any aspect of NOS. *Galaxies, Galaxies!* had one informed reference and *I, Galileo* had four informed references. However, once the trade books were modified, the number of informed references dramatically increased. Recall that there were two types of modifications: major and minor. Although the number of major modifications was kept consistent across books, the minor references varied based on the starting text. As such, the final number of informed references differed across books.

Every teacher read through the main text. As such, they read every reference from the book, whether it was informed or naïve. However, teachers differed in their own contributions to the discussion. Table 10 separates out informed and naïve references made by the teachers and those that were in the book. Examination of this table indicates the teachers made very few references of any type in their Level I discussions. The total number of references increased throughout the subsequent levels. I will consider the patterns of informed references first and then naïve references.

If teachers read the books verbatim, and did not include any additional commentary or discussion about NOS, students would have received informed messages about the targeted aspects of NOS in Levels II and III. In fact, this is how Ms. Green led her Level II discussion. She read the book through from start to finish, asking only questions related to literacy and literature concepts. She either ignored the "Think About It" questions or read them without pursuing their answers during the discussion. All of the other teachers included additional informed references to targeted NOS aspects during their Level II and III read-aloud discussions (see Figure 8). Consequently, this indicates that in addition to supporting informed discussions of NOS by including explicit references in the read-aloud text, the intervention also supported teachers in making their own additional informed references.

Table 10

Type, Quality, and Origin of NOS References During Read-Alouds, Sorted by Book

	Empirical										Inferential										Creative									
		Level I			Level II			Level III				Level I			Level II			Level III				Level I			Level II			Level III		
Teacher	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN
Come See the Earth Turn																														
Gerber	2	0	0	0							1	1	0	0							0	0	1	0						
Maloney								5	9	0								3	3	1								4	7	0
McKinley					5	4	1								3	4	0								3	4	0			
Crawford								5	2	1								3	8	0								4	1	0
Edwards	2	0	0	1							1	1	1	0							0	0	0	0						
Jenkins					5	6	2								3	0	0								3	3	0			
Smith	2	0	0	0							1	1	0	0							0	0	0	0						
Green	2	0	0	0							1	1	0	0							0	0	0	0						
Total	8	0	0	1	10	10	3	10	11	1	4	4	1	0	6	4	0	6	11	1	0	0	1	0	6	7	0	8	8	0
Galaxies, Galaxies																														
Gerber					11	6	0								5	7	0								4	3	0			
Maloney	1	0	1	0							0	0	0	0							0	0	0	0						
McKinley	1	0	0	0							0	0	0	0							0	0	0	0						
Crawford					11	1	0								5	4	2								4	0	0			
Edwards								11	6	2								5	4	2								4	0	0
Jenkins								11	3	1								5	2	2								4	0	0
Smith								11	4	3								5	1	2								4	0	0
Green					11	0	0								5	0	0								4	0	0			
Total	2	0	1	0	33	7	0	33	13	6	0	0	0	0	15	11	2	15	7	6	0	0	0	0	12	3	0	12	0	0

(continued)

Table 10 (continued)

	Empirical										Inferential										Creative									
	Level I				Level II			Level III			Level I				Level II			Level III			Level I				Level II			Level III		
Teacher	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN	BI	BN	TI	TN	BI	TI	TN	BI	TI	TN
															I, Galileo															
Gerber								5	7	0								3	2	0								4	4	0
Maloney					5	7	0								3	0	1								4	0	0			
McKinley								5	8	0								3	6	0								4	0	0
Crawford	2	0	0	0							1	4	0	0							1	0	0	0						
Edwards					5	6	3								3	1	0								4	3	1			
Jenkins	2	0	1	0							1	4	0	1							1	0	0	0						
Smith					5	7	3								3	0	0								4	3	0			
Green								5	5	0								3	0	0								4	0	0
Total	4	0	1	0	15	20	6	15	20	0	1	8	0	1	9	1	1	9	8	0	2	0	0	0	12	6	1	12	4	0

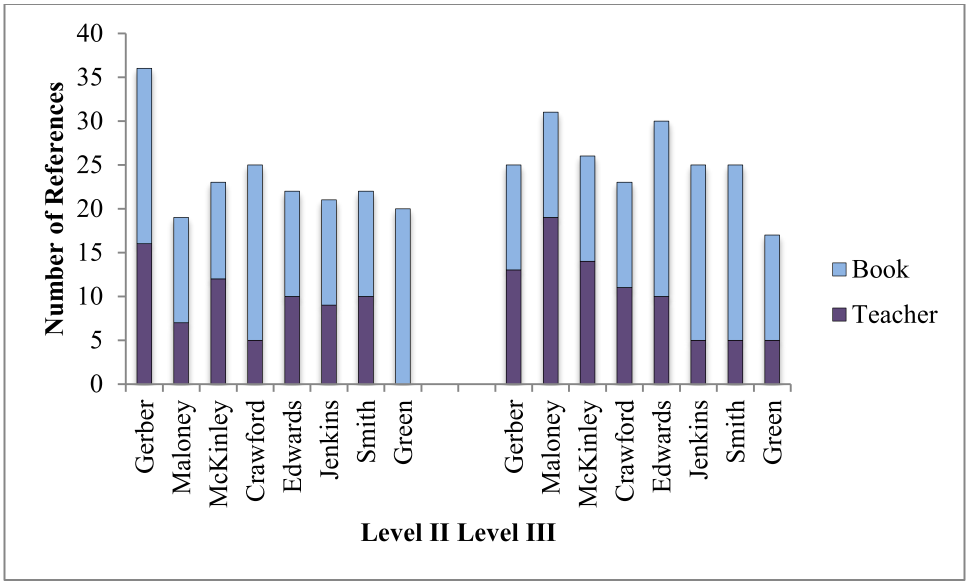

Figure 8. Origin of informed NOS references in Level II and III read-aloud discussions.

The absolute number of references does not provide a clear picture because the number of references originating in the book differed across books and so was not kept consistent within teachers from Level II to Level III. Therefore, I examined the proportion of informed references made by the teachers (see Figure 9). This analysis indicated that the majority of teachers made a greater proportion of informed references during the Level III read-alouds than during the Level II read-alouds. Only three teachers, Ms. Edwards, Ms. Jenkins, and Ms. Smith made fewer. These teachers showed other similarities in their read-aloud patterns and will be examined separately later. However, for the remaining teachers, the Level III supports appeared to empower them to contribute their own informed references to the read-alouds.

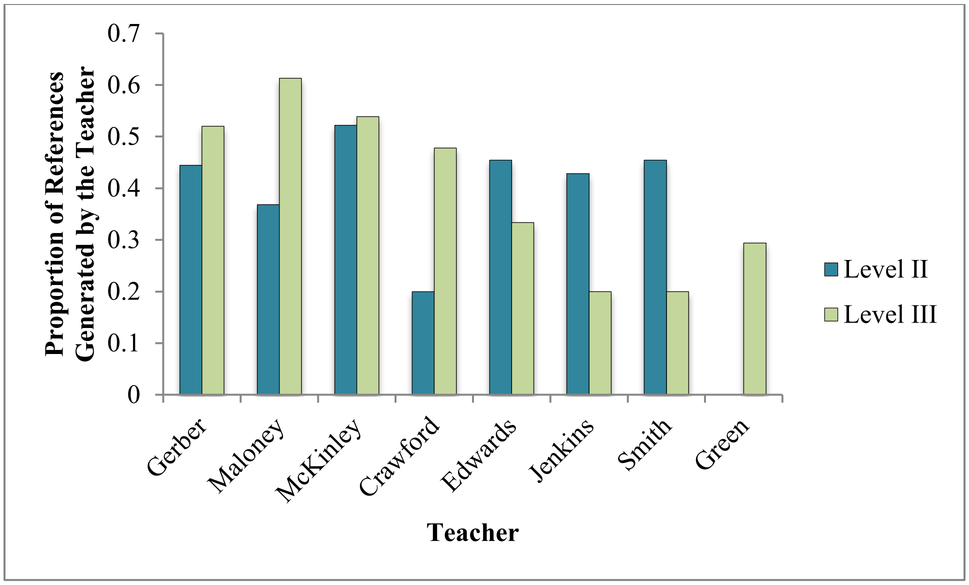

Figure 9. Proportion of informed NOS references made by teachers in Level II and III read-aloud discussions.

The number of naïve references was examined in a similar manner. Teachers tended to make very few naïve references across all levels. In fact Ms. Gerber and Ms. Green made no naïve references at all. Additionally, the majority of teachers made fewer naïve references in Level III than in Level II (see Figure 10). Similar to above, Ms. Edwards, Ms. Jenkins, and Ms. Smith broke from this pattern. It must be noted that all three teachers read *Galaxies, Galaxies!* in their Level III discussion. Although it might be something about the book that caused the teacher to generate fewer informed references and more naïve references, it is unlikely as this was not apparent in the Level II discussions. Further digging showed that these teachers had similarities in the way that they implemented the Discussion questions in the Level III book, which will be expanded upon in a later section.

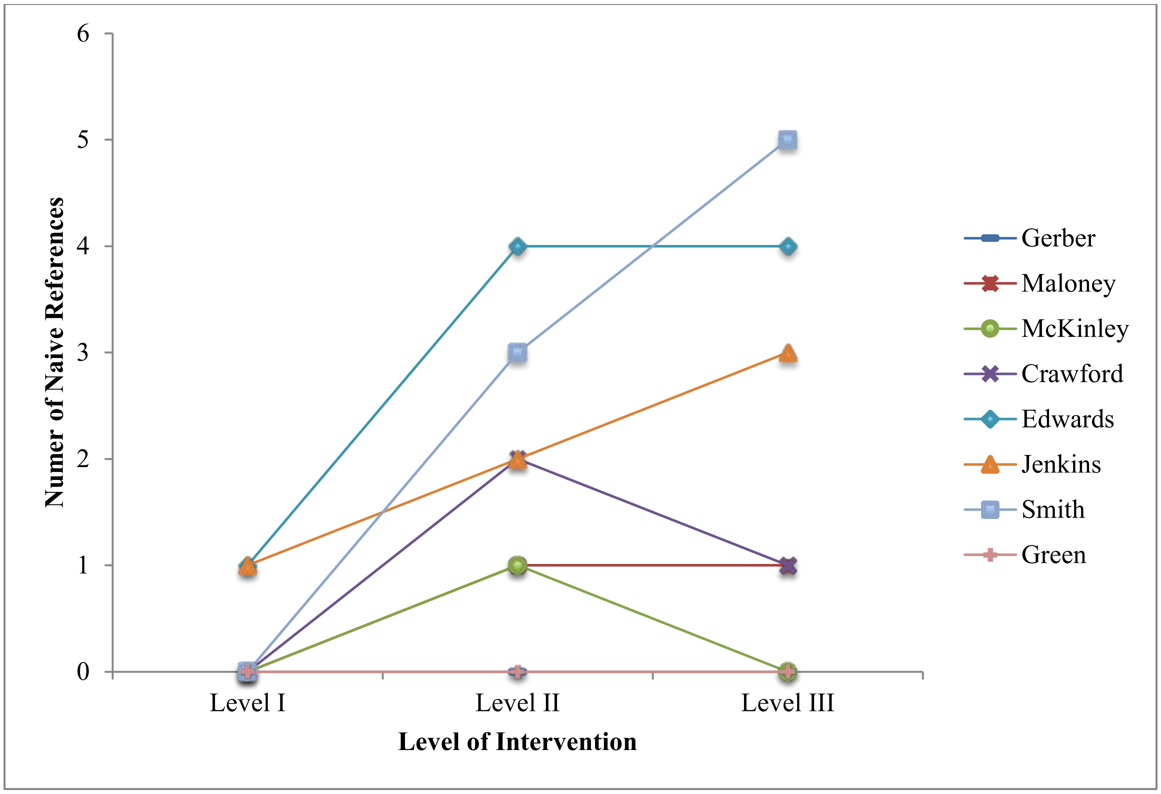

Figure 10. Number of naïve references teachers made in each level of intervention.

Trends across levels. Thus far I have considered the patterns presented in each teacher's discussion. However, by aggregating data across teachers, it is possible to see some larger trends. Teachers made very few NOS references of any type (explicit vs. explicit-reflective) or quality (naïve vs. informed) during the Level I discussions. The total number of references steadily increased for each teacher across levels, with the exception of Ms. Gerber. Ms. Gerber's references increased from Level I to Level II but then decreased between Level II and Level III (see Figure 11). Despite this decrease, her number of references remained well within the range of other teachers' Level III references. The total references in Level I discussions ranged from 1 in Ms. McKinley's class to 11 in Ms. Jenkin's class. In contrast, during Level III discussions, the number of references increased to a minimum of 28 in Ms. Green's class to a maximum of 48 in Ms. Edwards' class.

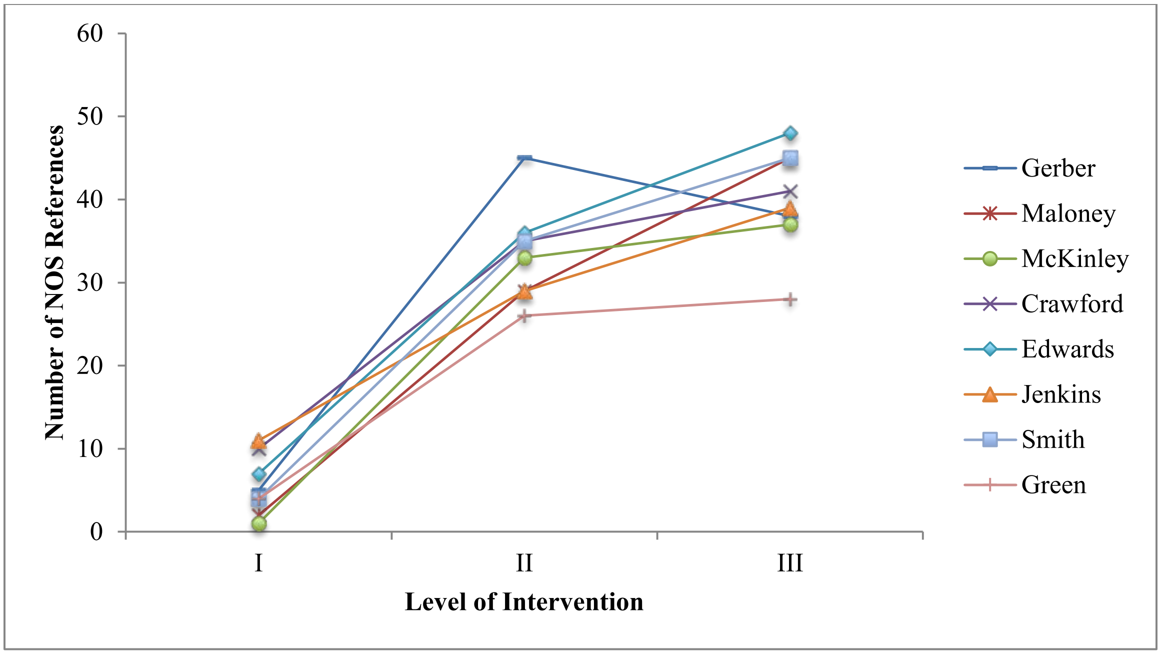

Figure 11. Total number of NOS references during read-aloud discussions.

Another general trend is that teachers tended to make more references to the empirical NOS than to either the inferential or creative NOS (Figure 12). However, when viewing the distribution of references by level of intervention, it appears that this difference is driven mainly by differences in Level II and Level III (see Figure 13). Teachers made a similar number of references to the empirical and inferential NOS during the Level I discussions.

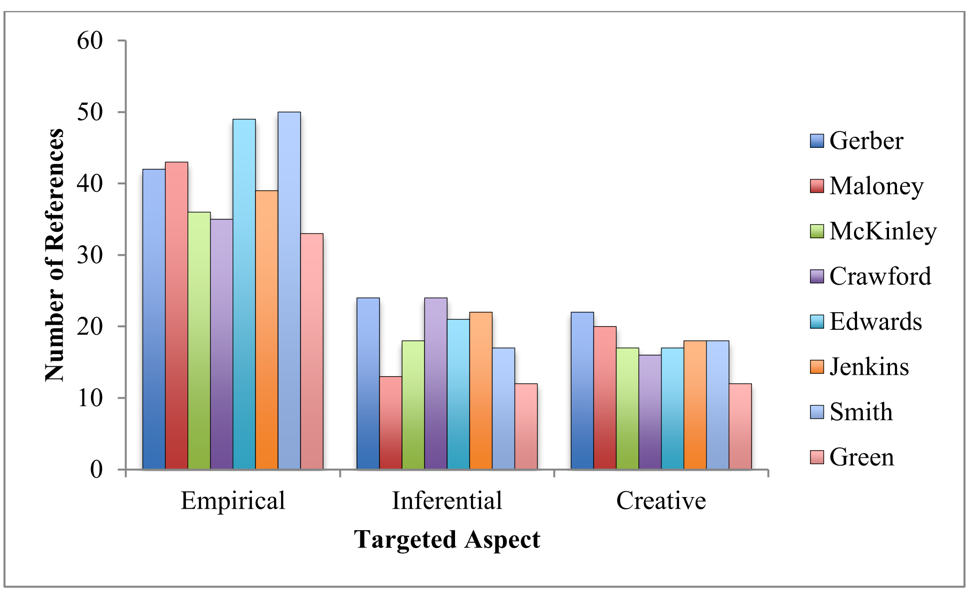

Figure 12. Total references for each targeted aspect, aggregated across levels of intervention.

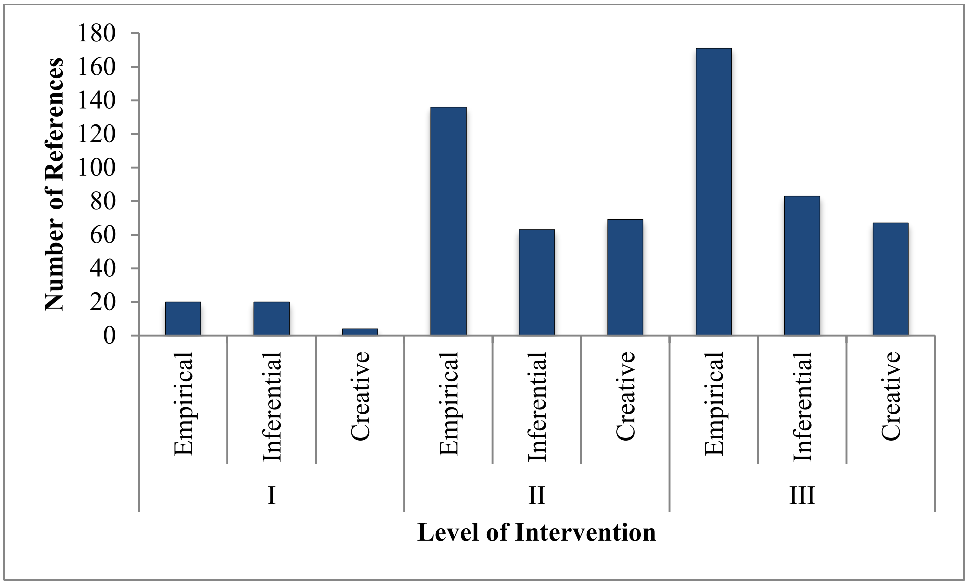

Figure 13. References for each targeted aspect, separated by level of intervention.

At this point it is apparent that the intervention had an impact on the number of references for each of the targeted aspects of NOS. The similarities in references to the inferential and empirical NOS disappeared by the Level II discussions, as teachers made substantially more references to the empirical NOS than the inferential. In fact, teachers made 6.8 times as many references to the empirical NOS in Level II, compared to Level I. This contrasts with only 3.2 times as many references to the inferential. Results for Level III remained similar to Level II for both the empirical and inferential NOS. These results indicate that the intervention might have targeted the empirical NOS more directly than the inferential NOS.

In a similar vein, the intervention had a larger relative effect on the creative NOS than either the empirical or inferential NOS. Despite the total number of references to the creative NOS remaining low compared to the empirical NOS, the proportional increase is larger than for either the empirical or inferential. Teachers increased the number of references to the creative NOS from 20 in the Level I discussions to 69 in the Level II discussions. This translated to 17.25 as many references in Level II as in Level I, a much higher level than either the empirical or inferential. The modified intervention materials clearly provided substantial support allowing teachers to include the creative NOS in their discussions.

Quality of targeted NOS references across levels. Because a reference is only beneficial to student learning if it is informed, I calculated the number of informed and naïve reference for each aspect of NOS (see Figure 14). Both the empirical and inferential NOS had a mixture of informed, reflective, and naïve references across all three levels of intervention. There was only one naïve reference to the creative NOS in any read-aloud session. This occurred during the Ms. Edwards' second read aloud when she asked her students why it was important to create better tools to make observations. A student responded with, "so we can have better stuff to do." He continued to explain how old cars got "better and better." Ms. Edwards accepted this students' response, affirming its appropriateness despite the fact that the development of cars is not related to observations.

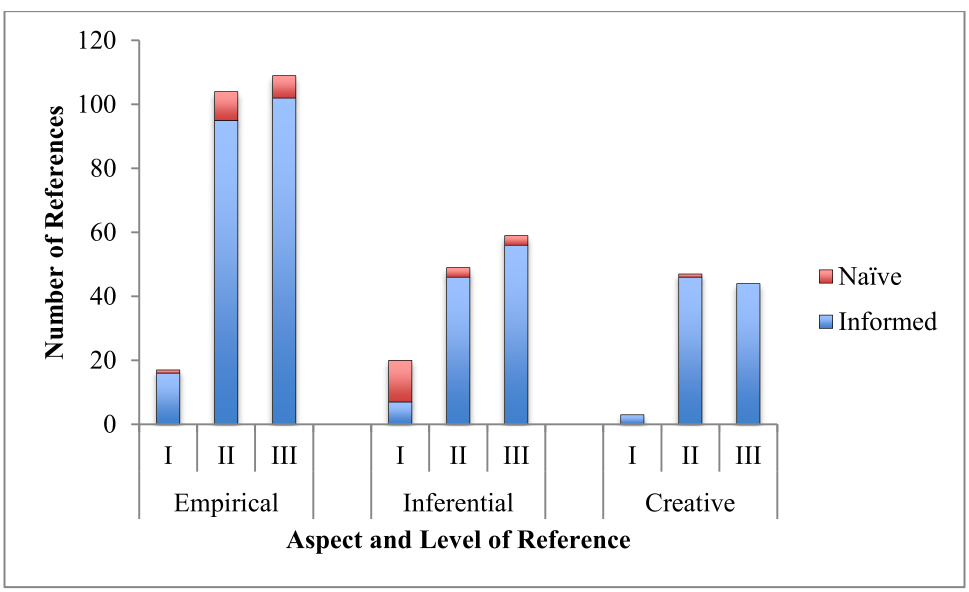

Figure 14. Total number of informed and naïve references across aspects.

Additionally, and more importantly, when considering the relative percentage of naïve references to the total number of references, there was a greater percentage of naïve references to the inferential NOS than the empirical (see Figure 15). However, whereas the proportion of naïve references to the empirical NOS remained relatively constant across levels of intervention, there was a sharp decrease to naïve inferential NOS references between Levels I and II. The percentage of naïve references remained at a similarly low level in Levels II and III.

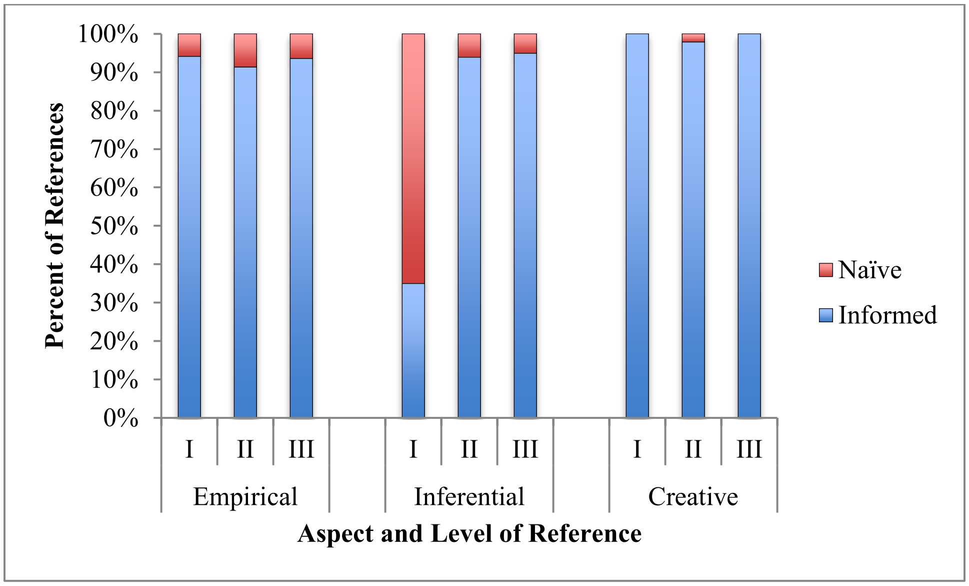

Figure 15. Percent of informed and naïve references in each level of intervention.

These results indicate that although teachers are prone to include naïve references to the empirical and inferential NOS, the negative impact of these references were somewhat washed out in Level II and III discussions due to the higher number of informed references. Additionally, although the teachers were unlikely to include naïve references to the creative NOS at any level, the total number of informed messages increased in Levels II and III. Taken together, the students engaged in these discussed received more consistently informed messages about the targeted NOS aspects during the read-alouds of the modified texts (i.e., Levels II and III) than they did while discussing the unmodified text.

Relation between views of NOS and informed references. It would stand to reason that part of the reason teachers made more informed references on their own to NOS in Level II and

III discussions was that teachers were developing more informed views of NOS. As such, this analysis only includes references generated by the teacher and does not include those that were designed to be in the book. Ideally to investigate this, I would compare the teachers' views with the number of informed references generated by the teacher in Level I and Level III discussions. However, as there were too few teacher-generated informed references in the Level I discussions, it was not possible to determine any pattern. Results for Level III are presented in Figure 16 a-c. Surprisingly, there appeared to be no relationship between the teachers' views of NOS and the number of informed references they made. Teachers with less-informed views of NOS made a similar number of references as those with more-informed views of NOS across all three aspects.

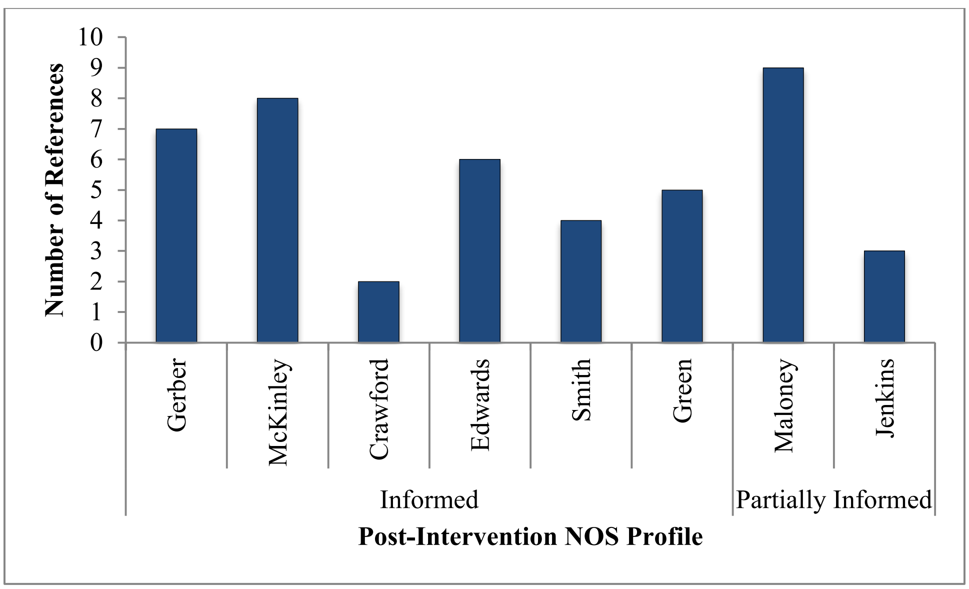

Figure 16a. Relation between teachers' NOS views and references for empirical NOS.

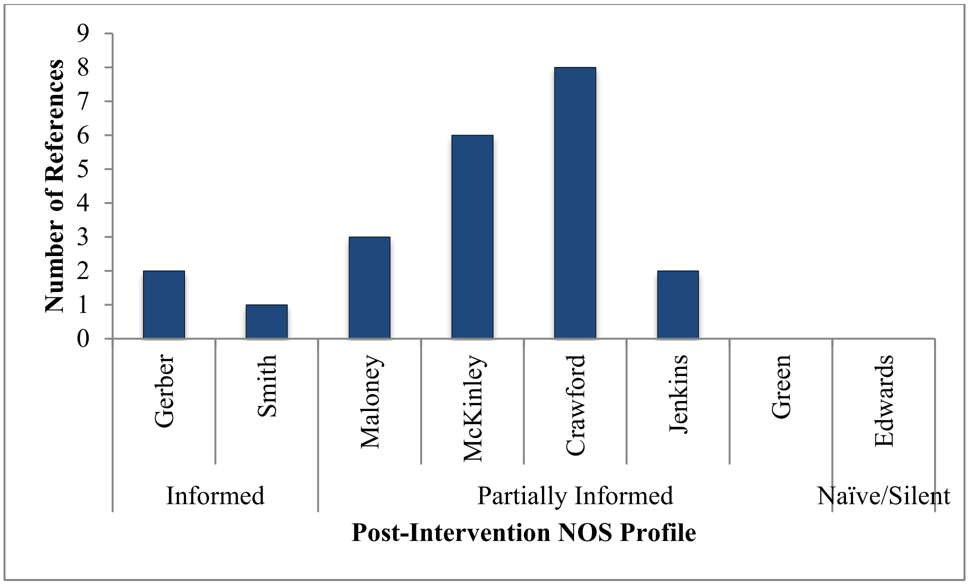

Figure 16b. Relation between teachers' NOS views and references for inferential NOS.

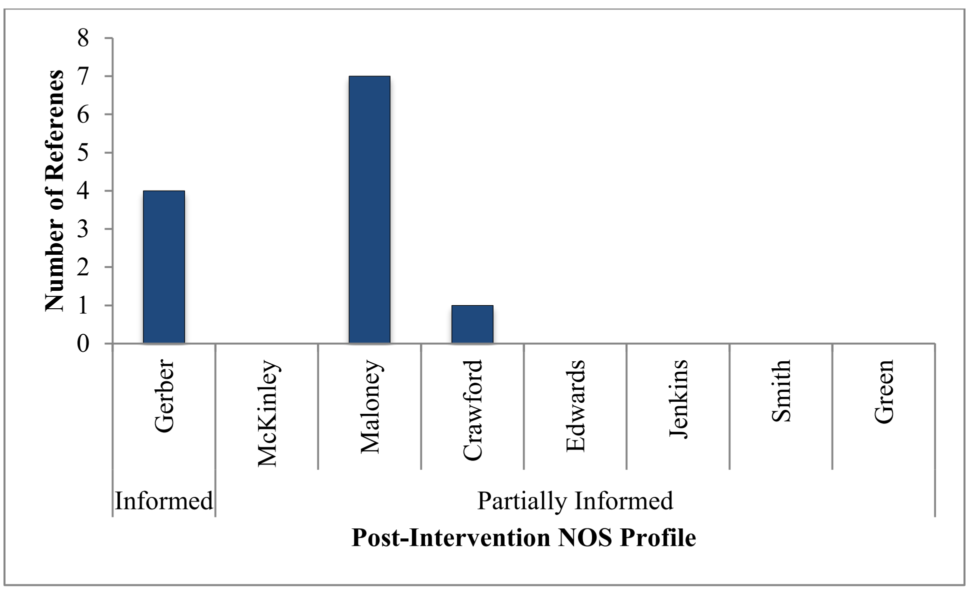

Figure 16c. Relation between teachers' NOS views and references for creative NOS.

The role of reflection. Thus far the analysis focused on how teachers implemented and built on the explicit references in their practice. However, the intervention also included two types of explicit-reflective prompts: Think About It questions, and Discussion questions. Recall that the Think About It questions were included in the modified trade books, and therefore were available to teachers in both Levels II and III. The Discussion questions were only present in the teachers' guide, and therefore only available to teachers in Level III sessions. Table 11 provides the number and type of reflective prompts in each book. The total number of Think About It and Discussion questions was the same across books, but the distribution across aspects differed, as the books provided different opportunities to address each.

Table 11

Number and Type of Reflective Prompts in Each Book

	Come See the Earth Turn		*Galaxies, Galaxies!*		*I, Galileo*	
Aspect	Think about it	Discussion	Think about it	Discussion	Think about it	Discussion
Empirical	3	3	3	2	2	2
Inferential	1	1	2	1	1	2
Creative	2	0	1	1	3	0

Although all teachers had access to the same number of questions and therefore had the same opportunity to ask them, in practice, teachers implemented these questions differently. None of the teachers read every single question in Level II and Level III. Indeed, this would have been surprising, given the constraints of teaching in a real classroom. In particular, teachers had to gauge the amount of time available for reading the book as well as the students' engagement in the books. In fact, the front matter of the teacher's guide specifically told teachers, "This teachers' edition includes several suggestions for teaching about space and the nature of science. You may choose to use all of the suggestions or pick several that make the most sense for you."

As noted above, three teachers in particular did not follow similar trends as the other teachers: Ms. Edwards, Ms. Jenkins and Ms. Smith. These differences were visible in the type and number of reflective questions that they chose to read, and those they chose to skip. Unlike the other teachers who read the majority of all reflective questions, these three teachers chose to skip some or all of the Discussion questions that were provided in the teacher's guide (see Table

12). Note that Ms. Crawford also skipped a large number of discussion questions in Level III, but this was due to time constraints in her Level III read-aloud, as discussed in a previous section. As such, she was not grouped with Ms. Edwards, Ms. Jenkins, or Ms. Smith.

Table 12

Number of Reflection Questions Skipped during Read-Alouds Discusions

	Level II	Level III	
Teacher	Think about it	Think about it	Discussion
Gerber	1	0	0
Maloney	3	0	0
McKinley	0	3	0
Crawford	1	0	3
Edwards	0	0	4
Jenkins	0	0	1
Smith	0	0	2
Green	6	0	0

Recall that these three teachers were similar in other ways. These teachers all had a large number of naïve references in their Level III read-alouds. Additionally, they were the only teachers had a lower proportion of informed references in Level III than in Level II. As such, it appears that there was an underlying factor that was similar across these teachers that affected their ability to implement the intervention materials in the same manner as the other teachers. Based on the data collected in this study, it was not possible to determine what that factor was.

Besides the number of reflective questions that were read, it is important to consider how teachers adapted and extended instruction to develop their own questions. This was exemplified in Ms. Gerber's Level III discussion, which centered on creativity. The modified text of *I, Galileo* stated, "Through observation, experimentation, mathematics, and a great deal of creativity, Galileo made extraordinary scientific discoveries. The question was whether the rest of the world was willing, or ready, to listen." Ms. Gerber called on her students to consider the four things again. She warned them that she was going to re-read the text while they "finger count" the four. She then proceeded to guide them in a discussion around what surprised them. One student said mathematics "cause [sic] in science you usually don't do math." Anne then stated that creativity surprised her.

> Anne: Creativity because you can't really be creative when you're studying. You can't make up your own thoughts about it. It has to be real.
>
> Ms. Gerber: So keep that in mind. Think about if you agree with that. That when you're studying information and that there's no room to be creative. What did you say?
>
> Anne: Because you can't make up your own- Like if you're saying something but you don't know it, you can't say it's true.
>
> Ms. Gerber: Okay. So you all understand what she's saying?
>
> Students: Yeah
>
> Ms. Gerber: Do some of you agree with what she's saying?
>
> Students: Yeah
>
> Ms. Gerber: Do some of you disagree with what she was saying? Okay, so keep those thoughts and we'll talk about that. Thank you for sharing that.

Ms. Gerber allowed Anne to express her disbelief that creativity has a role in science, but she encouraged Anne, and all the students, to keep thinking about creativity in science.

Several minutes later, Ms. Gerber read, "This position also left me with more chances to be creative in my thinking, a trait that is important for all scientists." She followed up by modeling her own reflections and changes in her learning. "What did I just read? This is something that I've learned out of reading these books." After this prompt, there was one more explicit reference to creativity in the text, "I had to think a lot about what these observations meant, and used my creativity to generate an explanation for my observations." Even though Ms. Gerber did not pursue the discussion of creativity in science with her students, she still provided explicit guidance on how creativity is an integral role in developing scientific knowledge.

Examples of NOS references. To illustrate the type of discussions that occurred during the read-aloud sessions, I present several examples of classroom exchanges. The examples were purposely picked to represent specific types of discourse. I describe examples of naïve and informed representations of the empirical NOS and inferential NOS. I follow this with a report on the role of effective questions, and conclude by exemplifying the explicit planning of NOS as a theme.

Empirical and inferential NOS. One common theme in read-aloud instruction was teachers recruiting their expertise in English language arts instruction and using it to address NOS concepts. Teachers did this when discussing the empirical and inferential NOS. In particular, the teachers made explicit connections between the use of the terms *evidence* and *inference* in the two subjects. Teachers provided several definitions throughout the read-aloud observations for these two terms. At times these did not align perfectly with informed views of NOS, but at other times teachers successfully connected the two subjects to use the terms in a manner that approached an informed representation.

For example, during the Level III read-aloud, Ms. Jenkins asked her students the Think About It Question: How are inferences different from observations? She defined inferences as, "Sort of those things that we have to use what we already know to sort of put it together. It's not gonna be directly stated to us. We sort of have to figure it out." This aligned with all of the other teachers' definitions of inferences and is an appropriate way to initially approach the meaning of inferences in science. Ms. Maloney more directly connected inferences in science with inferences in reading during her Level II discussion.

> Okay, you're putting together basically what the authors told you and what you already know about that subject and you kind of come to a conclusion, okay? If we wanted a quick example, if you saw somebody all the time that was dressed up in shorts and a basketball t-shirt and they were always watching the Chicago Bulls, you could assume

> that maybe what would they like? [Students respond by stating basketball or the Bulls.] Putting those things together is inferences. And that's what a lot of scientists and reading is about. Where you put those things together to find an answer.

Both Ms. Jenkins' and Ms. Maloney's descriptions of inferences refer to using what we do know—in the case of science, the evidence—to draw conclusions about what we do not know. In total, Ms. Jenkins, Ms. Crawford, Ms. Gerber, and Ms. McKinley all provided students with descriptions of inferences in a similar manner.

Although this view of inferences was a good approximation of the scientific definition, it missed the component that addresses the inability to directly observe the phenomenon about which inferences are being made. In contrast, Ms. Gerber effectively led her students from considering inferences as they relate to reading instruction towards inferences in science. I provide an excerpt from her Level II discussion to illustrate this shift. In this example, she began by providing a definition that related to reading, but then extended the description to science by anchoring it in a concrete scientific example.

> Ms. Gerber: I'm gonna ask you what 'infer' means. Because lots of times in reading we talk about inferring. So did last year's teachers, we talked about it a little bit this year.
>
> Ben: Maybe like guessing?
>
> Ms. Gerber: Um, tell me more.
>
> Ben: Using information that you have.
>
> Ms. Gerber: You use information that you know and what they tell you. And tell me more. It's not like a total guess. You're on the right track. And I think you said it. You use the information you have and that they give you, and what do you do with it?
>
> Ben: Um. [Pause] You put it all together.
>
> Ms. Gerber: You put it all together and you come up with an idea, right? Yeah, right. That's what inferring is. You take some information that you have, things you know, and you come up with kind of a conclusion or a thought. So

> you can't observe gravity directly. But what they can observe and what they can piece together, they've come up with an idea.

Ms. Gerber's initial description of inferences was in line with that of reading instruction. However, by providing an example at the end of gravity, and specifying that inferences are based on constructs that are not visible (i.e., gravity), she helped make the difference between inferences in reading and inferences in science explicit.

Teachers also provided multiple examples of evidence when discussing the empirical NOS. Some were in line with informed views and some were not. Descriptions of evidence included an experiment, variables in an experiment, tools used to make observations, and already-established research. This last definition was also aligned with one use of evidence in English language arts instruction. For example, Ms. Jenkins' discussed types of evidence in response to a Think About It question in her Level II discussion. After a student suggested that results from an experiment were evidence, she stated:

> Ms. Jenkins: So we wrote down our results. Did anybody do some research before they actually started their projected? Where did you find your research, Kadesha?
>
> Kadesha: Internet.
>
> Ms. Jenkins: Internet, ok. Did that give us some evidence?

When another student questioned how scientists got evidence before the Internet, she responded with, "Do you think that it was also maybe passed between other people, as to like, he said this so I'm gonna see if that's actually true?" Discussing evidence in this way encourages her students to view scientific evidence in terms of evidence in English Language Arts, such as when they might write a research report, and not the creation of new knowledge.

In contrast there were a multitude of times when teachers provided informed descriptions of scientific evidence. For example, during her Level III discussion, Ms. Maloney asked her students the Think About It question, “How was his evidence going to support the claim that the Earth was turning?” After a student gave an incorrect response about the changing of day to night, Ms. Maloney corrected with “So his experiment here is showing evidence that nothing else had shown before. So because of this, he’s saying that the pendulum moved differently than ever before.” She explicitly referred to the movement of the pendulum as the evidence—an observation—that allowed him to claim the Earth turned.

The importance of evidence was clear throughout discussions, even if the definition of evidence was not always clear. For example, Ms. McKinley reinforced the importance of evidence during her Level III discussion. She asked her students, “How do the observations scientists make lead them to ask good questions?” Maggie responded:

Maggie:	When someone says something, then they can ask questions like how they think that theory is possible.
Ms. McKinley:	Oh good, she talks about evidence!
Abby:	Without evidence, everything would be considered true.
Ms. McKinley:	Ooh, good, I like that! She said without asking questions, everything would be considered true. And Maggie said you have to find evidence! Good. Really good thinking!

(Note that in this case it is most likely that Maggie was using the word “theory” in the colloquial sense, to mean in general an idea scientists have.) Both Maggie’s and Abby’s statements, as well as Ms. McKinley’s response, indicated that students were internalizing the importance of evidence during the read-alouds. However, the students never provided a specific definition of evidence, and so it is not possible to determine if they were using it in an informed manner or not in this instance. However, at the very least, by infusing their responses with the language of evidence, students are demonstrating at least sensitivity to, if not full understanding of, the empirical NOS.

Planning for NOS as an instructional theme. How teachers began the read-aloud sessions was important as it set the tone and guided students for what was the most important content to attend to during the readings. Most of the readings began by focusing on a component of language or literacy instruction. For example, both Ms. Jenkins and Ms. Smith began all three of their read-alouds by doing a "picture walk" with their students. This entailed the teacher flipping through the pages of the book while the students attempted to predict what the book was about. Another common strategy was to highlight text features. For example, Ms. Green began her Level II read-aloud by stating, "This one is *Galaxies, Galaxies!* by one of my favorite authors, Gail Gibbons. There's gonna be text features in here as well when we're reading this. Let's see if we can find some of those." In this way, Ms. Green highlighted the text features as being one of the main focuses of the read-aloud.

In contrast, two teachers made NOS an instructional theme by putting it at the forefront of their instruction during their Level III read-alouds. Ms. McKinley did so by manipulating the placement of a Discussion question. Discussion questions were intended to be used after the teacher read the page, to connect the NOS content with the text. In fact, every other teacher used the Discussion questions in this manner. However, Ms. McKinley began by instructing her students to consider the Discussion question prior to reading.

> I noticed last time when I read the fairy tale, when I gave you questions ahead of time you did a much better job of answering the questions. So kind of thinking about that this morning, and thinking maybe we'd have some success if I told you some things ahead of time. So when I'm reading the beginning of this, I want you to think about how did Galileo's telescope change how scientists investigated space. Okay? Let me read it one more time. How did Galileo's telescope change how scientists investigate space? So be kind of thinking about that.

She then proceeded with her reading of the text. Throughout this read-aloud session, she prompted her students with the questions before reading the page, and then returned to elicit their responses when she concluded reading the text.

Similarly, Ms. Crawford began her Level III read-aloud with a question. However, unlike Ms. McKinley, Ms. Crawford began by generating her own NOS-related question. She began her read-aloud session by telling students, “It is *Come See the Earth Turn.* Before we start, does anyone know—Think about, how do we prove, what do you think about how we prove that the Earth turns?” Throughout the study, both teachers and students used the word “prove” interchangeably with “support” or “provide evidence.” So in this way, Ms. Crawford was highlighting the role of the empirical NOS from the start of her read-aloud session. This was an effective twist on the more-common strategy of asking students to predict what they thought the text was about by instead asking them to focus on the evidence that would be described in the text. Through both types of questions, the two teachers highlighted the importance of the NOS content before the reading began and encouraged students to think about the role of NOS throughout the reading.

The pervasiveness of literature and literacy instruction. Although it is not the point of this study to describe the role of literature and literacy instruction during the read-alouds, the presence of discussion around these topics was quite pervasive throughout the study and so must be considered as an important backdrop to the NOS instruction that occurred. Every teacher in every level of intervention included substantial amounts of literature and literacy instruction in their read aloud discussions. This instruction focused on a variety of concepts, including understanding the role of certain text features, checking for comprehension, and even relating the content to spelling words or new vocabulary. An example of highlighting text features comes from Ms. Smith's Level II read-aloud. She book-ended the reading of *I, Galileo* by pointing out the presence and function of the preface at the beginning of the book and a timeline at the end. For the preface she stated, "There is a preface to this story. So it's like a little note before you read." For the timeline, she informed students, "And so the back of the book here has a timeline of Galileo and some of the things that he has helped to kind of discover and some other ideas." Throughout the read-alouds Ms. Smith and other teachers pointed out other text features including, but not limited to, pictures and their captions, glossaries and pronunciation keys, and author's notes.

Ms. Edwards focused on students' comprehension through her read-alouds. At the beginning of her Level I read-aloud she explicated told students, "So I'm gonna stop and I'm gonna make sure that you guys understand the main idea of this. Um, this story is going to be nonfiction. Okay? So even though there's some pictures in it, it actually is nonfiction." She continued by asking students, "So one of the strategies we do when we read a book that's nonfiction is we stop, and what do we do?" They quickly replied, "Summarize." Making good on her promise, Ms. Edwards asked different students to summarize each page and pushed them to revise and refine their summaries when they did not meet her standards.

Multiple times throughout the read-alouds, teachers or students identified spelling words. Ms. Crawford pointed out that the word "scorn," used in *I, Galileo,* was a spelling word. After reading that Galileo scorned tradition, she asked students, "What does that mean? That's a spelling word. What is scorn?" She then elicited students' description of scorn and provided her own as well. Ms. Crawford even had an extended dialogue about the root of the word "telegraph" during her Level III read-aloud.

Sam: Why does it have tele in it?

Ms. Crawford: Tele? Why does it have tele in it?

Gertrude:	It's like a phone, like telephone.
Ms. Crawford:	Tele means what?
Phillip:	Long distance.
Sam:	Is it a suffix?
Ms. Crawford:	It is a suffix. What is it? It's a Greek or Latin—Do you know what it means?
Phillip:	It's Latin and it means communication?
Ms. Crawford:	Distance. It tells distance. So phone is you can talk on the phone on a distance and hear someone. This is visualizing something from a distance.

Other teachers addressed similar things, like how to approach difficult to pronounce words and the use of context clues to determine a word's meaning.

Even while addressing NOS concepts, the teachers maintained a high level of literature and literacy instruction. That is, the teachers included substantial NOS instruction in the Level II and III discussions despite the inclusion of literature and literacy concepts. This is important, as it was through this instruction that teachers encouraged students' comprehension and connection across subjects. In effect, the teachers all performed high quality read-alouds. This provides further evidence that differences seen across levels in teachers' practice, and those that occurred within students to be described later, were due to the intervention and not teachers' competence at guiding read-aloud activities.

Teachers' Perceptions of the Modified Trade Books and Educative Curriculum Materials

In this section, I describe teachers' perceptions of the modified trade books and educative curriculum materials. I present the results in three sections. The first describes the teachers' perceptions of how the modified books and educative curriculum materials supported their instructional practices around NOS, including perceptions on how it impacted their own views of NOS. The second section reports how teachers perceived changes in students' views of NOS through their interactions with the intervention materials. The third compares the teachers' practices of reading aloud the intervention materials with their typical read-aloud practices. Throughout the results I include specific suggestions the teachers provided to improve the intervention materials and read-aloud practices.

Supporting instructional practices. All of the teachers had favorable views on the intervention materials support of their understanding NOS concepts and instructional practices around NOS. Taken together, these views amounted to the teachers perceiving the materials as increasing their comfort level with teaching NOS. The views varied from those of Ms. Crawford who expressed simple appreciation of the educative materials, to Ms. Gerber who described her changed views of NOS and the support for teaching NOS were transformative in her views of teaching science in general. To parse out these views, I discuss the perceptions of the intervention materials on teachers' views of NOS and teachers' preparation for the read-alouds.

Teachers' views of NOS. The teachers' perceived the intervention materials as supporting their changing views of NOS. It is important to note the difference between the teacher's *perceptions* of the change in their views of NOS and the previously described analysis of their change of views based on their pre- and post-intervention VNOS-CE questionnaire responses. The teachers' perceptions rely on their internal judgment of learning, as opposed to the external evaluation of changes as gauged by the VNOS-CE instrument. If the participating teachers perceived a change in their views based on their interaction with the intervention materials, it is likely they would also see value of the intervention materials. Because all of the teachers perceived the intervention materials as supporting their changing views of NOS, it is more likely that they will use such materials in the future. As such, it is important to note which components of the educative materials teachers viewed as being most helpful. To this point, I separated out specific references to the effectiveness of the front matter of the text from the more general comments towards the teacher's guide in its entirety.

The front matter of the educative materials was considered separately because they were written explicitly to support changing teachers' views of NOS. None of the teachers had negative views of the front matter, but two explicated neutral views. It is important to note that although their views of the front matter were neutral, their views in general remained positive. The positive views will be discussed in detail later. Recall that the front matter had two educative features directly addressing NOS: descriptions of the three targeted NOS aspects and connections between NOS and related standards. During her first interview, Ms. Edwards indicated that she skipped over the front matter and just read the supportive material embedded within the main text. This was partly guided by her lack of interest in the NGSS, as she did not regularly teach science in her class and presumably she believed it did not contain important information for guiding her instruction. At the end of the first interview, I suggested that she read the front matter before teaching her final read-aloud lesson. Upon following up with her in the second interview, she stated that she mainly focused on the connections to the CCSS-ELA, but that, "It was helpful to see how it related to the text." Furthermore, she explained that prior to reading the front matter, she "didn't exactly know what nature of science was" but the front matter helped provide her with a label for the concepts that were being made explicit in the other books (i.e., NOS). Ms. Edwards' response to the front matter illustrated the need for teachers to see a direct benefit to their teaching practice in the materials that they use to prepare for instruction.

It is also possible that teachers did not perceive value in the front matter because they did not understand fully the purpose of the front matter in an *educative* teacher's guide compared to the typical teacher's guide with which teachers are familiar. In this intervention, the educative teachers' guide provided information to support teachers' understanding of NOS. When asked about her perceptions of the front matter, Ms. McKinley stated,

> I don't know that it helped the lesson go better. It's helpful if I were reporting out what I was covering or lesson planning maybe, but as far as the discussion went, I think it probably would have gone the same way.

Ms. McKinley focused on the role of the teacher's guide for supporting pedagogical decisions. However, the front matter in this intervention was written to support teachers' understanding of NOS. The difference between the educative teacher's guide and a typical teacher's guide was never explicitly described to the teachers in this intervention. In fact, the similarities between the two were highlighted instead, as a way to encourage teacher's to use the teacher's guide in a manner in line with their usual teaching practice.

Contrary to the neutral opinions of the front matter from Ms. Edwards and Ms. McKinley, five teachers (i.e., Ms. Gerber, Ms. Crawford, Ms. Jenkins, Ms. Smith, and Ms. Green) explicitly described positive views of the front matter in supporting their understanding of NOS content. Ms. Maloney was the only teacher that did not comment on her views of the front matter.

In direct contrast to Ms. Edwards' views, Ms. Smith remarked on the benefits of having the standards addressed in the front matter, stating, "It was helpful to . . . have the standards so we could see where the questions were stemming from and what standard they were trying to hit." It is important to point out the difference between Ms. Smiths' and Ms. Edwards' view of the role of standards. Interestingly, neither Ms. Edwards nor Ms. Smith taught science to their students. Although neither of them was very familiar with the NGSS, unlike Ms. Edwards who remained uninformed about the standards, Ms. Smith indicated it was important to understand these standards. However, Ms. Smith also described the full standards as being “wordy and specific,” which make them difficult to understand. In contrast, the connections described in the teacher’s guide provided a parsed down view of the standards that related directly to her instruction.

Other positive views of the front matter in supporting teacher’s understanding of NOS ranged from mildly positive to transformative. For example, Ms. Crawford said simply, “I liked that” because it helped her make connections between science and other units. Similarly, Ms. Jenkins indicating that the front matter helped clarify some things.

In contrast to the comments specific to the front matter, it was more common for the teachers to make claims about the effect of the instructional materials on their views of NOS in a holistic manner. These comments were consistently positive across all teachers. Ms. Maloney, for example said, “After reading that book yesterday, I learned a lot about science too! You have to have inferencing. You have to put the clues together.” She continued to describe how her current science curriculum addresses NOS in an implicit manner. “We don’t talk about inferencing or putting those clues together at all. It’s supposed to be already understood.” By stating that it’s *supposed* to be already understood, Ms. Maloney was perhaps implying that it was not actually understood, in contrast with the intervention materials. Based on these comments it was not clear which part of the intervention materials had the most impact on supporting their changing views of NOS, only that there was a perceived change in toward a more informed view of NOS.

The changes in Ms. Gerber's views of NOS and the role of NOS in instructional practice deserve particular attention due to the extreme nature of the change and the excitement that accompanied her change in views. Ms. Gerber described "an aha moment" that occurred to her during her participation in this study. The level of emotion Ms. Gerber was feeling does not translate well to paper, but was apparent in her interview. The excitement was almost tangible as it bubbled out of her while she discussed her changed views. Ms. Gerber went from feeling very constrained in her view of science, a view that appeared almost uncomfortable to her but ingrained throughout her previous experience with science, to an apparent liberation of her views. Specifically, she stated that she "had never looked at [science] this way" because she was "very tunnel visioned." She continued,

> I think most of my science learning was from a book and what the book said and regurgitating information. We did a few experiments and this and that, but it was mostly just reading and learning facts and definitions. And basically learning what other scientists already know about science and who they are and what they did.

Most science textbooks do not describe NOS in an effective manner (e.g., Abd-El-Khalick, Waters, & Le, 2008; Abd-El-Khalick et al., accepted) and so perhaps it was not surprising that Ms. Gerber did not feel supported in viewing science in a manner in line with informed views of NOS.

In contrast, after interacting with the intervention materials, Ms. Gerber perceived a change in her views of NOS and scientists' work. Specifically, she stated,

> I think it made me understand a lot more of how with the same data you can actually interpret it different or get different answers. And I never thought about it, that their experiment might be the same but their question might be different. Like they're looking for different things . . . I guess I just never thought that they're creative or thinking of anything on their own. I thought they're always rehashing what everyone else is doing. Like all they do is try to prove or disprove what's already out there and keep working on the same things over and over. I guess I had a very narrow thought about what they did.

The intervention was clearly transformative in Ms. Gerber's views of NOS and the importance of teaching NOS. Indeed, she explicitly stated, "[the intervention] gave me a new enthusiasm for [teaching science] that's been lacking for a long time." This, taken in context of the changes of her practice between Levels II and III, indicate that the teacher's guide was transformative of her teaching experience.

Although some teachers, such as Ms. Jenkins or Ms. Edwards, felt that the teacher's guide was beneficial because it gave a name for the concepts that the books were supporting, Ms. Gerber appeared to have a deeper change in views. Throughout the study, Ms. Gerber struggled with how she thought science was supposed to be taught, based on her previous experience with science instruction, and how she wanted to teach it. The teacher's guide provided her with the connections to standards, terminology, and the explicit content that aligned with her views of science. In effect, interacting with the teacher's guide legitimized her beliefs and solidified her views of NOS.

Teachers' instructional practice. Throughout the interviews, the teachers consistently indicated the most favorable views toward the intervention materials in supporting changes in their instructional practices. Teachers' responses were grouped into three themes: providing an overarching focus to the read-aloud, planning effective questions, and supporting teachers in leading effective discussions. Each will be described separately. It is important to keep in mind that the interviews were open-ended, and as such not every teacher addressed every theme as they were not pre-planned prior to the interviews. A lack of a response was not necessarily indicative of a negative view, but instead it might be an artifact of the interview strategy.

Providing an overarching focus. Ms. Crawford commented on how the teacher's guide was effective at providing an overarching focus for the third read-aloud that was not present in the first two read-aloud sessions. Ms. Crawford described this as having more guidance and knowing "what the objective was, the key points to get out of [the read-alouds]." This change in perception aligned with the change in her questioning strategy, as she began her instruction with a NOS-related question, indicating to her students that NOS would be a central theme of the discussion.

Planning effective questions. Both Ms. Jenkins and Ms. Maloney made claims about the effectiveness of the questions in the teacher's guides. Ms. Maloney described how in the first read-aloud, without the questions she did not know where to insert questions and instead asked herself, "Well, where are my questions supposed to go?" Similarly, Ms. Jenkins stated that she "liked having the questions already there." Specifically, she described how typically during read-alouds she would make a mental note or have a sticky note to support her questioning but would lose track of the question in the moment of reading. In contrast, with the teacher's guide, "it helped having those guiding questions just so that way I had a starting point" and did not have to think of appropriate questions on her own. Additionally, during her read-alouds Ms. Jenkins demonstrated a reliance on the physical copy of the teacher's guide to support her questioning strategies. In the third read-aloud, she projected the modified text on the document camera so that the students could clearly see the pictures and kept the teacher's guide in her hands to read. In this manner, she did not have to keep track of the questions she had pre-planned because they were already in her hands. It is interesting to note, however, that Ms. Jenkins was one of the few teachers who did not ask all of the Discussion questions during the third read-aloud, despite having the teacher's guide in front of her.

Teachers appeared to be more engaged with the Discussion questions in the teacher's guide than the "Think About It" questions in the modified text. For example, Ms. McKinley noted that when they were short on time, she preferred using the discussion questions than the Think About It questions. This was reflected in her Level III data, as she skipped three of the Think About It questions, but none of the Discussion questions. Ms. McKinley explained that her class:

> Responds better to deeper thinking questions like that and they really like to feed off each other and almost battle. They love those heated debates and so just reading through I thought those were questions that I thought they'd be most interested in and it did seem to work.

She continued to explain that because the discussion questions were already planned in the text, the discourse seemed more "seamless."

Support in leading effective discussions. The most consistently stated perception teachers had of the instructional materials was the benefit of the teacher's guide in leading effective discussions. The teachers indicated that the increased content knowledge, described previously, and the in-the-moment support from the teacher's guide allowed them to more effectively structure their instruction. Ms. Gerber, Ms. Edwards, and Ms. Jenkins all spoke directly to this.

Perhaps because she had the most transformative view of NOS, Ms. Gerber was also the most emphatic about the additional support the educative materials provided in guiding discussions. She described both shying away from difficult discussions in the second read-aloud and increased confidence in tackling difficult questions in the third read-aloud. Specifically, she stated that:

> In the one that just had the guided questions, I didn't ask all the questions if I didn't think I knew how to respond to their answers. I saw they were there and they were good, but I skipped over some if I thought I wasn't equipped enough to respond to them or if it was a blatant error. I'm always worried about that. I'm not worried about getting them to think about things, but I'm really worried about teaching them something incorrect. And that would be the one thing they remember!

The worry that students would learn something incorrect was specific to Ms. Gerber's science instruction. She perceived science as being a higher stakes subject than the others that she taught. She explained:

> I don't open myself up to teaching [science] like I might teach reading or something like that. I don't know, I just think they're going to be questions about it later on or it's things that they really definitely need to understand and understand correctly. And I think it would be harder for them to unlearn!

Ms. Gerber saw having sufficient content knowledge to lead deep discussions as being imperative. Without this content knowledge, she felt uncomfortable with her own abilities and therefore unwilling to lead students through complex discussions.

In contrast, with the support, she described much more confidence in leading these tricky discussions. She specified that although she was able to come up with deeper level questions, she did not know what the answers were:

> I didn't always know if their answers were right or I didn't have the science background knowledge. But with the guided book, I had read the teacher's notes and so when I asked, I knew kind of what I was supposed to be looking for. Or if they answered something that wasn't that, I could comment on that was a good idea and redirect to say if it was correct or incorrect.

It was not only the questions that provided Ms. Gerber confidence, but the accompanying possible student responses and rationale for the responses that bolstered her ability to engage with the materials. The contrast between her lack of confidence in the first two read-alouds and the increased comfort in the third read-aloud was obvious.

Not only did Ms. Gerber perceive a difference in her confidence, but she also perceived a difference in how she enacted the instruction. Referring to a debate about the role of creativity in science, she explained, "I think I used some examples in the book and the previous book . . . I just got *convinced* [emphasis in original] there's creativity in it, and some of my questions were guiding and leading them towards seeing the creativity." Because she had an increased content knowledge for NOS and support for this knowledge in the books, she welcomed the debate and was able to mediate it effectively. Through this experience, she was able to reflect on the previous readings and identify instances in which she missed opportunities to address creativity:

> I think in one of the earlier books I didn't even catch that the guy was being creative when he learned something by observation until I had read the other book and had more background knowledge and had somebody pointing out the creativity.

This acknowledgement directly relates to the issue of needing explicit, planned, instruction in NOS. Ms. Gerber held an informed view of the creative NOS prior to the intervention, but was not able to act on this in her instruction. Once the curriculum materials supported this connection, she effectively included the concept in her discussion about the book.

Similarly, although perhaps at a different scale, Ms. Edwards described having difficulty with answering students' questions if she did not have a deep content knowledge to support her answers. During the first and second read-alouds she described not wanting to "go into depth about their questions because I wasn't really confident" and so she just accepted all of the students' answers without guiding them toward an informed view. In contrast, she felt the questions with the teacher's guide "were more targeted and there was an actual answer they're trying to get." This was evident in her use of the Think-About-It questions, which related directly to the text. In contrast, Ms. Edwards skipped all of the Discussion questions, which related to the NOS concepts on a more general scale. It is possible Ms. Edwards that the teacher's guide provided some support in answering questions, but Ms. Edwards would have benefited from even more support for the higher-level Discussion questions. Additionally, after floundering to provide a real-life example of making inferences during her second read-aloud, she described the higher level of confidence in completing this same task during the third read-aloud due to better preparation from the teacher's guide.

Supporting students' views. In addition to describing their perceptions of changes in their own views of NOS, the teachers described perceptions of students' learning of NOS. All of the teachers felt that the students could identify at least some of the NOS content after participating in the three read-alouds. When asked what main ideas students took away, Ms. Crawford described the role of creativity in science. She said students noticed "that because of what is in our world is because of scientists. It didn't just happen. Scientists actually created the knowledge."

Ms. Edwards was a little more skeptical, but still had positive perceptions. When asked what students learned, she said:

> They learned a little but I think if I had understood what NOS was from the first, I could have emphasized it throughout the whole unit so they would walk away with more knowledge about what NOS is. But I do think they learned some information about scientists and creativity and evidence.

Indeed, the creative and empirical NOS were cited most often as being understood by students. In general, Ms. Edwards felt her students' understanding was "very knowledge level," presumably referring to a Bloom's Taxonomy-type hierarchy of learning. This is unsurprising, as the students only engaged in the three read-aloud discussions and did not have access to the additional supportive materials in the teacher's guide.

In line with Ms. Edwards' views that students only understood the creative and empirical NOS, Ms. Jenkins described students' difficulty with the inferential NOS. "The word inferencing freaks them out. That's why every time when that word came out, I was like, 'let me explain what infer means.'" It is important to note that Ms. Edwards appeared to be talking about drawing inferences in the context of reading. She continued to describe inferences as being equivalent to forming conclusions to a question. Given that she exhibited difficulty in understanding the inferential NOS based on her VNOS-CE questionnaires, it is predictable that she would not perceive her students as understanding it as well.

In addition to perceiving that students learned at least some NOS content, Ms. Gerber and Ms. McKinley also described a newfound view of the importance of students' understanding NOS. Ms. Gerber stated that she believed it was important to understand NOS because "it's just given me a deeper understanding of science and where it comes from. And why things are different. I never looked at it this way!" She continued to explain:

> I always thought of scientists as very serious and they always knew what they were doing and were very methodical. And they knew what they were trying to prove or they knew what they should be doing. And I never really looked that a scientists had their own thoughts and their own ways and curiosities."

She felt that it was important to convey these ideas to her students, as she had become more convinced herself that this was how science actually happened.

Alignment with typical read-aloud practices. All of the teachers described some alignment of the intervention read-alouds with their typical read-aloud practices. This came mainly from descriptions of how they prepared for the read-aloud sessions. Every teacher who addressed this question specified that they read through the book, identify main themes, and planned guiding questions to ask the students. They indicated that they prepared in this manner for the first read-aloud session. However, in the second and third session, some teachers noticed that the work of identifying the main themes and planning guiding questions was already done for them. As described above, the teachers noted that the teacher's guide made explicit the NOS themes and the guiding questions were perceived as being helpful. Specifically, Ms. McKinley described how she would ask similar questions in her own read-alouds as those that were provided in the teacher's guide. Ms. Edwards also addressed how she spent more time in the third read-aloud "reading the questions ahead of time and seeing what is expected versus trying to look back and figure out what the answer would be" in the second read-aloud, that did not include a teacher's guide. However, in general, the questioning practices aligned with what teachers typically expected of a read-aloud.

Some teachers did note differences between the intervention read-alouds and their typical teaching practices. In particular, Ms. Smith noted that she typically reads fiction out loud, while the intervention book was nonfiction. Similarly, Ms. Crawford pointed out the students' perceived comfort with narratives as a reason for using them as read-alouds instead of non-narrative books, such as *Galaxies, Galaxies*! Additionally, all of the teachers pointed out differences between guided reading in small groups and the whole-class intervention read-alouds. Ms. Jenkins stated,

> In whole groups it's difficult because there are so many different levels of science in what they know or don't know. Some dominate the conversation and others have way-off answers. It's not that they're not interested. It's just too much for them to take in all at once.

She went on to discuss her preference for using trade books with smaller groups, as opposed to the whole class, so that she could differentiate the instruction more.

In addition to being difficult to differentiate instruction during whole class discussion, teachers cited difficulty in completing an entire read-aloud during one session. Ms. Edwards described rushing at the end. "I remember it went really long so I was rushing at the end [snapping her fingers in a fast, repetitive pattern]. Okay, we need to move on!" She continued by saying she would rather split the reading into two days. Ms. McKinley recounted a similar feeling of being rushed. However, she stated that she would prefer to read the books through once in the first sitting so students could understand the overall structure and flow of the book and then read it through a second time, perhaps the next day, to allow for more in-depth questioning. Despite the difficulty in completing the read-aloud during one session, neither teacher indicated that it would stop them from utilizing such a book in their own instruction.

Indeed, all of the teachers described the books themselves as being similar to ones they would pick for instruction on the topic. When she saw the book *Galaxies, Galaxies!* Ms. Green smiled and declared her love of Gail Gibbons' books. Ms. Crawford expressed her interest in all of the books, but in particular *Come See the Earth Turn!* Additionally, she felt that "the kids were very interested." Finally, while the teachers felt that the reading level might have been challenging for students to read on their own, they felt that it was not a problem during a read-aloud. In particular, Ms. Smith stated that when she chooses books for read alouds, she "typically shoots for the upper end of your spectrum in the classroom and so I do have some students that would be at about that level so I think that was okay to do as a read aloud at that level." Choosing books of an appropriate reading level is specifically of a concern with science texts as they tend to be written at a higher reading level than their intended interest level, as was the case with all three of the intervention books. As such, teachers' perceptions of the books being an appropriate reading level is important as it allows them to see the intervention as a possible to perform in their own classrooms.

Student Interaction with NOS Concepts

In this section I present data related to students' interaction with the NOS concepts. The results are divided into three parts. The first considers the free response data that was collected from every student in every class. The second part investigates more closely the students who were targeted to participate in more in-depth interviews pre- and post-intervention. These interviews allowed for examination of individual students' changes in NOS conceptions. The first two parts provide snapshots of students' views at various points in the study. To provide a more holistic view, the section closes with the presentation of a single case that tracks the changes in one student's view of the creative NOS through multiple sources of data to illustrate how one student interacted with and was influenced by the intervention materials.

Free responses. Every student who was present for the read-alouds was instructed to complete a free response sheet after the reading. These responses were then analyzed for any references the students made to the targeted aspects of NOS. There was quite a bit of variety in what students wrote, and some of the responses were quite amusing. For example, after listening to her teacher read *I, Galileo*, one student wrote that she decided Galileo should be named Clark. Similarly, a student in Ms. Edwards' class inexplicably listed "Caillou"[5] as his only response to the story about Galileo. Despite the occasional off-topic comment, the vast majority of free response sheets were related to the text. However, throughout the free response tasks, in all classes, many students seemed quite reluctant to commit anything to paper. "How much do I have to write?" was a frequent question asked during this time. Even with the offer to transcribe students' thoughts onto paper, many students were disinclined to write much and only filled out a few lines. Notwithstanding the lack of in-depth responses, some clear patterns were visible in the free response data. In the following, I first describe patterns in students' free response data. Then I describe common alternative themes in student responses.

Patterns in free response data. The most obvious pattern is the small fraction of responses that pertained directly to any of the targeted aspects of NOS. Out of the 470 written responses that were collected across all teachers throughout all read-aloud sessions, 22 students made a total of 38 explicit references to the empirical, inferential, or creative NOS (8 students made 2 references each). These references were distributed across every teacher and every session (see Table 13). It is important to keep in mind that there was a different number of

[5] Caillou is a cartoon character who is featured in the eponymous educational show aimed at toddlers.

students in each class and, even within classes, the number of students between sessions differed due to student absences.

Table 13

Distribution of Responses for Targeted NOS Aspects

Teacher	Level I			Level II			Level III		
	Empirical	Inferential	Creative	Empirical	Inferential	Creative	Empirical	Inferential	Creative
Gerber	1	0	0	0	0	0	2	0	2
Maloney	0	0	0	1	0	0	1	1	0
McKinley	4	0	0	1	0	1	2	0	0
Crawford	2	0	0	2	0	0	2	1	0
Edwards	0	0	0	0	0	0	1	0	0
Jenkins	2	0	0	3	1	1	0	0	0
Smith	2	0	0	1	0	0	1	0	0
Green	0	0	0	0	0	0	3	0	0
TOTAL	11	0	0	8	1	2	12	2	2

Aggregating references from all teachers and levels of intervention showed that the majority related to the empirical NOS (see Figure 17). In fact, in Level I, the empirical NOS was the only aspect upon which students commented. Although students included references to the inferential and creative NOS in the second and third free response task, the empirical NOS remained the dominant aspect across all levels (see Figure 18).

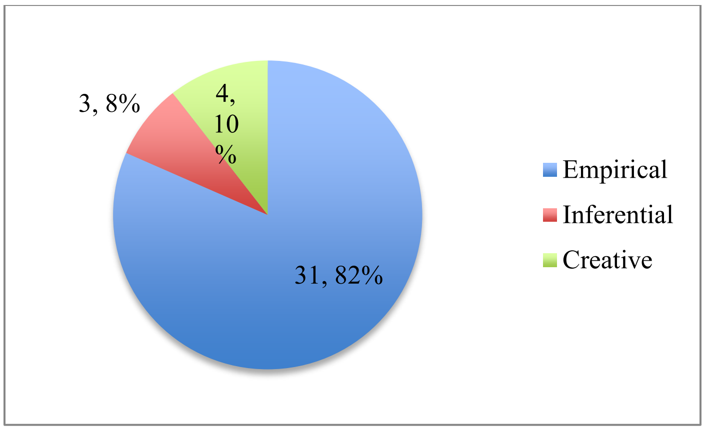

Figure 17. Total explicit NOS references in student free responses, aggregated across teachers and levels of intervention.

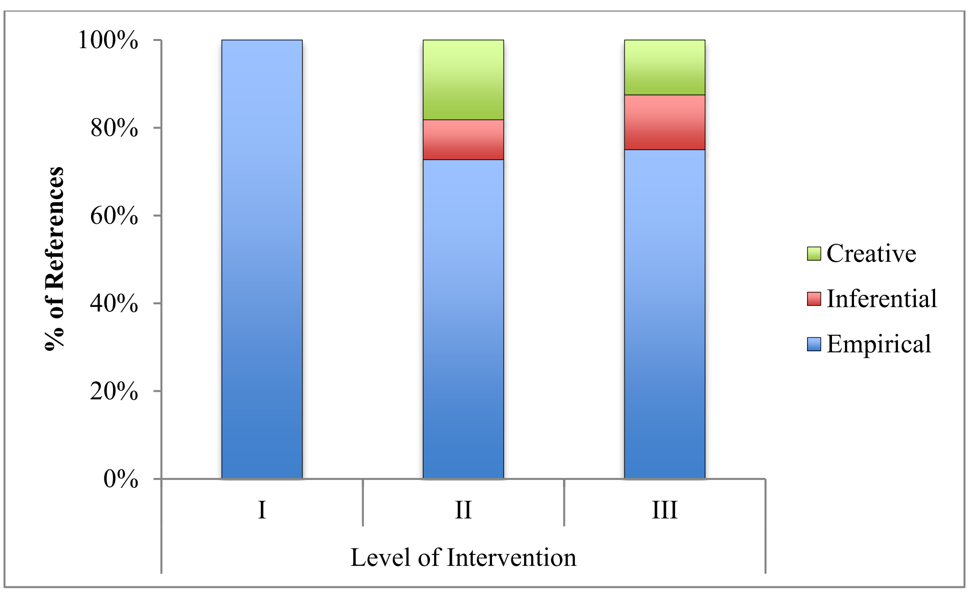

Figure 18. Percentage of NOS references in student free responses in each level of intervention.

Based on these patterns, it seems that students are more likely to discern and speak to the empirical NOS than the creative or inferential NOS. However, even with the greater number of references to the empirical NOS compared with the creative or inferential, the number of students who identified anything relevant to the role of evidence in the readings was quite low compared to the total number of students who submitted response sheets. To illustrate, the percentage of students referencing each aspect of NOS was aggregated across teachers and calculated (see Table 14). Aggregating across teachers produced a more meaningful representation, as the number of references in each class was so small. In fact, the percentage of students who made references to the any aspect during any level of intervention never exceeded 8%. Although being led in discussions around the creative and inferential NOS appeared to have an impact on a few students during the second and third read-aloud sessions, the number (and, likewise, the percentage) of students who identified relevant ideas still remained quite low. The low number of responses may be attributed to students not picking up on any of the ideas. However, it is very possible that the nature of the task, and the reluctance to commit ideas to paper, also played a role. That is, students may have considered NOS but simply did not write down anything related to NOS.

Table 14

Percentage of NOS References Aggregated Across Teachers

Aspect	Level I (N = 161)	Level II (N = 156)	Level III (N = 153)
Empirical	7%	5%	8%
Inferential	0%	<1%	1%
Creative	0%	1%	1%

Alternative responses. To illustrate the reluctance to comment on the substance of the read-alouds or discussions, I identified three major alternative themes in student responses.

These alternative themes were considered related to NOS, but did not represent informed views of NOS. These consisted of mentioning inventions, listing scientific “facts” from the books, or including an opinion about the book (e.g., “This book was my favorite”). Two things should be noted about this analysis. The first is that although the development of inventions is related to the creative NOS, none of the students explicitly discussed the use of the inventions for developing of scientific knowledge. Instead, references remained contextually isolated, such as one made by a student in Ms. Green’s class who wrote “2 people made 2 kinds of telescopes.” To be coded as relating to the creative NOS, he would have had to include some explanation about how telescopes are used to gather evidence or make new discoveries. The second thing to note is that although student responses were coded for listing “facts” about the books, they were not evaluated for the correctness of those facts or the alignment of facts with information in the text. Despite the fact that students had access to the books during the free response task, most students relied on memory and may have mis-recalled the information in the text. Although students should know scientific facts, it is undesirable and antithetical to an informed view of NOS to see science as simply a listing of facts. Viewing science as only facts ignores the human aspect of creating scientific knowledge.

Similar to the NOS references, the references to each of the alternative themes were aggregated across teachers so that the percentage of students making the references could be calculated (see Table 15). Even though these were the most common responses, the highest percentage of students responding to any theme was only 43%. The paucity of students responding directly about the science content may be indicative of students’ hesitancy to record responses in general.

Table 15

Alternative Themes

Theme	Level I (N = 161)	Level II (N = 156)	Level III (N = 153)
Inventions	17%	14%	20%
Scientific “facts”	43%	28%	19%
Opinions	9%	6%	12%

One may wonder what students wrote if their responses were not related to the targeted NOS content or the identified alternative themes. Many of the students wrote questions and/or opinions about the content of the book. These responses were related to the text, but not the *science content* of the text. For example, after listening to *Come See the Earth Turn,* one student in Ms. Edwards’ class queried, “If he was a surgen [sic] would he keep his job?” This question related to the narrative of the text because it described Leon Foucault’s failed attempt to become a surgeon. However it did not relate to he provided evidence that the Earth spins on its axis. Similarly, several students expressed dismay at Galileo suffering under house arrest. For example, one student in Ms. Crawford’s class wrote, “People treated him unfairly,” in reference to Galileo. Although this clearly related to the narrative, it did not directly relate to any science content in the narrative and was not useful for elucidating students’ views on the targeted aspects of NOS.[6]

Student interviews. To better track how students interacted with the NOS concepts, and how these interactions impacted their views of the targeted aspects, three students from each class were interviewed before and after the intervention. Students in every class except Ms. Edwards’ class were available to be interviewed two times. All three of Ms. Edwards’ students were not in class on the scheduled post-interview day, and so they are not included in the

[6] It should be noted that comments about Galileo’s house arrest may relate to the sociocultural NOS, an important NOS concept, but because this was not a targeted aspect, it was not coded as such in this study.

following analyses. I will first present an overview of the changes in students' NOS profiles and then discuss alternative views to those in the reform documents.

Changes in students' profiles. Similar to the profiles generated from the teachers' VNOS-CE questionnaires, student interview responses were used to generate profiles on the targeted three aspects. Changes in each student's views are presented in Table 16. It should be noted that a large number of students had profiles including *Silent* codes. Some students were quite reluctant or shy to answer questions during the interview, despite assenting to participation. For example, Geoff in Ms. Gerber's class was coded as being silent in all three aspects of his second interview. Although his second interview lasted just 9 min and 50 sec, he managed to respond with "I don't know" 11 times. During this interview his classmates were preparing for recess and Geoff was clearly anxious to join them. As such, a code of silent may not indicate that a student does not have any views of the relevant aspect, but that his or her response may have been influenced by an outside factor.

Table 16

Students' Pre- and Post-Intervention NOS Profiles

		Empirical		Inferential		Creative	
Student	Teacher	Pre	Post	Pre	Post	Pre	Post
Anne	Gerber	P	I	S	I	N	P
Geoff	Gerber	P	S	S	S	P	S
Leo	Gerber	P	P	P	P	N	P
Craig	Maloney	N	N	P	N	P	P
John	Maloney	N	P	S	P	N	N
Alice	Maloney	P	P	S	P	P	P
Bobby	McKinley	P	P	P	P	N	N
Bailey	McKinley	P	I	P	I	N	N
Abby	McKinley	P	P	S	I	P	P

(continued)

Table 16 (continued)

Student	Teacher	Empirical		Inferential		Creative	
		Pre	Post	Pre	Post	Pre	Post
Maya	Crawford	N	I	N	N	P	P
Steve	Crawford	N	N	N	N	P	S
Harold	Crawford	P	P	P	S	P	P
Kadesha	Jenkins	N	I	P	P	P	S
Stephanie	Jenkins	P	P	S	S	P	P
Dave	Jenkins	P	P	P	S	S	S
Jackson	Smith	P	I	N	P	P	S
Desiree	Smith	P	P	S	S	P	P
Emma	Smith	P	P	I	I	P	P
Jordyn	Green	P	P	S	S	N	N
Lily	Green	P	P	P	S	P	P
Mason	Green	P	P	N	P	N	N

Note. I = Informed, P = Partially Informed, N = Naïve, S = Silent. Light shading indicates gains from pre- to post-intervention; Dark shading indicates losses.

Table 17 shows the changes in each aspect, aggregated across all students. (Note: Due to rounding error, the Empirical row does not add to 100%.) For each aspect, the majority of students made no changes in their views of NOS. This is perhaps unsurprising, as students were exposed to, at most, the three read-aloud sessions and did not have access to the educative teachers' guide. Indeed, some students were absent for one or more of the sessions and so were not exposed to the full impact of the intervention. For example, Mason was absent for the second read-aloud session and so was only present for one session of the modified text.

Table 17

Changes in Students' Views for Each Targeted Aspect

Aspect	No change	Desired change	Undesired change	Change to silent
Empirical	14 (67%)	6 (29%)	0 (0%)	1 (5%)
Inferential	10 (48%)	7 (33%)	1 (5%)	3 (14%)
Creative	15 (71%)	2 (10%)	0 (0%)	4 (19%)

The most common change was in the desired direction. At least one student in every class made desired changes in their views of NOS. It was more common for students to make changes in the empirical and inferential NOS than the creative NOS. In fact, the creative NOS was the only targeted aspect for which no student indicated an informed view. These results mirror those of the teachers, in that the creative NOS was the most resistant to change.

Interestingly, the inferential NOS was the aspect that also showed an undesired change in one student's view. Craig changed from a partially informed view in his initial interview to a naïve view in his second interview. Although it is possible that this response indicates an actual change in his view, it is more likely that his views are still forming and as such, he may hold a mixed view but the post-intervention interview only captured the naïve component. To illustrate, in his initial interview, Craig indicated a mixed view of the inferential NOS by stating that scientists could use their logic when they see the effects of a black hole. He described how scientists might see a hole appear in the clouds that could indicate a black hole, presumably sucking up the clouds. Although description of clouds in space is not accurate, the underlying idea that scientists could see a change caused by a black hole, but not the actual black hole, is in line with the informed view of the inferential NOS. However, after describing how scientists must need direct photographic or video evidence of a black hole, he stated that scientists cannot be certain of a black hole's existence because they have no direct proof. This naïve view of the inferential NOS is in contrast to his informed statement. In contrast, in his second interview, Craig did not indicate any way that scientists could see the effects of the black hole. Instead he stated that scientists must see a picture of the black hole to know it exists. Additionally, he made an explicitly naïve reference to the inferential NOS when discussing how scientists develop knowledge. He stated,

> I honestly don't know what they write for dinosaurs because no one was alive back then, only cavemen. And maybe they were scientists somehow and then it was a generation where they kept on writing notes where they died. Kept on writing notes until today.

In this way he was indicating that scientists must have direct observational evidence of events to understand how they occurred, an idea that is not in line with the desired views of NOS.

Alternative views. Although the interviews indicated that participating in the read-aloud sessions provided students with at least the possibility of impacting their views of NOS, many students still held alternative views to those presented in the intervention materials. The prevalence and persistence of these alternative views demonstrates the tenacity of some ideas. Specific alternative views for each of the targeted aspects are presented next.

Empirical NOS. The empirical NOS had the most variety of alternative views. Altogether, students described six different ideas relevant to the empirical NOS. Students most commonly described alternative view was evident when answering the question "What is evidence?" It is important to note that what counts as evidence may vary depending on the discipline. However, the question was followed with several questions probing specifically about the use of evidence in science, such as "What kind of evidence do scientists use?" This provided students with an opportunity to frame the role of evidence in relation to science specifically. And indeed several students did identify relevant types of evidence. However, their initial responses did not revolve around scientific evidence, and so their alternative views must be considered.

The most common response was that evidence is something you find in a text or on the computer. In total, 14 of the interviewed students indicated that evidence related to information in the text, which is consistent with the aforementioned teachers' reference to evidence as textual information when viewed from a literary perspective. The students were distributed across all of the classes except Ms. Gerbers' class. The students' responses were in line with the teachers' responses, as several also made reference to evidence in reading during their interviews. For example, Ms. McKinley stated, “I definitely think evidence is something that is fresh in their brains. They’re always thinking because [the teachers are] always bringing it up.” When probed as to when she would discuss evidence, she explained that they discussed evidence during reading. She continued to state, “I don’t know that because our day is so intermixed and interdisciplinary. I’m not sure they knew [the read-aloud] was even a science lesson.” Although one of the benefits of elementary instruction is that it allows for instruction across disciplines, an idea that is supported by this very dissertation, the conflation between scientific evidence and evidence in other disciplines is one that must be directly addressed in instruction so that students are able to determine the difference between the two.

Additional common conceptions of evidence included clues in a crime scene, presented by five students, including those in Ms. Gerber’s class, and something that scientists “just know,” presented by three students. The idea that scientists “just know” scientific knowledge is troublesome, as it portrays scientists as being exceptionally smart or driven. For example, Kadesha in Ms. Jenkins class, described scientists as geniuses. For example, Aaliyah in Ms. Edwards’ class described a fellow student who was very interested in science as being a genius. When asked if all scientists are geniuses, she stated, “Kind of. Yeah.”

Additional representations of evidence included a conflation of evidence with conclusions, written evidence in math problems, and evidence as the materials for building inventions. Each of these representations was provided by one student.

Creative NOS. Students most directly demonstrated their views of the creative NOS when answering the question, “Do you think that scientists use their creativity or imagination in their investigations?” The most common response related to the creative NOS was that scientists are creative when they develop new inventions or come up with innovated ways to solve a problem. In other words, scientists are creative when they demonstrate ingenuity. Eleven students described this type of creativity. Although holding this view of the creative NOS is not counter to the informed view, it is not a complete view as it ignores the role of creativity in generating explanations. As such, it is detrimental to students' understanding when this view *replaces* the more informed view and is a positive, transitional view.

Students also demonstrated the naïve views that scientist are not creative because they cannot make up data. For example, when asked if scientists are creative, Bailey from Ms. McKinley's class explained, "I don't think they'd use their imagination to write down what was true because then they'd be writing down stuff that isn't a fact." For these students, creativity only had a role in determining how to investigate a question, but then it must take a back seat as the data answered the question on its own. This view of the creative NOS ignores the role of scientists in interpreting the data and coming up with explanations for the data.

Inferential NOS. Students described two alternative views to the inferential NOS. The first was that there is no role for inferences in science. That is, without direct empirical evidence, scientists cannot make any scientific claims about scientific constructs. This was in line with Craig's view, as described above. The other alternative view that students made was that scientists cannot know about past experiences because only God knows. Two students described this view when explaining if scientists could ever determine the origin of the moon. For example, in his first interview Craig in Ms. Maloney's class stated, "There's no proof that either of them happened! Because God just may have just put it there. Because God made everything." Kadesha in Ms. Jenkins' class provided a similar response in her first interview, indicating that scientists cannot know because of the role God played in the creation of the universe. Interestingly, neither student mentioned God in their second interview.

A case study of one student's interaction with NOS. In this section, I consider how a combined view of the free response data, interview responses, and observation data from the read-alouds could illustrate how one student wrestled with the NOS concepts addressed in the study. This case is not meant to be representative of all students, but instead is used to connect data from the different measure to illustrate how one student wrestled with, and subsequently internalized, new views of NOS concepts across the entire intervention. The case centers on Anne, a student from Ms. Gerber's class. Although Anne made gains in all three targeted aspects, the case focuses on her views of the creative NOS. This was the aspect about which Anne was most vocal in the read-aloud discussions. Admittedly it is possible, and perhaps even probable given the changes in her views, that Anne wrestled similarly with the other aspects. However, the lack of observation evidence limits the description of these struggles.

In her initial interview, Anne held naïve views of the creative NOS. When asked if scientists could be creative, she stated, "Not really. Because they can't make up an answer for this. So if any question, they don't know the answer, they can't just be like I'm going to guess it's so and so." This is a naïve view of the creative NOS, as it ignores the role that creativity plays in all aspects of scientific investigations, including analyzing data and developing explanations from the data.

Evidence of Anne's struggle with the creative NOS comes from the third read-aloud. Recall that during the third read-aloud session as she read *I, Galileo*, Ms. Gerber engaged students in a discussion about creativity. In particular, she prompted students to consider a portion of the text that stated, "Through observation, experimentation, mathematics, and a great deal of creativity, Galileo made extraordinary scientific discoveries." She then asked students if anything surprised them. Anne responded with, "Creativity because when you're studying stuff, you can't make up your own thoughts about it, like it has to be real thoughts." She was openly stating her unease with the content of the book. Although Ms. Gerber did not address the issue further at the moment, she encouraged students to keep the question in mind. Anne did indeed consider this question, as evidenced by her writing "Are scientists really creative?" on her free response sheet.

In her post-intervention interview, Anne softens her view about creativity in science a bit. Instead of a solid no to the question about creativity, Anne responded with a less-definitive "Half and half." While she was still adamant that "They can't use creativity to say something's true," she modified her initial response to include the use of creativity in designing experiments. She explained how in the book Galileo dropped two cannonballs from the Leaning Tower of Pisa, although she did not remember the word for cannonballs or the name of the Tower, to determine the effect of gravity was the same on each. She concluded by stating, "It doesn't mean he couldn't have done it another way." This indicates that she at least considered how scientists approach investigations to involve creativity.

At the end of the intervention Anne still held less-than-informed views of the creative NOS. This is not surprising given the limited interaction she had with the intervention materials. However, the evidence of Anne's consideration of, and struggle with, the NOS content is important to note as it implies that that the modified text and accompanying questions encouraged students to reflect on the NOS content. This case provides further support for the effectiveness of the modified content in promoting reflection about NOS concepts, a necessary step in changing views of NOS.

Chapter V

Discussion and Conclusions

The present study investigated the impact of elementary science trade books that have been enriched to include explicit-reflective references to three targeted aspects of NOS on teacher's views and teaching practices during a read-aloud of the trade book. Additionally, the study explored the connection between the changed teaching practices and student learning. Specifically, I investigated four research questions: (a) What is the impact, if any, of modified trade books and educative curriculum materials on teachers' understandings of NOS? (b) What effects do modified trade books and educative curriculum materials have on the observable instructional behaviors of teachers related to NOS? (c) What are teachers' perceptions of the efficacy of modified trade books and educative curriculum materials in supporting their understanding of, and teaching about, NOS? and (d) In what ways do students interact with, and understand, the NOS concepts being addressed during the read-alouds of trade books? This chapter attempts to explain the connection among the changes in teachers' views, practices, and student learning. Additionally, the chapter explores the importance of teachers' perceptions of the intervention materials because as they relate to the likelihood of using such materials in the future.

Unpacking Changes in Teachers' Views and Practices

The connection between teachers' views and practices is complex. Previous research has indicated that teachers will not teach concepts of NOS that they do not understand (Abd-El-Khalick & Lederman, 2000b; and Lederman, 1992, 2014). However, other research has shown that even with informed views of NOS, teachers still struggle to teach it effectively (Abd-El-Khalick, Bell, & Lederman, 1998; Abd-El-Khalick & Lederman, 2000b; Lederman, 1999;

Wahbeh & Abd-El-Khalick, 2014). Taken together, this body of work implies that there is a disconnect, or at best a lag, between the development of informed views and implementing those views into practice. Results from this study indicate that this disconnect may be ameliorated by the availability of materials that explicitly support NOS instruction.

Source of change in teachers' views. Previous interventions aimed at changing teacher's views of NOS have utilized long professional development experiences (e.g., Akerson & Hanuscin, 2007; Lederman & Lederman, 2004). This study brought about reasonable changes in teachers' views with a minor intervention that did not rely on heavy researcher guidance. Building on previous research that utilized explicit and reflective instruction in NOS (Abd-El-Khalick et al., 1998; Khishfe & Abd-El-Khalick, 2002), interaction with the trade books and teacher's guides proved to be effective at impacting teachers' views on both the targeted and interrelated aspects.

Changes in views were not consistent across teachers. Indeed, teachers each began with different profiles of their views of NOS, with some being more informed—such as Ms. Gerber—and others being less informed—like Ms. Ms. Jenkins. Similarly, their post-intervention profiles differed as well. Ms. Gerber developed informed views on all three aspects of NOS while others remained partially informed on one or more aspects. What is important to note though, is that all teachers made desired changes to at least one targeted aspect and, perhaps more importantly, none of the teachers maintained their naïve views. Previous research indicates that individual teacher variables (e.g., teaching experience and comfort with science) may impact a teacher's ability to translate views of NOS into classroom practice (Akerson & Abd-El-Khalick, 2003; Lederman, 1999; Wahbeh & Abd-El-Khalick, 2014). However, the teachers in this study were relatively homogenous in their background demographics. As such, it was not possible to account for the differences in teachers' views. It is possible that variables that were not investigated in this study, such as worldview (Abd-El-Khalick & Akerson, 2004; Akerson & Donnelly, 2008), underlie these differences.

Another important issue to consider with the documented changes in teachers' views is the connection between the targeted aspects and other NOS aspects. Previous research suggested that acquiring informed views of the empirical, inferential, and creative NOS were attainable to elementary aged students (Akerson & Abd-El-Khalick, 2005; Akerson & Donnelly, 2010; Akerson & Hanuscin, 2007; Akerson et al., 2014; Akerson & Volrich, 2006; Lederman & Lederman, 2004; Quigley, Pongsanon, & Akerson, 2010). As such, these were the three aspects that were targeted in this study. Results indicate that the teachers did in fact make changes in their views towards these aspects. However, teachers also made changes in other aspects of NOS. In fact, at least one teacher improved views of every aspect except the nature of, and relation between, theories and laws. Modifications in the trade books did not include major changes to the non-targeted aspects. However, when these aspects were addressed in a naïve manner in the original text, they were modified to be in line with the desired views. As such, teachers received informed messages about multiple aspects of NOS, beyond those targeted by the intervention.

It is also possible that the major modifications aimed at the three targeted NOS aspects also influenced the non-targeted aspects. That is, for example, changes relating to the creative NOS may have impacted teachers' views of the myth of The Scientific Method. Indeed, three teachers developed informed views of this myth by the end of the study despite no modifications to the texts relating to it. This is particularly interesting as one of these teachers, Ms. Smith, had a scientific method poster in her room and actively referred to it during her Level II read-aloud session. Other aspects of NOS are similarly interrelated (Abd-El-Khalick et al., 2013) and so this logic may be extended to include those aspects as well.

Relation between teachers' views and practices. Changes in views of NOS and changes in practices related to NOS instruction occurred in tandem in this study. These findings differ from previous research that showed little to no relation between views of NOS and teaching practices (Abd-El-Khalick & Lederman, 2000; Lederman, 1999). The major difference between the current results and those from previous studies is the presence of modified instructional materials (i.e., the trade books) and the educative curriculum materials. The educative curriculum materials aimed to change teachers' views through their instruction. That is, there was no separate intervention that led to changes in teachers' views. Instead, it was through the consultation of and immersion in the educative materials that teachers' changed their views. The addition of reflective questions that, on the surface, were aimed at engaging students in reflective consideration of NOS concepts also required teachers to consider, and reflect on, these same concepts. There was differential success in the effect of questions without support (i.e., Level II) and those with support (i.e., Level III). In fact, several teachers, such as Ms. Edwards and Ms. Green, demonstrated an inability to address these questions in the Level II read-alouds. In contrast, during the Level III read-alouds, most of these teachers effectively guided students through discussions around the NOS concepts.

In fact, throughout the study, teachers played an important role in mediating the students' reflections, as they were the ones presenting the questions and guiding students through considering appropriate answers. Teachers did this in two ways: through incorporating the questions in the modified text and teacher's guides, and through developing their own reflective questions. Additionally, one teacher, Ms. Gerber encouraged reflection through direct questions and also modeled the process of reflecting for her students as she informed them of her changing views of the creative NOS. Interestingly, she did it in a manner that did not provide students with an ultimate “answer” about the role of creativity in science. The impact of her reflection and modeling were visible in one of her student’s data. By tracking Anne’s responses from her pre-intervention interview, contributions to classroom discourse, free response data, and post-intervention interview, I was able to determine that Anne had taken up some of the ideas about creativity with which Ms. Gerber was encouraging her to wrestle. Although it is not possible to say how providing a desired answer would have impacted this student’s post-intervention views, it is obvious that the reflection itself was impactful and provides further evidence that reflection is an important component of NOS instruction and may be occurring in tandem in both teachers and students.

Perhaps one of the most important findings of this study is the ability of teachers with partially informed views of targeted NOS aspects to effectively promote the desired views of NOS. The presence of the explicit references to NOS, and inclusion of reflective questions, ensured that the language of NOS permeated classroom discussion in a desired way. Granted that it is highly desirable for all teachers to hold informed views of NOS, the fact is that we are a long way from achieving that in the K-12 school system (Abd-El-Khalick & Lederman, 2000b; and Lederman, 1992, 2014).). Consequently, this intervention, which encourages the inclusion of informed NOS references as teachers and students alike develop their understanding of NOS, is a significant step towards impacting a large number of teachers and their students. The current evidence suggests that repeated use of similar materials across contexts and content will likely deepen teachers’ understandings of NOS, increase their level of comfort with these understandings, and, consequently, help them to better and more effectively infuse NOS instruction into their science instruction (at least, when taking the form of reading science tade books).

Improving Students' Views

Students' views of NOS did not change as much as teachers' views. However, they did change. This is important, considering the only interaction students had with the NOS content was through the read-alouds and accompanying discussions. Additionally, it is impressive that some change was evident among students as their teachers were in the process of developing more informed views of NOS. Previous research has incorporated science trade books into NOS instruction (e.g., Akerson & Donnelly, 2010; Akerson et al., 2014; Akerson & Volrich, 2009; Quigley et al., 2010) but none has ever used trade books as the only component of an intervention until this study. Just as important, but less visible, than the documented changes in students' views is the evidence that students wrestled with the NOS concepts. The case of Anne provides some observable support for this internal struggle, which is crucial to genuine conceptual growth and learning about abstract NOS ideas, such as the creative NOS. It is likely that if Anne was engaged in this struggle, other students were engaged in a similar one. Encouraging students to develop informed views of NOS from an early age is especially important, as these views become harder to change as students become older and the views become more ingrained.

Perceptions of the Teaching NOS and Intervention Materials

All of the quantitative results from the study relating to changes in teaching practice indicated a substantial difference between practices at Level I and Level II, and Level II and III of the intervention. The explicit informed references in Level II helped teachers include NOS throughout the read-aloud discussions, whereas they were largely absent in the Level I read-alouds. Additionally, the inclusion of the educative teacher's guide in Level III led to teachers feeling more comfortable and prepared to lead discussions around the NOS concepts. This, coupled with the higher-level Discussion questions, led to the inclusion of more informed references of NOS during the Level III read-aloud sessions. Elementary teachers typically have very low levels of comfort teaching science in general (Abell & Roth, 1992; Bleicher, & Lindgren, 2005; Davis, Petish, & Smithey, 2006; Palmer, 2001, 2006b; Rice & Roychoudhury, 2003; Sutton, Watson, Parke, & Thomson, 1993). The teachers in this study ranged from being somewhat uncomfortable to very comfortable with teaching science. However, even teachers that reported being very comfortable perceived the teacher's guide as being an important tool in leading effective discussions.

The use of the teacher's guide was not ideal by any means. Teachers were not aware of the specific educative features in the guide, and as such many did not utilize them to their full extent. Specifically, they skipped or glossed over the front matter, which explicitly addressed the what NOS concepts were and why they were important to be taught. Additionally, the three teachers who exhibited different practices in Level III did not use all features of the teacher's guide during their instruction. In particular, they skipped the Discussion questions. In future studies, the teacher participants may benefit from explicit professional development on how to use the educative teacher's guide. The main point of this type of teacher's guide is to empower teachers to make more informed pedagogical decisions that are appropriate for their own teaching situations by educating them on the content so that they are able to determine how best to teach their students (Davis & Krajcik, 2005). Teachers must be aware of this point to effectively put it into practice. Instead, in this study, the teachers overwhelmingly read through the entire book, including all the reflective questions. Although asking every single question will most likely give students the widest exposure to NOS concepts, the teachers described it as being unrealistic for a typical teaching experience. Instead, teachers should feel capable of picking and choosing questions which are most relevant to their students. As an example, if the teachers realize the students have a handle on the empirical NOS, they may choose to skip a discussion question around this idea, in favor of more directed discussion on a less-understood aspect.

Despite the fact that teachers did not completely understand the function of the educative teacher's guide, they still perceived the intervention materials in an overwhelmingly positive light. In addition to feeling more comfortable teaching NOS concepts with the support from the teacher's guide, the teachers felt that they had a better understanding of why NOS was important to teach in science and that teaching through trade books was an effective way to do so. Albeit, teachers also had some negative perceptions of the intervention, these perceptions related mainly to the timing of the intervention and not the materials themselves. In particular, teachers felt that the trade books were too long to read in one sitting. This concern would be easily mitigated if the teachers were free to structure the read-aloud around their own schedules instead of trying to fit within the schedule of the research project. Consequently, if teachers were to use the materials on their own, outside a research setting, this concern would be ameliorated.

The Need for Explicit References in Trade Books

Thus far it is apparent that the intervention was successful at impacting teachers' views of NOS and instructional practice. Subsequently, through the changed instructional practice, there is evidence to suggest that students' views were impacted as well. These changes were all made possible through the interaction with trade books that provided explicit and informed references to NOS and encouraged reflection on these NOS concepts. As such, the availability of trade books that contain these explicit and informed references is necessary.

Unfortunately, there is a dearth of trade books that meet these criteria. In fact, in a review of 50 science trade trade from the Outstanding Science Trade Book List from NSTA indicated that the vast majority of trade books either included naïve references to NOS or did not address NOS at all (Brunner & Abd-El-Khalick, accepted). Alternative research has shown that NOS is present in trade books that are classified as "literature of inquiry" (Zarnowski & Turkel, 2013), that is, books that address the role of humans in developing scientific knowledge. However, it is important to keep in mind that these books address NOS in an implicit manner, which is not likely to produce desired changes in either teachers' or students' views. Nevertheless, the focus on the role of humans in developing scientific knowledge is important to keep in mind as books are being developed. In the current study, *I, Galileo* and *Come See the Earth Turn* focused on the role specific scientists played in developing new knowledge about the earth and space. In contrast, *Galaxies, Galaxies!* implicitly related the role of scientists as it referred to scientists who developed telescopes or discovered galaxies. The modifications made these connections more explicit. Additionally, the guiding questions encouraged students to consider the role of humans in developing scientific knowledge. Guiding questions can be added in any book, regardless of the explicit discussion of scientists in the main text, and therefore may encourage students to engage with NOS concepts in books that are not considered "literature of inquiry."

Limitations

The limitations in this study relate to the sample, the effectiveness of the student written task as a measure of understanding NOS, and the ecological validity. Additionally, the durability of changes must be considered. Each will be considered in turn.

Eight elementary teachers and their students were recruited in this study. These teachers taught in similar schools and had similar backgrounds. As a result, it was not possible to parse out the effect their background variables had on changes to their views of NOS or their practices. Additionally, the current study's data are suggestive of some trends, such as an increase in time spent on Level II and II discussions, but there was not enough power with eight teachers to determine statistical significance. A larger number of teachers, with more varied backgrounds, might help address some of the questions that remain in this study.

A second limitation of this study related to the free response task. The students' responses were highly diverse. Although most related to the text in some manner, they tended not to be related to NOS content in the text. This may indicate that students did not pick up on the NOS content. However, the changes in targeted students' views of NOS related in the post-intervention interviews do not support this conclusion. It is more likely that because the measure itself was not targeted specifically at eliciting students' reaction to NOS concepts in the trade books, students did not think to address NOS. Future studies should include a more targeted task to obtain information about students' views of NOS related to the trade books.

A third limitation relates to the ecological validity of the intervention. This intervention involved teachers reading three trade books to their students. The trade books were not connected with the science instruction that typically occurred in the classrooms. In fact, Ms. Edwards and Ms. Smith did not even teach science to their students during the typical school year! As such, the read-alouds were isolated events that did not mirror the connectivity they may have had if they were situated within a broader science unit. Although the specific trade books were not related to the classroom science instruction, it is important to remember that the act of reading trade books aloud to students and engaging them in discussion around the ideas in the books was one that teachers typically engaged in. This matter minimizes the extent of this limitation somewhat and should be kept in mind when considering implications of this study.

Finally, it is not possible to know the effectiveness of this study on long-term changes in views or practices. It is notoriously difficult to impact changes in long-held views of concepts. Additionally, the changes in views and practices recorded in this study were supported by the presence of the modified materials and it is obvious that at least some teachers relied exclusively on the materials to change their teaching practices. This is most obvious in Ms. Green's Level II read-aloud, in which she only read the content of the book and did not engage students in any additional discussion around the NOS concepts. It stands to reason then that it is unlikely the teachers will maintain these changes without the continued support of the NOS-rich materials. In fact, the typical elementary classroom actively works to counteract changes, as materials that promote naïve views are ever-present in the environment (think posters describing "The Scientific Method"). It is possible, however, that similarly minimal interventions that extend throughout the school year and are incorporated into typical science teaching practices may help address this limitation. One such possibility is described in more detail below.

Conclusions and Implications for Future Research

The findings of this study have some meaningful implications for future research on teaching and learning of NOS. This study demonstrates the importance of developing materials that specifically support the inclusion of informed messages about NOS and encourage teachers to develop informed views themselves. In this way, teachers can change both their views of NOS and their teaching practices. Furthermore, the intervention in this study exhibited that these changes can be done with minimal intervention, unlike previous research.

However, the promising results in this study were only possible with the inclusion of modified trade books and educative materials that included the explicit references. These materials were not readily available and as such specific modifications were made to meet the requirements of the study. This points to the need for more widespread development of materials that include informed messages of NOS. This need has been highlighted in other research. For example, research on representations of NOS in trade books have generally indicated a lack of informed messages (Abd-El-Khalick, 2002a; Brunner & Abd-El-Khalick, in process; Ford, 2006). Additionally, Wabeh and Abd-El-Khalick (2014) determined that it is difficult for teachers to translate informed views of NOS into effective teaching unless given supports specific to the context in which it is taught.

Additionally, the effectiveness of such minimal interventions is noteworthy. Although intensive research interventions may be more impactful than the one used in this study, future research should explore the effectiveness of other minimal interventions. These interventions can be scaled up relatively easily and thus, reach a larger audience. This consideration is important, as there are a large number of practicing teachers that do not have informed views of NOS (Abd-El-Khalick & Lederman, 2000b; and Lederman, 1992, 2014).) and consequently there is a generation of students progressing through the school system with naïve views of NOS. However, minimal inventions, such as the one used in this study, are cost effective, as they do not rely on extensive materials; able to be realistically implemented, as they do not require the direct participation of a researcher; and easily distributable.

This study indicates directions for future related research. The possibility of students' learning from trade books without the guidance of teachers might provide a fruitful research path. One teacher in the study, Ms. Green, did not include any additional NOS references in her instruction outside of those that were incorporated in the texts. Even with this more minimally intense intervention, her students still made changes in their views of NOS. These results suggest that even without the teacher mediating discussion around the NOS content, students still pick up informed NOS concepts. This speculation leads to the question of what concepts students would learn if they read the trade books by themselves, without the teacher mediating. One major drawback of this line of research would be finding books that are at an appropriate reading level for students to read on their own. However, adaptive technologies, such as text to speech, could help overcome this issue. Addressing this question is important as independent reading is a popular task during school time and encouraged at home.

The results from this study also indicate the possibility of a second line of research. In this study the teachers read trade books that were isolated from the typical science instruction. This is not characteristic manner of instruction. However, as trade books and other reading activities are frequently used in elementary science instruction (Banilower et al., 2013), the intervention developed for this study could be situated within an inquiry science unit. Incorporating the trade books within an inquiry unit provides multiple benefits. First, it directly connects students with the practices about which they are learning. Engaging students in inquiry and learning NOS *through* inquiry is recommended for higher learning gains (Akerson & Abd-El-Khalick, 2003; Akerson & Hanuscin, 2007). Indeed, the use of educative curriculum materials could be expanded to support NOS instruction throughout the unit. Lin et al. (2012) have successfully incorporated NOS instruction into an elementary inquiry chemistry unit. Second, the structuring of the trade books within a broader unit will help to differentiate the read-alouds as being a science learning activity. When isolated, teachers put literature and literacy instruction at the forefront. Clear connections with the inquiry science activities may help anchor the read-aloud activities as a science learning task.

One change to the design of the study should be made, regardless of the form of future research in this area. Teachers on their own did not effectively include NOS as a main theme of instruction. Indeed, they glossed over or ignored completely the front matter of the teacher's guide that helped frame the importance of the NOS content. Based on these practices, it would be beneficial for future studies to include some component that specifically addresses the importance of including NOS as a central theme. These may be done explicitly, such as by providing teachers with materials, similar to the teacher's guide, that address NOS, but there is not guarantee that teachers will attend to these materials. Instead it may be more effective to instruct teachers on the specific differences between the educative teacher's guides and typical teacher's guides. In this manner, teachers will be drawn to read the educative materials that explicitly address the content of the NOS aspects, as well as the importance of their inclusion in instruction.

In sum, the combination of modified trade books and educative teacher's guides that support the inclusion of NOS instruction during read-alouds is an effective intervention strategy for changing teacher's views of NOS, their teaching practices, and subsequently students' views, which has and continue to be a much desired—albeit hard to achieve—goal for K-12 science education.

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Appendix A

Teacher Survey

Name: ___________________________

Gender (circle one): M F Age (in years): _________

Race (circle one): White, non-Hispanic Black Asian Hispanic Other

1. How many years have you taught elementary school? _______

2. During those years, which grades have you taught and how long have you taught each grade?

3. How many of those years have been in the Champaign Unit 4current school districts? _______

4. What is your highest degree earned and in what area was it earned? _______

5. If you specialized in a subject or subjects during your preservice training, please indicate it here.

6. How many science methods courses did you take during your preservice training/undergraduate schooling? _______

7. What, if any, professional development activities directly related to science teaching have you completed in the past 2 years?

8. How often do you teach science in your classroom? ___________

9. On average, how many minutes do you teach science over the course of a typical week? __________

10. How comfortable do you feel teaching science in your classroom? (Circle one)

- ☐ Very comfortable
- ☐ Somewhat comfortable
- ☐ Somewhat uncomfortable
- ☐ Very uncomfortable

11. How do you typically deal with questions you may have about the science lessons you are supposed to teach?

12. Is there any other information or thoughts you would like to share about teaching science?

Appendix B

Student Demographic Survey

For each of your students, please provide the following information.

Student #	**Gender**	**Race**	**Free/Reduced Lunch (Y/N)**	**ELL (Y/N)**	**Science Achievement** (Indicate if the student is *at* grade level, *above* grade level, or *below* grade level.)	**Language Arts Achievement** (Indicate if the student is *at* grade level, *above* grade level, or *below* grade level.)

Appendix C

Views of Nature of Science Questionnaire (VNOS)
Form CE

Name:

Date:

Instructions

- Please answer each of the following questions.
- **There are no "right" or "wrong" answers to the following questions. We are only interested in your views on a number of issues about science.**

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. How do scientists produce scientific knowledge (facts, laws, and/or theories)?

3. What is an experiment?

4. Does the development of scientific knowledge **require** experiments?
    - If yes, explain why. Give an example to defend your position.
    - If no, explain why. Give an example to defend your position.

5. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   - If you believe that scientific theories do not change, explain why. Defend your answer with examples.
   - If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories? Defend your answer with examples.

6. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

7. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence **do you think** scientists used to determine what an atom looks like?

8. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

9. Scientists present their research at professional conferences and publish their findings in scientific journals.
    - How do scientists go about presenting their research and publishing their findings?
    - Why do scientists present their research at professional conferences and publish their findings in scientific journals?

10. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and use the **same set of data** to derive their conclusions?

11. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.
    - If you believe that science reflects social and cultural values, explain why. Defend your answer with examples.
    - If you believe that science is universal, explain why. Defend your answer with examples.

12. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
    - If yes, then at which stages of the investigations you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
    - If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix D

Student Interview Questions

What is science?

Scientists produce scientific knowledge. Some of this knowledge is found in the books that you've read in class. How do scientists produce this knowledge?

What does the word "evidence" mean to you? What does the word "data" mean to you?

What ways do scientists use to collect "evidence" or "data"?

Why do scientists collect "evidence" or "data"?

Scientists try to find answers to their questions by doing investigations or experiments. Do you think that scientists use their creativity or imagination in their investigations? Explain why or why not.

Scientists believe that there are black holes in space, but cannot actually travel to the black holes. How do scientists know that black holes really exist?

How can scientists learn about black holes if they cannot travel to them?

How certain are scientists about the way they believe the black holes look and act?

Scientists know that there is a moon that orbits the Earth, but they don't agree about where the moon came from. Some scientists say that the moon was an asteroid that was captured by the Earth's gravity. Others say a big piece of the Earth broke off and formed the moon when a meteor hit the Earth. Have you heard about this issue before? If so, what is your view on the issue? Why do you hold this view?

Does it surprise you that scientists disagree about where the moon came from?

We know that all of the scientists have the same information about the moon. How can it be that these scientists use the same information but come to different conclusions about the moon?

Appendix E

Free Recall Task Sheet

Name: ____

Your teacher just read you a book about Space. In the space below, list anything that you remember from the book or your class discussion about the book. There are no right or wrong answers.

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____
11. ____
12. ____
13. ____
14. ____
15. ____
16. ____
17. ____
18. ____

Appendix F

Teacher Interview Questions 1

I see on your survey sheet that you typically teach science __ often. What do those lessons typically look like? (Follow up by asking about hands-on activity, read-aloud, web activity, etc. if necessary)

Can you tell me how you usually prepare to teach a science lesson? You can think of the last lesson you taught and use that as an example.

How often do you use trade books in science instruction? In what ways do you use trade books?

What do you think are the benefits/burdens (advantages/disadvantages) of using trade books in science instruction?

How often do you use read-aloud activities in science instruction?

What do you think are the benefits/burdens (advantages/disadvantages) of using read-alouds in science instruction?

The second book that you received included some changes that focused on NOS. What did you think about those changes?

Did your preparation for the second lesson differ at all from the preparation for the first lesson? If so, how?

How do you think the changes in the second book affected your students' learning? (Did they learn NOS concepts?)

The last book had similar changes, but also included a teacher's guide. What did you think about the teacher's guide? (Do you think it helped you prepare for teaching the NOS content? Did you learning something new about NOS or about how NOS is important for NGSS?)

Did your preparation for the third lesson differ at all from the preparation for the first or second lesson? If so, how?

Appendix G

Teacher Interview Questions 2

How do you feel about the lesson that was just taught? (Did it go as planned? Any problems? Anything that went particularly well?)

How effective do you think the teacher's guide was in helping you plan discussion around the book? (Follow up with references to specific questions or comments made during the discussion.)

How effective do you think the teacher's guide was in providing you information relevant to the NOS concepts?

Think about how your second lesson went, compared to this lesson. Did you feel more prepared, less prepared, or about the same? Please explain why or give examples.

Do you think your students learning something about NOS today? If so, what? (How do you think your students' learning of NOS today compared with their learning around the last book?)

You've taken the VNOS survey twice in the past few weeks. I'd like to talk about some of your responses. (Follow up with by first clarifying responses to second VNOS and then asking about changes in first and second VNOS responses.)