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The Inclusion of the Nature of Science and Its Elements in Recent Popular Science Writing for Adults and Young Adults

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IN RECENT POPULAR SCIENCE WRITING FOR ADULTS AND YOUNG ADULTS

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of the requirements for the degree of
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ABSTRACT

This study was conducted to examine the inclusion of nature of science (NOS) in popular science writing to determine whether it could serve supplementary resource for teaching NOS. Four groups of documents published from 2001 to 2010 were included in the analysis: *Scientific American*, *Discover* magazine, winners of the *Royal Society Winton Prize for Science Books*, and books listed in National Science Teacher Association's (NSTA) *Outstanding Science Trade Books for Students K-12*.

First, computer analysis was performed to categorize passages in the selected documents based on their inclusions of NOS. Then, follow-up human analysis was conducted to assess the frequency, context, coverage, and accuracy of the inclusions of NOS within computer identified NOS passages. The results reveal that NOS was rarely addressed in selected document sets. About two to five passages explicitly addressing NOS were observed in every thousand passages. Interestingly, NOS is frequently addressed in the letters section of the two magazines. This result suggests that readers seem to be interested in the discussion of NOS-related issues. In the popular science books analyzed, NOS presentations are more likely to be aggregated in the beginning and the end of the book, rather than scattered throughout. The most commonly addressed NOS elements in the analyzed documents are "science and society" and "the empirical aspect of science." Only three inaccurate presentations of NOS were identified in all analyzed documents.

Unfortunately, the findings suggest that popular science writing generally may not be a good resource for science educators to search for materials for teaching NOS. Since both science textbooks and popular science writing are generally disappointing in their inclusion of NOS topics, it seems to be necessary to create new science curriculum with rich features in NOS.

Contrary to the disappointing findings on the presentation of NOS in popular science writing, the text mining technique used to identify NOS presentations demonstrated exciting performance. The successful application of the text mining technique in the current study invites more applications of such technique on the analysis of other aspects of science textbooks, popular science writing, or other materials involved in science teaching and learning.

This dissertation is approved for recommendation
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DEDICATION

To my parents, who have been continuously support me.

To my wife, who has always been there for me.

Words cannot express how much I love you all.

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CHAPTER I

INTRODUCTION

Statement of the Problem

One major goal of science instruction is to promote scientific literacy for all students by focusing science teaching on a number of essential elements. The nature of science (NOS) is frequently considered one such essential element (American Association for the Advancement of Science, 1994; National Research Council, 1996; National Science Teachers Association, 2000). The purpose of NOS instruction is to help students understand what science is and how it works as a special way of knowing and, as such, should have a special focus in science teaching. However, this goal is not easily achieved. Studies conducted and opinions offered in the last half century show that most teachers' and students' understandings of NOS are insufficient (e.g. Kang, Scharmann, & Noh, 2005; Lederman, 1986; Miller, 1963; Rubba & Andersen, 1978). Traditional science instruction is based on the assumption that students' understandings of NOS can be automatically developed through the study of science content or engaging in scientific inquiry. Nevertheless, empirical studies have rejected this assumption and revealed that NOS must be explicitly addressed in science teaching (Abd-El-Khalick & Lederman, 2000). This finding suggests that both the science curriculum and science instruction need significant changes to fulfill this requirement.

Teachers and students rely heavily on science textbooks, but current science textbooks commonly do not meet all the requirements of scientific literacy, particularly with respect to a rich inclusion of NOS. Studies have shown that science texts generally fail to provide a balanced view in different aspects of scientific literacy (Chiappetta & Fillman, 2007; Chiappetta, Sethna,

& Fillman, 1991, 1993; Lumpe & Beck, 1996; Wilkinson, 1999). Almost all science textbooks focus on science content knowledge, while scientific inquiry, scientific thinking and the social aspects of science are often overlooked. These are a few of the important elements of what is commonly included with the domain of the nature of science (NOS).

Previous analyses of NOS presentations in science textbooks have shown that science textbooks for different grades and different science disciplines generally lack explicit discussions of NOS, and the views of NOS implied in science textbooks were frequently not in alignment with current science education standards documents (Abd-El-Khalick, 2002; Abd-El-Khalick, Waters, & Le, 2008; Alshamrani, 2008; Brooks, 2008; Irez, 2009; Lee, 2007; McComas, 2003; Phillips, 2006). Moreover, previous analyses also displayed that most of the presentations of NOS in science textbooks were limited in a few introductory chapters separated from science content.

However, popular science writing (i.e. textual presentations of science aimed for general audience) has not been systematically studied for their inclusions of elements of the NOS, leaving the inclusion of NOS in popular science writing mostly unknown. A few exceptions include Abd-El-Khalick's (2002) analysis on the inclusion of NOS in general science trade books for young students, and McComas's (2007) examination of historical examples in NOS-focused science trade books. However, no study has been conducted to examine the inclusion of NOS generally in science trade books for adults or science magazines. Science magazines such as *Scientific American* and *Discover* play an important role in communicating science to the general public and have a huge number of readers, but they are generally overlooked in educational research.

Studies on the teaching of NOS found that teachers may encounter several difficulties when communicating it to students, one of which is the deficiency of NOS related teaching materials (Hanuscin, Lee, & Akerson, 2008). As a consequence, teachers tend to rely on a few pre-packaged NOS activities if they teach NOS at all (Hanuscin et al., 2008; Schwartz & Lederman, 2002). However, those materials are not sufficient for everyday science teaching, and teachers still need extra materials to facilitate their NOS instruction (Hanuscin et al., 2008). Popular science writing may serve as valuable supplementary materials for science teaching and learning. In fact, they might be seen by students as more interesting than textbooks, and they could be more flexible to use. Therefore, some of them could be useful in NOS instruction.

To examine the inclusion of NOS in popular science writing, the first step would be to locate NOS discussions in these texts. Since reading the thousands of pages available (even in the past decade) would be impossible, it would be helpful if there were a technique that could automatically locate relevant text which addresses NOS explicitly. However, keyword searching would not be effective, because NOS ideas cannot be simply summarized into a few keywords for searching. Most NOS discussions do not specifically use the term “nature of science.” As for the specific aspects of NOS, such as tentative, subjective, or creative nature of scientific knowledge, all of them can be expressed in many different forms, and use of the specific terms are not required for delivering those ideas.

On the other hand, using human experts is time consuming and therefore prohibitively expensive. Based on the previous analyses of textbooks (e.g. Abd-El-Khalick et al., 2008; Chiappetta & Fillman, 2007), it is reasonable to assume that the proportion of NOS discussion in popular science writing is also limited, particularly considering the limited NOS content in the textbooks that have been studied. Therefore, it would be too inefficient for human analysts to locate the contextualized NOS discussions by simply reading through all the pages. On the other hand, using random sampling to select pages is not an appropriate strategy in this kind of scenario. Random sampling would be more suitable when NOS discussions are evenly spread throughout each book or each issue of a magazine. However, since it is likely that NOS discussions are not evenly spread, the results obtained from randomly selected pages very likely do not represent the NOS inclusion of the whole.

Fortunately, automated text mining could be an effective strategy. Text mining is a powerful technique which discovers patterns from textual data sources through computer-assisted analysis. Based on these patterns, predictive models can be established and used to automatically identify specific features within textual materials. This technique has been successfully applied to fields such as business, medicine, and national security. For example, text mining can be used to analyze customers' comments and opinions from their textual feedbacks (Gamon, Aue, Corston-Oliver, & Ringger, 2005). In medicine, text mining can be used to improve health-care quality by analyzing textual information provided by patients, and prescriptions and notes made by their physician within digital clinical records (Raja, Mitchell, Day, & Hardin, 2008). In national security, text mining can be used to combat terrorist activities by detecting links between people and organizations, trends of social and economic actions, or topics of interest in suspected websites and on-line chatting logs (Zanasi, 2009).

Although text mining has been applied to a variety of fields, its potential has not been widely recognized by educational researchers. The few studies located include Rosé, Roque, Bhembe, and Vanlehn (2003) who applied text classification to analyze student essays. In addition, Villalon, Kearney, Calvo, and Reimann (2008) developed a writing support system called Glosser which uses text mining techniques to provide content clues for students to help them answer questions.

Purpose of the Study

In this study, a robust text mining technique was applied to locate the paragraphs which explicitly address NOS from popular science writing, and then manually analyze the coverage, context, and accuracy of the NOS elements embedded in identified paragraphs. The target documents for analysis in the study are defined with the following criteria:

1) This study focused on popular science writing for adults and young adults. Popular science writing for children or pre-high school students was not included in the scope of the study. The writing style of pre-high school texts could be dramatically different from the writing style of texts for adults and young adults, and different training materials would be required to analyze them within the text mining approach.
2) This study focused on two types of popular science writing: science magazines and general science trade books. Popular science writing such as science blogs was not included due to the difficulty in defining these types of materials.
3) To set a boundary for the time frame, this study only focused on the popular science writing published in the last ten years, i.e. from 2001 to 2010. The selection of this time frame was also because the notion of NOS has been massively changed in the last half century (e.g. Kuhn, 1962; Popper, 1963), and it reached a relatively stable status in the last decade.

Based on the above criteria, four groups of documents are selected for analysis: 1) *Scientific American* magazine issues from 2001 to 2010, 2) *Discover* magazine issues from 2001 to 2010, 3) the winners of *Royal Society Winton Prize for Science Books* from 2002 to 2011, and

4) the listed books in National Science Teacher Association's (NSTA) *Outstanding Science Trade Books for Students K-12* from 2002 to 2011. The book prizes were awarded a year after the book publication, so prizes given from 2002 to 2011 were selected to represent books published from 2001 to 2010.

The purpose of this study was threefold. First, it assessed the inclusion of NOS in selected popular science writing using an appropriate text mining technique. Each paragraph in the documents was judged for whether it explicitly addresses NOS by computer analysis, and then those paragraphs identified through text mining as containing NOS were re-examined in the follow-up human analysis. The frequencies of NOS inclusions were counted and reported. Second, human analysis was conducted to examine the coverage, context, and accuracy of the presentations of NOS in the paragraphs which have been identified as containing explicit inclusion of NOS. Third, the effectiveness of text classification technique in locating NOS texts was examined.

Specific Research Questions

The following questions were addressed in the study:

1. How accurate is the text mining approach in identifying inclusion of NOS in recent popular science writing?
2. To what extent does the 12 category framework chosen as the analytic tool correspond with instances of the NOS in popular science writing?
3. With what frequency do explicit presentations of NOS appear in recent (past 10 years) popular science books and magazine articles (called popular science writing)?

4. Within what contexts do explicit presentations of NOS appear in recent popular science writing?
5. With what frequency do explicit presentations of NOS elements appear in recent popular science writing?
6. How accurately are NOS elements presented in recent popular science writing?

Brief Overview of the Research Method

In its nature, this is a mixed-method content analysis study. The study contains two major analyses. First, a computer-assisted quantitative analysis was performed to label each paragraph according to the existence of explicit inclusion of NOS. Second, for each paragraph which was labeled as having explicit NOS inclusion in the first analysis, a qualitative analysis was conducted to examine the embedded NOS elements.

The major procedures in the first analysis include: 1) collecting positive (documents having inclusion of NOS) and negative (documents having no inclusion of NOS) training examples; 2) establishing and validating the predictive model based on the selected training examples; 3) collecting selected popular science writing as sample documents for analysis; 4) analyzing sample documents and report results. It is worth noting that, due to the lack of labeled documents for NOS elements, the first analysis did not examine the elements of NOS. The accuracy of the first analysis was evaluated in two ways. First, the classification model was cross validated within randomly assigned training datasets and test datasets. Second, the classification model was validated with labeled documents.

The major procedures in the second analysis include: 1) collecting paragraphs which are identified as explicitly addressing NOS in the first analysis, 2) reexamining the inclusion of NOS in those paragraphs to eliminate false positive cases, 3), identifying the contexts of the inclusions of NOS, 4) examining the NOS element(s) addressed in each paragraph, and 5) examining the accuracy of the NOS idea conveyed in each paragraph. The second analysis was conducted in a qualitative fashion as suggested by Alshamrani's (2008) conceptual framework and coding guide, which has been validated in his study. The consistency of the second analysis was assessed with inter-rater reliability. To do so, three other informed analysts, who were also graduate students specialized in science education and had taken a course in NOS, were invited to analyze the selected paragraphs. Each paragraph was independently analyzed by two analysts.

Significance of the Study

The findings of this study could be applied in several ways. The frequency, context, coverage and accuracy of the inclusion of NOS in recent popular science writing will be known. Science educators could gain better understanding of popular science writing in terms of their inclusion of NOS. Valuable popular science writing could be identified and examined and perhaps proposed as supplementary materials to support the teaching of NOS in science classrooms.

The established classification model can be almost directly implemented to other popular science writing which have not been analyzed in this study. Moreover, the automatic text analysis strategy to be implemented in this study, which uses the text mining technique to handle massive textual materials, is not well known in the educational research community. This study will demonstrate the power of the text mining technique in analyzing educational materials to educational researchers. The text mining technique has a strong potential to be extended to other analyses of educational materials. Except for analyzing the NOS inclusion in science writing, similarly text mining can be used to analyze other aspects of science writing, such as the appearance of science subjects, the presentations of scientific inquiry or even social scientific issues. Moreover, pedagogical features of science writing and science textbooks could also be analyzed with similar techniques. Text mining could also be applied to analyze teachers' journal entries or students' essays and lab reports. Text mining can also be widely applied into other fields of social science research. For example, it can be used to analyze survey responses and interview transcripts.

Assumptions

According to previously cited studies, science textbooks generally devote limited space on NOS. Therefore, it is assumed in this study that the proportion of NOS discussion in recent popular science writing is also very small. Consequently, it is necessary to use the text mining technique to locate NOS discussions from a large pool of popular science writing.

Delimitations of the Study

The focus of this study is on the inclusion of NOS in popular science writing for adults and young adults in a particular time frame. The sample includes science magazines, science trade books for adults, and science trade books for post-elementary school students. Findings of this study cannot be generalized to other types of popular science writing or to those from previous eras.

CHAPTER II

REVIEW OF THE LITERATURE

This chapter reviews literature relevant to the study. It is organized into three sections: 1) NOS and science education, 2) the text classification technique, and 3) gaps in the literature regarding the analysis of NOS in popular science writing.

NOS and Science Education

This section reviews NOS in the context of science education in the following aspects: the definition of NOS and the major NOS elements recommended by science educators, the purposes and utilities of NOS in science education, and the inclusion of NOS in science textbooks. A summary is provided at the end of this section.

What Is the Nature of Science?

Although the term NOS is widely used, it is difficult to find a commonly accepted definition of NOS. Philosophers of science, historians of science, and science educators seem to use the term differently (Abd-El-Khalick, Bell, & Lederman, 1998). However, even though disagreements exist in terms of the definition or meaning of NOS, more consensuses exist than disagreements and the disagreements are irrelevant to K-12 science education (Lederman, 2007). Constrained by the scope and the purpose of the study, NOS in this study refers to the NOS in the context of K-12 instruction.

Generally speaking, NOS is the study of science which blends the aspects of philosophy, history, sociology, and psychology of science (McComas, Clough, & Almazroa, 1998). More specially, NOS is “a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors" (McComas et al., 1998, p. 4). According to Lederman (2007), NOS refers to "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (p. 833).

Although the field of NOS is fairly broad, the major elements of NOS recommended by science educators for teaching at the K-12 level are in a limited range. For example, McComas (2005) listed 9 principal components of NOS, and Lederman (2007) listed 7 in his review of the research in NOS teaching. By reviewing recommendations from several sources, Alshamrani (2008) summarized 12 major aspects of NOS:

1. Scientific knowledge is not entirely objective
2. Scientists use creativity
3. Scientific knowledge is tentative but durable
4. Scientific knowledge is socially and culturally embedded
5. Laws and theories are distinct kinds of knowledge
6. Scientific knowledge is empirically based
7. The absence of a universal step-wise scientific method
8. The distinction between observations and inferences
9. Science cannot answer all questions
10. Cooperation and collaboration in development of scientific knowledge
11. The distinction between science and technology
12. The role of experiment in science

Importance of NOS in Science Education

The focus of NOS is on the discussion of what science is, how it works, and its relationship with the society. These issues have long been emphasized by science educators. It is fair to say that improving students' understandings of NOS is always the intended goal of science education. However, throughout the history of science teaching, NOS has rarely been explicitly addressed in science textbooks or science classrooms. A significant change occurred in the end of the last century. NOS was explicitly addressed in the National Science Education

Standards (National Research Council, 1996) and similar standards documents from several other countries (McComas & Olson, 1998).

Driver, Leach, Millar, and Scott (1996) suggested five reasons for including NOS in the goal of science education. First, in the utilitarian view, understanding of NOS is necessary for people "to make sense of the science and manage the technological objects and processes they encounter in everyday life" (p. 16). Second, in the democratic view, understanding of NOS is necessary for people "to make sense of socio-scientific issues and participate in the decision-making process" (p. 18). Third, from the cultural perspective, understanding of NOS is necessary for people "to appreciate science as a major element of contemporary culture" (p. 19). Fourth, from the moral perspective, understanding of NOS helps people understand the "norms of the scientific community, embodying moral commitments which are of general value," (p. 19). Fifth, from the science learning perspective, understanding of NOS supports "successful learning of science content" (p. 20). In addition, McComas et al. (1998) pointed out that understanding NOS enhances people's interest in science and decision making ability, as well as helping teachers teach science.

Although NOS has long been advocated by science educators, it was just recently addressed in science curriculum. One possible reason is related to an underlying assumption which assumes students' understandings of NOS can be automatically developed during the process of learning science content or participating in science activities (Bell, Blair, Crawford, & Lederman, 2003). However, students' lack of understanding of NOS, which is supported by overwhelming empirical evidence, suggests that this assumption cannot be held. Based on the findings from several empirical studies (e.g. Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Scharmann, Smith, James, & Jensen, 2005), science educators now widely accept that NOS must be taught explicitly and reflectively (Abd-El-Khalick & Lederman, 2000; Lederman, 2007).

Inclusions of NOS in Science Textbooks and Trade Books

Researchers have extensively examined the inclusion of NOS in science textbooks from a variety of angles. In this section, the related studies are reviewed in three categories: analyses of the overall presentation of NOS, analyses focused on the presentation of specific aspects of NOS, and analyses focused on the integration of NOS and science content.

Overall Presentations of NOS in Science Textbooks

Led by Chiappetta, a group of researchers from the University of Houston established a line of research analyzing science textbooks according to their presentations of the themes of scientific literacy. Garcia (1985) developed a conceptual framework for analyzing earth science textbooks. The themes of scientific literacy were categorized into four aspects: a) science as a body of knowledge, b) science as a way of investigating, c) science as a way of thinking, and d) the interaction among science, technology, and society (STS). Chiappetta, Sethna, & Fillman (1987) developed a quantitative content analysis technique for quantifying major themes of scientific literacy in science textbooks. They adopted Garcia's four categories and made small modifications on the descriptors to make the framework more adaptable to various disciplines of science textbooks. Chiappetta, Fillman, & Sethna (1991a) wrote a 25-page manual to train analysts who might like to use their quantitative analysis technique. With this training manual, their analytical technique and analytical framework became replicable for future studies. By following the same analytical technique and analytical framework, the results are also made directly comparable. The common practice in those studies was having two researchers independently analyze five or ten percent of randomly selected pages from each selected textbook. Inter-rater agreement was calculated to assess the reliability of this analysis technique.

In the 1990s, five studies were conducted utilizing this analytical technique and analytical framework. In this set of studies, Chiappetta, Fillman, & Sethna (1991b) analyzed a life science textbook, an earth science textbook, a physical science textbook, a biology textbook, and a chemistry textbook; Chiappetta, Sethna, & Fillman (1991) analyzed five high school chemistry textbooks, Chiappetta, Sethna, & Fillman (1993) analyzed five middle school life science textbooks, Lumpe & Beck (1996) analyzed seven high school biology textbooks, and Wilkinson (1999) compared eight Australian physics books before Victorian Certificate of Education (VCE) to twelve books after VCE.

The manual for the content analysis was revised in 2004. The analytical framework was changed from scientific literacy to NOS. The four main categories were retained, but the authors appended several descriptors regarding nature of science to all categories. However, integrating the category system of scientific literacy with NOS probably caused some confusion. The authors combined the nature of scientific knowledge into the first category and changed the label of the category from “science as a body of knowledge” to “knowledge produced by science and nature of knowledge.” Consequently, descriptors related to science content knowledge (A. facts, concepts, laws, and principles; B. hypothesis, theories, or models; C. questions asking for recall of information) were mixed with descriptors related to the nature of scientific knowledge (D. tentativeness and durability of scientific knowledge; E. distinctness of scientific knowledge). Supposing a textbook obtained a score, say 60%, in this category, one would have to cautiously distinguish how many are contributed from science content knowledge, and how many are contributed from the nature of scientific knowledge. Fortunately, this problem seems to not extend to the other three categories.

Four more studies were conducted based on the revised manual. Phillips (2006) analyzed twelve middle school science textbooks; Chiappetta & Fillman (2007) analyzed five high school biology textbooks; Lee (2007) examined four high school biology textbooks and Brooks (2008) added five physical science textbooks to the database.

By comparing those conducted in the 1990s and those conducted in the 2000s, some changes can be observed in science textbooks. Most of the analyzed textbooks published in the 1980s and 1990s devoted about 70% in science content knowledge, 20% in scientific inquiry, less than 5% in scientific thinking, and about 5% in STS. As for those textbooks published in the 2000s, science content knowledge got around 50%, scientific inquiry got around 40%, and scientific thinking and STS still maintained less than 10%. Apparently, a significant change occurred with an increased emphasis on scientific inquiry in new science textbooks. Interestingly, the textbooks published in the 1980s and 1990s were all written before the release of the National Science Education Standards (NSES), while the textbooks published in the 2000s were all after NSES. Therefore, this increasing attention on scientific inquiry in science textbooks may reflect the impact of the 1996 published NSES, which has a strong orientation towards scientific inquiry. In addition, another noticeable trend demonstrated in the comparison is that scientific thinking and STS, the two categories which are most related to NOS, were still ignored by science textbook writers.

Besides the studies conducted by Chiappetta and his colleagues, NOS-related textbook analyses have also been conducted by other researchers. The earliest empirical study of textbooks found was conducted by Gibbs & Lawson (1992). They examined the nature of scientific thinking reflected in fourteen college biology textbooks and eight high school biology textbooks. The analyzed textbooks were published between 1985 and 1990, with the exception of one published in 1978. The authors did not provide a coherent conceptual framework nor a detailed description of their analysis process. The main focus of the study was examining how the textbooks address the issues of scientific method, hypothesis, theory, law, and principle. The major findings included: 1) Only a few textbooks mentioned the inherent flexibility of the scientific method. The authors suggested that all textbooks should make this point clear and commit more explanations. 2) Hypothesis was treated as a central component in biology investigations, but three common shortcomings were identified. First, some textbook authors did not know that hypotheses are generated from creative abduction, but stated that hypotheses came from inductive reasoning. Second, in some textbooks, hypothesis is merely defined as a guess or educated guess. Third, some textbooks confused hypotheses with predictions when they gave examples. 3) Theory was addressed in most textbooks. However, many textbooks mistakenly defined theory as hypotheses that have been supported over a long period of time, which is not necessarily true. Moreover, it was also found that biology theories were frequently overlooked or presented as facts in textbooks. 4) Principle and law were rarely defined in textbooks. Many textbooks did not use the terms principle, law, and theory carefully. Those textbooks which explicitly addressed principle, law and theory commonly treated principles and laws as higher level of knowledge than theories. Many textbook writers continue the common misconception that evidence permits the creation of hypotheses which become theories and then theories become laws (or principles), which is similar to the finding of McComas (2003). In sum, the researchers concluded that most textbook writers did not have sufficient understanding of scientific thinking.

Abd-El-Khalick (2008) developed an analysis framework including ten issues in NOS, which are empirical, inferential, creative, theory-driven, tentative, the myth of "the scientific method," scientific theories, scientific laws, social aspects of science, and social and cultural embeddedness of science. He also designed a scoring rubric (see Table 2.1) to provide criteria for calculating an overall score for each textbook. Fourteen high school chemistry textbooks published from 1966 to 2005 were analyzed to examine the trend during the past four decades. A portion of each textbook was selected for analysis. The analyzed chapters or sections were "the scientific method," "the scientific process," "how science works," etc., and the topics related to atomic structure, kinetic molecular theory, and gas laws. It was concluded that analyzed textbooks placed limited attention on NOS. NOS was never a major topic in any of the analyzed textbooks, and none of them covered all issues of NOS in the rubric. Moreover, chronological comparisons displayed that textbook scores remained unchanged or even decreased during the examined four decades. Abd-El-Khalick suggested that there was a complete disconnection between the science textbook publishing system and the needs and opinions of science education community. By comparing textbook authors and publishers, he found that the author was a more important factor than the publisher. He suggested that future research should focus on local and state assessments, evaluations, and textbook authors. A merit of the study is that the scoring rubric provided an overall judgment on textbooks by combining the type of presentation (explicit or implicit) and the quality of presentation (informed or uninformed) together. However, some other important information, such as the length of presentation, was not included in the overall judgment. The structure or the form of the presentation (separated or integrated, contextualized or decontextualized) of NOS was not assessed either.

Table 2.1
Scoring Rubric Used in Abd-El-Khalick et al. (2008)

Point	*Criterion*
+3	Explicit, informed, and consistent representation of the target NOS aspect
+2	Explicit, partially informed representation of the target NOS aspect
+1	Implicit, informed, and consistent representation of the target NOS aspect
0	The target NOS aspect is not addressed
-1	Implicit misrepresentation of the target NOS aspect
-2	Convey mixed explicit and/or implicit messages about the target NOS aspect
-3	Explicit, naive representation of the target NOS aspect

Alshamrani (2008) added to our knowledge of textbooks with his analysis of NOS presentations in seven secondary school physics textbooks which were most widely used in the United States in 2005. By carefully reviewing recommendations from several sources, Alshamrani identified eighteen aspects of NOS, and twelve of them were considered as the most important aspects of NOS and were chosen as the target aspects for analysis. The procedures and protocols for data collection were recorded in detail in a coding guide. The coding guide contains six parts: A) A description and ideal indicators for each of the 12 major aspects of NOS, B) the rules for identifying the simple coding unit, C) the rules and examples for NOS units, D) the definition and the categories for the contexts of NOS presentation, E) how to use the descriptions and ideal indicators of NOS aspects to answer the four research questions, and F) the data recording sheet. To ensure the validity of the coding guide, Alshamrani invited two science educators who specialized in NOS to review and modify the coding guide. The reliability of the content analysis was examined through inter-rater reliability and rate-rerate reliability. The analyses consisted of four aspects: the included NOS aspects, the frequency of NOS inclusion, the contexts for NOS inclusion, and the accuracy of NOS inclusion. The research findings included: A) The number of included NOS aspects in each textbook ranged from five to eleven. The distinction between observations and inferences were addressed in none of the analyzed textbooks. B) The number of NOS elements in each textbook ranged from 41 to 174, i.e. 5 to 23 per 100 pages. Some of the NOS aspects, such as the tentativeness of scientific knowledge, were more frequently presented in textbooks, while some others, such as the subjectivity of scientific knowledge, were less frequently presented. C) About 85% of NOS elements were presented in main texts. The rest were presented in other contexts, such as figures, lab activities, boxed-in sections, and glossary. D) Most of the identified NOS presentations in textbooks were accurate. Overall, only 2.3% NOS elements were inaccurate. However, the percentage of inaccurate NOS elements in each textbook ranged from zero to 9.8%. The strength of the study can be identified in three aspects. First, the conceptual framework was well established. The major aspects were selected from plausible sources and were chosen with pervasive reasons. The conceptual framework is also valuable for future research in NOS related studies. Second, the research procedure was strict and the findings are credible. The content analysis followed the coding guide written by the author made the study replicable. The validity and reliability of the analyses were also carefully examined. Third, the analysis is comprehensive. Unlike many other studies which only focus on one aspect of the presentations of NOS, this study covered several aspects of inclusion of NOS in textbooks. The analyses included the coverage, frequency, context, and accuracy of inclusion of NOS in textbooks. The findings provided a comprehensive overview of how NOS was presented in the analyzed textbooks. However, one aspect was not included in the analysis. That is, the study did not examine how the presentations of NOS are located within the textbooks. Do they all aggregate in a stand-alone chapter which focuses on the discussion of NOS, or are they spread out in different chapters? This is not difficult to examine, but it is an important feature in terms of the inclusion of NOS in science textbooks. The difference between the separated presentations and the integrated presentations of NOS is important for the given analyses. The coverage, frequency, context, and accuracy of inclusions of NOS in NOS-specific chapters maybe different from those embedded in science content. For example, the number of NOS elements per 100 pages would be dramatically different in those two situations. In sum, it would be better if the study also provided an analysis of this aspect.

Irez (2009) examined five commonly used Turkish 10th-grade biology textbooks, published in 2006 or 2007, to examine the nature and the quality of treatment given to NOS. The methodology of the study was referred as “ethnographic content analysis.” The analytic procedure consisted of four steps. 1) Coding of the data, by which sentences providing information about NOS were marked with numbers. The product of this step was coded sentences. 2) Theme generation. Explanations regarding the same NOS aspects were grouped together. There were several predetermined themes guiding this step of the analysis, but others also emerged and were included during the analysis. At the end of this process, 11 themes regarding NOS were identified. Some of the statements were placed within more than one theme as they applied to all these themes. The product of this step was categorized explanations. 3) Summarizing. Detailed explanations were summarized into single sentences or phrases. The product of this step was summarized statements. 4) Generation of cognitive maps. The main ideas regarding NOS for each textbook were organized into the form of cognitive maps. The product of this step was cognitive maps.

Rich descriptive data were generated from this procedure. Although all textbooks devoted six or seven pages for the sections related to NOS, NOS was explicitly described only in the first unit of one textbook. All textbooks started describing science from scientific enterprise, and science was described as a body of knowledge. Textbook authors also emphasized the “objectivity” in science, and this characteristic of science was confused with the characteristic of scientists. Irez argued that the textbook authors mixed up “objectivity in science” and “objectivity of scientists,” and overlooked the role and function of scientific community in making science objective. He felt that the authors wrongly attempted to list the characteristics of scientists, and this was misleading in presenting the image of science. All the textbooks presented scientific method as a series of steps that should be followed, thus establishing one of the central myths of science. Most textbooks were good at presenting hypotheses and predictions, but all the textbooks were misleading in how they presented theories and laws. For example, some authors presented scientific theories as supported hypotheses, and all the authors presented scientific laws as having developed from theories. Irez suggest that teacher education, curriculum, and curriculum materials (including textbooks) should be treated as a whole to advance the quality of science education.

There are also some other related studies. Knain (2001) analyzed three Norwegian 8th grade science textbooks to examine the ideologies presented in school science textbooks. He found that the analyzed science textbooks generally present scientists as individual inquirers and omit the social interactions within science communities. Knain also pointed out that science textbooks only focused on science content knowledge and failed to present science as an enterprise in contemporary society. He suggested that science textbooks served well in providing scientific knowledge but less suitable for preparing students as future adults, an aspect which demands an understanding of NOS and socio-scientific issues.

Presentations of Specific Aspects of NOS in Science Textbooks

McComas (2003) examined 15 secondary school biology textbooks to find out how they presented “law” and “theory,” and how they distinguished the terms. Firstly, the author designed a six-part model definition for “law” and “theory” based on a review of the literature of the philosophy of science with special reference to biology. Then, two analysts worked independently to analyze the textbooks. Finally, they compared and discussed their results to ensure reliability. The data revealed that the definitions of “law” and “theory” in biology textbooks were incomplete. Only 3 of 15 textbooks provided definitions (even vague inclusion of any element is counted) of “law.” The treatment of theory was better, but was still incomplete. About half of the books introduced how theories are validated and supported, but only a few of them addressed that theories are broad unifying statements and theories can be used to make predictions. Moreover, several books presented theories misleadingly. McComas concluded that all the analyzed books provided unacceptable views of laws and theories. He suggested that this was because of the confusing common use, mathematical use and scientific use of the terms, or because the textbooks copy from each other.

Presentations of Integrated NOS and Science Content in Science Textbooks

Some researchers were not only interested in how NOS was presented in science textbooks, but also interested in how it was integrated with specific science content. Several studies were identified in this group of research.

Niaz (1998) developed an analytical framework (see Table 2.2) based on history and philosophy of science (HPS) to examine how college chemistry textbooks describe the atomic structure. Based on the evaluation of 23 college chemistry textbooks, he concluded that most of the textbooks seemed to emphasize experimental details but without historical framework or philosophical perspective. Under the same framework, Rodr ǵuez & Niaz (2002) compared 23 new (1970–1992) and 30 old textbooks (1929–1967), and found that the new textbooks improved slightly as compared to old ones, but still lacked a philosophy of science perspective. Rodr ǵuez

& Niaz (2004) applied the same analytical framework in evaluating 39 college general physics textbooks. Based on the comparison of the textbooks in different periods, they found mean scores of textbooks decreased after 1991. It appears that there is less emphasis on HPS in newer general physics textbooks.

Table 2.2
Niaz's (1998) Analytical Framework for the Evaluation of Textbook Presentations of the Formulation of Atomic Models

- T1 – Cathode rays as charged particles or waves in the ether.
- T2 – Determination of mass-to-charge ratio to decide whether cathode rays were ions or a universal charge particle.
- R1 – Nuclear atom.
- R2 – Probability of large deflections is exceedingly small as the atom is the seat of an intense electric field.
- R3 – Single/compound scattering of alpha particles.
- B1 – Paradoxical stability of the Rutherford model of the atom.
- B2 – Explanation of the hydrogen line spectrum.
- B3 – Deep philosophical chasm.

Note: T = Thomson; R = Rutherford; and B = Bohr.

Niaz (2000) developed an analytical framework based on HPS to examine how college chemistry textbooks describe the kinetic theory and related issues. Six criteria were created from this analytical framework (see Table 2.3). He evaluated 22 freshman/college level textbooks using these criteria, and judgments were made in three levels: "satisfactory", "mention", or "not mention". Obtained results show that most analyzed textbooks ignore some parts of scientific progress, and few textbooks utilized a historical framework to present the development of the kinetic molecular theory. Some textbooks present historical details in the form of general introduction of scientists. Niaz argued that these presentations lacking the philosophy of science framework could not provide insight to students as how scientists work and how scientific theories are developed. He concluded that textbooks ignore historical details due to a lack of a history and philosophy of science framework. No detailed information of analysis procedure was presented, and neither reliability nor validity was addressed.

Table 2.3
Niaz's (2000) Analytical Framework for the Evaluation of Textbook Presentations of the Formulation of the Kinetic Molecular Theory of Gases

1. Maxwell's simplifying (basic) assumptions
2. Inconsistent nature of Maxwell's research program
3. Maxwell's statistical considerations
4. Van der Waals' contribution: Reducing/modifying basic assumptions
5. Kinetic theory and chemical thermodynamics as rival research programs
6. From 'algorithmic mode' to 'conceptual gestalt' in understanding the behavior of gases

Guisasola, Almudí & Furió (2005) combined common characteristics of NOS and the history of development of the magnetic field theory to generate an analytical framework (Table 2.4) for assessment. Using these criteria, they analyzed how NOS was integrated into science content knowledge. Based on the evaluation of 30 college physics textbooks (published in 1972 to 1999), they concluded that the majority of books present the theory of the magnetic field in a non-problematic, non-historical, 'linear accumulation' manner, and NOS is not mentioned in the textbooks or is only mentioned in an implicit way.

Table 2.4
Guisasola, Almudí & Furió's (2005) Analytical Framework for the Evaluation of Textbook Presentations of Development of the Theory of Magnetic Field

1. The problem of the interpretation of magnetic interaction
1.1. At least two examples are used to get an idea of the problems that will be tackle with the introduction of the magnetic field.
1.2. At least one task or problematic situation is proposed whose treatment justifies the introduction of the different sources of stationary magnetic field.
1.3. At least one problematic situation is proposed in which the unity of the sources of the stationary magnetic field is made evident.
2. The construction of the magnetic field theory
3. The processes of unification
4. Critical view of the theory

The above cited studies examined how NOS was presented in an integrated form with science content knowledge. Although the findings are valuable, the researchers did not show a uniform routine in generating analytical frameworks for assessing the contextualizing of NOS into science content knowledge. In other words, all the mentioned studies in this section utilized science content sensitive analytical frameworks, and their criteria were highly related to specific science content knowledge. Therefore, these analytical frameworks cannot be transferred to other science topics.

Presentations of NOS in Science Trade Books

A few studies have been conducted to analyze the inclusion of NOS in science trade books. Abd-El-Khalick (2002) randomly selected four middle-grade nonfiction science trade books from NSTA recommended science trade books for the years 2000 and 2001, and then analyzed those books under the framework of the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1994) and the National Science Education Standards (National Research Council, 1996). All the books were read three times for coding, categorizing and rechecking. After the reading, the researcher generated themes from the analysis results for each book. In the analysis procedures, NOS ideas that were either explicitly presented or implicitly conveyed were all considered. The results revealed that none of the four analyzed books had any explicit instruction in NOS. Science was narrowly presented as a body of knowledge in all the books. The author argued that student experiences with such books contributed to their development of naive ideas about NOS.

Ford (2006) randomly selected 44 nonfiction science trade books from a suburban public library to analyze the explicit and implicit representations of science. By reading through the books, she identified all the explicit passages from all the books. As a result, 379 passages were identified in total and 11 books were found contain no explicit presentation of NOS. Then she coded the passages according to involved themes of NOS. The analyzed trade books generally represent science as facts and scientists as knowers of facts. Scientific practices were mostly represented as observations and experiments. Some also describe scientific methods as a universal step-by-step procedure. Ford suggested that science trade books can be used to convey representations of NOS, but only a few of them can be served as standalone resource, and the majority of them should be used with critical examination.

Summary of Literature on NOS and Science Education

NOS is a field of study which integrates philosophy, history, sociology, and psychology of science. In K-12 science education, the major elements of NOS recommended by science educators include subjectivity, creativity, tentativeness, empiricalness of science, as well as social and cultural embeddedness, the absence of a universal step-wise scientific method, the distinction between laws and theories, the distinction between observations and inferences, and the distinction between science and technology. NOS has now been explicitly addressed in science education standards documents. The purposes and utilities of including NOS in science curriculum include preparing students to be better science learners, decision makers, and future citizens. However, understandings of NOS cannot be automatically formulated from science content or scientific inquiry. Rather, the teaching of NOS must be explicit and reflective. Unfortunately, content analyses revealed that presentations of NOS in science textbooks and science trade books are generally insufficient and inaccurate.

In the studies examined here, the presentation of NOS in science textbooks and trade books was evaluated in different aspects through different ways. McComas's (2003) assessment was focused on specific elements of NOS, while the majority of assessments were more general. Their examinations included not only what was presented (informed or misunderstood), but also how it was presented (explicit or implicit). Abd-El-Khalick's (2008) examination was the only study which provided an overall quantitative judgment. Irez (2009) applied ethnographic content analysis in assessing science textbooks, and rich description was obtained. The problems identified in science textbooks were also observed in science trade books. Based on the above reviewed studies, we can conclude that those common misunderstandings of NOS among teachers and students also happen with many authors of science textbooks or trade books.

Text Classification

This section provides an introduction of the text mining technique. First, a brief introduction of text mining and text classification is provided. Then, detailed description is given to preprocessing procedures and weighting schemes of text classification.

Text Mining

Text mining is a computer-assisted text analysis technique which "seeks to extract useful information from data sources through the identification and exploration of interesting patterns" (Feldman & Sanger, 2006, p. 1). Data mining, which also aims to extract patterns from data sources, is a technique similar to text mining. However, the data sources used in data mining are structured datasets, but in text mining tasks are unstructured textual data.

In data mining, structured data refer to the data that can be presented in a spreadsheet, or a tabular format. In this form of data presentation, rows are data records, or sometimes referred to as observations, instances, or cases; columns are variables, or sometimes referred to as attributes, features, measures, fields, or dimensions. Each data cell corresponds to a measure of a feature within an instance. Data in this form can be easily manipulated in mathematical processes, especially convenient for matrix algebra.

However, unstructured textual data in the form of natural language documents cannot be directly processed by mathematical means. Therefore, preprocessing operations must be performed to prepare and transform textual data to numerical data before mathematical processes. After documents are transformed to their numerical representations, mathematical processes can be undertaken for a variety of text mining tasks.

Text mining is a broad term which includes several different types of analysis tasks. The following is a list of some common types of text mining tasks (Feldman & Sanger, 2006; Weiss, Indurkhya, & Zhang, 2010).

- *Information retrieval*: identify relevant documents from a set of documents according to the query.
- *Information extraction*: identify relevant segments (sentence, words) from documents according to the query.
- *Information filtering*: filter out irrelevant documents according to the query.
- *Document/text classification/categorization*: categorize documents based on a set of given labels, i.e. assign label(s) to documents. It is also called supervised learning.
- *Document clustering*: categorize similar documents based on a given similarity measure, i.e. separate documents to groups. It is also called unsupervised learning. Document

clustering is different from document classification because no predetermined label is defined before the analysis. However, it discovers hidden themes and generates labels at runtime.

Text Classification

Text classification is one sort of text mining task which classifies documents with the classification model trained in a machine learning process. Because the labeled examples are provided as part of the machine training regime, this approach is also called supervised learning. Based on the training data, different sorts of algorithms can be used to build predictive models. The performance of the models is generally evaluated with cross validation between randomly assigned training datasets and test datasets.

The progress of a general text classification task includes following steps: pre-processing, feature selection, machine training, cross validation, and classify new documents. These procedures are briefly described as follows:

Preprocessing. Preprocessing is a set of tasks which prepare textual documents and convert them to numerical representations. The first step is collecting all the digital documents into the corpus. As needed, documents can also be segmented into sections, passages, or sentences. After the corpus is established, two optional procedures, *stemming* and *stop-word removal*, can be implemented to reduce the dimensionality of the dataset. Finally, features are weighted by a certain numerical measure to obtain numerical representations of the documents. The details of preprocessing procedures are introduced in the next section.

Feature selection. Based on a certain weighting measure, only part of the features will be selected for further analysis from all available features. Feature selection is a dimension reduction procedure, which is supposed to use a subset of features to represent the documents. Feature selection may have a wide range of impact on the performance of prediction. It is not required for text classification. On the other hand, it can be conducted more than once to obtain best representative features.

Machine learning. After the numerical representations of the labeled documents are obtained, they are ready to be used in training the classifier, i.e. the classification model. The nature of machine learning is similar to using exemplar data to solve the regression equation in regression analysis. Several kinds of algorithms, such as support vector machines (SVM), naïve Bayes models, and evolutionary algorithms, have been widely studied. However, SVM is commonly regarded as the state of the art in text classification.

Cross validation. To obtain the best performance, the predictive model is evaluated through cross validation. That is, the documents in the corpus will be randomly split into two or more datasets. One dataset will be used to test the model, and other datasets will be used to train the classifier. After the classification model is established with the training datasets, it is validated with the testing dataset.

Classify new documents. After a classification model is established, it can be implemented to classify new documents. This procedure is similar to the use of a regression model to make predictions after the parameters of the model are found.

Preprocessing Procedures

Preprocessing procedures are conducted before training the classifier. The first step of the preparation procedure is to collect all the digital documents into a dataset, i.e. the corpus, waiting future processing. Before further operations, an optional procedure that can be conducted is *segmentation*, which slices document into sections, passages, or even sentences. In some cases, the lengths of raw documents vary greatly in the original dataset. It would be helpful if the documents are adjusted to similar lengths. Slicing long documents, e.g. books, into passages also increase the quantity of instances in the dataset, which could be beneficial for both training and testing.

A document in the corpus is equivalent to an instance in a dataset. Each document is considered as “a bag of words.” The most commonly used features in text mining tasks are the terms (words or phrases) in the textual documents. Thus, each unique term within the document is called a “feature” in the terminology of text mining. Therefore, texts in the documents will be firstly broken into words. This operation is called *tokenization*. At the meantime, the special characters, punctuations, numbers, and extra white spaces are removed from the documents. All the letters are also transformed to their lower-case forms by a *down-case* procedure. Table 2.5 demonstrates the product of the tokenization procedure. For the purpose of demonstration, the corpus only consists of three documents and each document only contains a sentence.

Table 2.5
An Example of Tokenization in Preprocessing

	Raw Document	**Tokenized Document**
1	To be, or not to be: that is the question.	to be or not to be that is the question
2	It was the best of times; it was the worst of times.	it was the best of times it was the worst of times
3	I would rather live with a good question than a bad answer.	i would rather live with a good question than a bad answer

Twenty-four distinct terms, i.e. features, can be identified from the corpus[1]. In a real-world study the corpus will be much larger, so the number of features will be far larger than the above example. It can easily achieve a number of tens of thousands. Each feature, i.e. distinct term, will become a dimension when the documents are transformed into their numerical representations. Therefore, a large number of features will lead to a high dimensionality problem in future mathematical operations. This high dimensionality is a common characteristic in text mining tasks. At this stage, stemming and stop-word removal are commonly used procedures to reduce the dimensionality.

Table 2.6
An Example of Stemming in Preprocessing

	Tokenized Document	**Stemmed Document**
1	to be or not to be that is the question	to be or not to be that is the question
2	it was the best of times it was the worst of times	it is the good of time it is the bad of time
3	i would rather live with a good question than a bad answer	i will rather live with a good question than a bad answer

The *stemming* procedure changes words to their basic forms and removing suffixes, e.g. transformation of “learning” to “learn.” In the previous example, “was” can be transformed to “is”, “would” can be transformed to “will”, “best” can be transformed to “good”, “worst” can be transformed to “bad”, “times” can be transformed to “time”. By doing so, the variations of a same word are merged to the basic form of the word, and the number of distinct terms becomes smaller. Therefore, the dimensionality of the dataset is reduced by the stemming process.

[1] The 24 distinct terms are “a”, “answer”, “bad”, “be”, “best”, “good”, “i”, “is”, “it”, “live”, “not”, “of”, “or”, “question”, “rather”, “than”, “that”, “the”, “times”, “to”, “was”, “with”, “worst”, and “would.”

Following the previous example, the stemmed documents are listed in Table 2.6. The number of distinct terms is reduced from 24 to 20.

The *stop-word removal* procedure eliminates the most commonly used words (e.g. a, an, the, he, she, we, etc.) from the documents. In the previous example, “a”, “be”, “i”, “is”, “it”, “not”, “of”, “or”, “rather”, “than”, “that”, “the”, “to”, “with”, “will” can be considered as stop-words. Following the previous example, the product of stop-word removal is listed in Table 2.7. The number of distinct terms is reduced from 20 to 6[2].

Table 2.7
An Example of Stop-word Removal in Preprocessing

	Stemmed Document	Stop-word Removed Document
1	to be or not to be that is the question	question
2	it is the good of times it is the bad of times	good time bad time
3	i will rather live with a good question than a bad answer	live good question bad answer

Although stemming and stop-word removal can be used to reduce the dimensionality of the dataset, they are optional for a text mining task. The impact of these procedures on the performance of analysis is not straight forward, and it varies depending on the characteristics of the analyzed documents. Therefore, in most cases the impact of these procedures can only be found through trail-and-error experiments.

Table 2.8
An Example of Numerical Representations in Preprocessing

Document *	Features					
	answer	bad	good	live	question	time
1	0	0	0	0	1	0
2	0	1	1	0	0	2
3	1	1	1	1	1	0

* Document 1 = “To be, or not to be: that is the question.”
Document 2 = “It was the best of times; it was the worst of times.”
Document 3 = “I would rather live with a good question than a bad answer.”

[2] The 6 distinct terms are “answer”, “bad”, “good”, “live”, “question”, and “time.”

The central task of preprocessing operations is to prepare natural language documents for numerical analysis, i.e. to transform textual documents to their numerical representations. To do so, features are weighted with a certain numerical measure. A quick measure of the features is the times of their occurrence in each document. Following the previous example, the numerical representations of the documents are listed in Table 2.8. Several other ways of weighting do exist, and they are introduced in the next section.

Weighting Schemes

To obtain numerical representations of the documents, terms are weighted according to their frequencies of occurrence in the documents. Several weighting schemes, such as *binary*, *tf* (term frequency), or *tfidf* (term frequency – inversed document frequency), are usually used in classification tasks. The impact of different weighting schemes on the performance of prediction is complicated, because it depends on the characteristic of the dataset (Yang & Chute, 1994). In the *binary* weighting scheme, a term is simply measured by whether it appears in the document, but the time of occurrence is not considered. In the *tf* weighting scheme, a term is measured by its frequency of occurrence in the document. In the *tfidf* weighting scheme, the weight of each term in the document is mathematically defined as following:

$$w = [1 + \log(tf)] \cdot \log(\frac{n}{1 + df})$$

where *w* is the weight of a term in a document, *tf* is the time of occurrence of this term in the document, *df* (document frequency) is the number of documents in which this term occur at least once, *n* is the number of documents. Because the length of the documents may vary, the weights of the terms are normalized by the following formula:

$$w' = \frac{w}{\sqrt{\sum w_i^2}}$$

where the denominator, which represents an average distance of a document in the vector space, is the square root of the sum of the squares of all the weights in the document which contains the weighted term.

Gaps in the Current Literature

First, popular science writing is generally overlooked by researchers as adjuncts to science instruction generally and with respect to NOS specifically. Dozens of studies have been undertaken to analyze the presentations of NOS in science textbooks. However, the presentation of NOS in popular science writing has not been thoroughly studied. On the other hand, it can be reasonably assumed that popular science writing has more varieties than science textbooks, because science textbooks have been accused of being too similar to each other. Moreover, science trade books for adults are more overlooked than children's books, even though they are far more informative and probably contain more presentations of NOS. Similarly, science magazines are also overlooked in science education research.

Second, although researchers have provided analyses on science textbooks and popular science writing, there is a lack of an efficient way to identify useful information from educational materials without resorting to small samples and randomization. Presentation of NOS is a typical example in such cases. A reusable method of locating discussions of NOS from a book would be more practically valuable than an overall judgment on the presentation of NOS in the book. This study will not only show how NOS is presented in popular science writing, but also provide an effective and efficient method of locating NOS presentations from popular science writing. This study will also demonstrate the power and potential of the text mining technique in analyzing educational materials, which has not been widely recognized by the educational research community.

CHAPTER III

RESEARCH METHOD

The nature of science (NOS) is a central element of science literacy. Previous studies revealed that the presentations of NOS in science textbooks and science trade books were generally insufficient and inaccurate. This study examined the frequency, context, coverage, and accuracy of NOS presentations in popular science writing for adults and young adults. The study contains two major analyses. First, a computer-assisted quantitative analysis was performed to label each paragraph according to the existence of explicit inclusion of NOS. Second, for each paragraph which has been labeled as having explicit NOS inclusion in the computer analysis, a human analysis was conducted to examine the embedded NOS element.

Research Questions

The following questions were addressed in the study:

1. How accurate is the text mining approach in identifying inclusion of NOS in recent popular science writing?
2. To what extent does the 12 category framework chosen as the analytic tool correspond with instances of the NOS in popular science writing?
3. With what frequency do explicit presentations of NOS appear in recent (past 10 years) popular science books and magazine articles (called popular science writing)?
4. Within what contexts do explicit presentations of NOS appear in recent popular science writing?
5. With what frequency do explicit presentations of NOS elements appear in recent popular science writing?

6. How accurately are NOS elements presented in recent popular science writing?

Nature of the Study

In nature this is a mixed-method content analysis study. The study contains two major analyses. The first analysis, which applied the text mining technique to label each paragraph according to the existence of explicit inclusion of NOS, is a quantitative content analysis. The second analysis, which examined the embedded NOS element in each paragraph which has been labeled as having explicit NOS inclusion in the first analysis, is a qualitative content analysis that must be conducted with human interpretation.

Analyzed Documents

The educational materials studied were influential popular science writing. The target documents for analysis in the study were defined with the following criteria: 1) This study focused on popular science writing for adults and young adults. That is to say, popular science writing for children or pre-high school students were not included in the scope of the study. This is because the writing style of those texts could be dramatically different from the writing style of texts for adults and young adults, and different training materials would be required for analyzing them with the text mining technique. 2) This study focused on two types of popular science writing: science magazines and general science trade books, because other types of popular science writing, such as science blogs, are difficult to delineate. 3) To set a boundary for the time frame, this study focused on the popular science writing published in the last ten years, i.e. from 2001 to 2010. This is because the notion of NOS has been dramatically changed in the last half century and reached a relatively stable status in the last decade.

Based on the above criteria, this study selected four groups of documents for analysis: 1) *Scientific American* magazine issues from 2001 to 2010, 2) *Discover* magazine issues from 2001 to 2010, 3) the winners of the *Royal Society Winton Prize for Science Books* from 2002 to 2011, and 4) the listed books in National Science Teacher Association's (NSTA) *Outstanding Science Trade Books for Students K-12* from 2002 to 2011. Prizes awarded from 2002 to 2011 correspond to books published from 2001 to 2010.

Although there are no publicly accessible data indicating the number of subscribers for each science magazine, *Scientific American* and *Discover* magazine are considered by many to be two of the most popular ones. As for science trade books, ideally it would be best if the analysis can be conducted on the most influential popular science books. However, there is no authoritative resource regarding the influence or popularity of popular science books. Some resources, such as book selling websites (e.g. Amazon, Barnes & Noble), do provide ranks of bestselling science books, but they do not separate popular science books from other science-related books, such as science textbooks, health books, or even the APA manual. Therefore, this study used awards as reference in selecting science trade books. There are also some book prizes, such as the National Book Awards and the Pulitzer Prize, but they do not specifically address science books. In this study, a sample of popular science books were selected according to the Royal Society Winton Prize for Science Books and the National Science Teacher Association's (NSTA) list of Outstanding Science Trade Books for Students K–12.

The Royal Society Winton Prize for Science Books is the most legitimate reward for popular science books. The prize is given to general science books for adults, which are available to buy in the UK. The Royal Society nominates and awards the Royal Society Prizes for Science Books every year for the previous year's best general science books from 1988. Two prizes are awarded. Royal Society Young People's Book Prize is given to the best science writing for children. Royal Society Winton Prize for Science Books is given to general science books for adults. Since science trade books for adults and young adults are the focus of the study, only the Royal Society Winton Prize for Science Books will be considered. This study included the 10 winners of the prize which were awarded from 2002 to 2011.

The list provided by NSTA includes science trade books for K-12 students, but it also provides guidelines regarding the reading level for each book. This study only included the 42 books at the advanced reading level, i.e. for 9-12 grade students, in the lists from 2002 to 2011.

Research Procedure

The study consisted of the following major steps.

1. Collect training examples. Positive training examples (documents have explicit inclusion of NOS) and negative training examples (documents have no explicit inclusion of NOS) were collected for machine learning.
2. Train the classifier. After the examples were obtained, the machine learning process was conducted to establish a classification model, which was used to categorize popular science writing according to their inclusion of NOS.
3. Validate the classifier. The classification model was first cross validated through the randomly assigned training dataset and testing dataset. Moreover, the classifier was also validated with labeled documents including benchmark statements from science education standards document and the first issue of 2012 *Scientific American*.

4. Collect and analyze targeted documents. A set of popular science books and magazines, which are described in the previous section, were collected for analysis. The documents were analyzed according to the inclusion of NOS with the trained classifier.
5. Collect and analyze paragraphs which were identified as having explicit inclusion of NOS. Human analysis was conducted to reexamine the inclusion of NOS in these passages. False positive passages were identified and removed, while only true positive passages were retained for further analysis. Based on Alshamrani's (2008) coding guide, each paragraph was read again to determine the included NOS elements and the accuracy of NOS presentations. Two analysts independently analyzed the paragraphs to check for inter-rater reliability.

The two most important steps in the computer analysis, training and classification, were performed with the computer program LIBLINEAR 1.8 (Fan, Chang, Hsieh, Wang, & Lin, 2011). All the other steps of computer analysis were performed with self-written Visual C#.NET programs.

Evaluating the Performance of the Classification Model

The performance of the classification model was measured at two stages. First, cross validation was conducted on training examples. Second, the model was evaluated with labeled documents.

Cross Validation for Text Classification

N-fold cross validation is a commonly used approach in evaluating the performance of a classification model. Example documents are randomly spliced into N even data sets, and then the evaluation procedure is conducted for the N datasets. Each time, one dataset is used for testing and the other N-1 datasets are used for training, and the accuracy is calculated. By conducting the evaluation procedure N times, N accuracies are obtained and then are averaged to obtain an overall accuracy of the cross validation. In the current study, 5-fold cross validation was conducted.

Ensuring the Validity of the Classification Model

To ensure the validity of the classification model, the model was tested with a set of new documents. In this study, the labeled documents consisted of two groups of texts.

The first group of texts was collected from science education standards. In science education standards, students' learning objectives are expressed in bullet points. For example, in each chapter of *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1994), the learning objectives are stated after "By the end of the x grade, students should know that . . ." These statements each consists of one sentence, and each expresses one idea for students to learn. Obviously, the benchmark statements from the NOS chapter all explicitly address NOS and should be labeled as positive. In contrast, the statements from science content chapters do not explicitly address NOS and should be labeled as negative. Some other chapters which are neither NOS or science, such as Chapter 2 (The Nature of Mathematics) and Chapter 3 (The Nature of Technology), were excluded from the study. In this study, testing was conducted at the passage level, so every three statements were aggregated into passages in validating the classification model.

The second group of texts was collected from the first issue of *Scientific American* from year 2012. For purpose of testing, this issue was specifically selected from outside of the target documents. A human analysis was conducted to label the passages before they were used for validating the classification model.

Analyzing the Context of NOS Presentations

To analyze the context of NOS presentations, popular science magazines and popular science trade books were treated in two different ways. For popular science magazines, the articles containing the identified NOS presentations were located, and then the sections containing those articles were identified. The number of NOS presentations from each section of the popular science magazines was counted and reported.

For popular science books, the pages containing the identified NOS presentations were located, and then the distribution of NOS presentations in each popular science books was visually represented with a histogram-like diagram. The x-axis represents the page number from each document, while the y-axis represents the frequency of the paragraphs which explicitly address NOS in each page. Some hypothetical distributions are provided in Figure 3.1.

A B C

Figure 3.1 Examples of visualizations of the distribution of NOS presentations.

As depicted in Figure 3.1, NOS inclusions in book A are almost evenly distributed. While in book B NOS inclusions are aggregated in the beginning, and in book C NOS inclusions are aggregated around the third quartile. For all three examples the number of NOS occurrences per page is only one or zero, but this will vary in reality allowing for a y-axis.

Analyzing NOS Elements

After the paragraphs which explicitly address NOS are identified from the documents, the manual analysis was conducted following Alshamrani's (2008) conceptual framework and coding guide. By carefully reviewing recommendations from several sources, Alshamrani identified eighteen aspects of NOS, and twelve of them were considered as the most important aspects of NOS having been cited by the majority of experts. These twelve aspects (see Table 3.1) were also chosen as the target aspects for analysis in this study.

Table 3.1
NOS Elements in Alshamrani's (2008) Conceptual Framework

1. Scientific knowledge is not entirely objective
2. Scientists use creativity
3. Scientific knowledge is tentative but durable
4. Scientific knowledge is socially and culturally embedded
5. Laws and theories are distinct kinds of knowledge
6. Scientific knowledge is empirically based
7. The absence of a universal step-wise scientific method
8. The distinction between observations and inferences
9. Science cannot answer all questions
10. Cooperation and collaboration in development of scientific knowledge
11. The distinction between science and technology
12. The role of experiment in science

The procedures and protocols for data collection were carefully described in a coding guide. The coding guide contains six parts: A) A description and ideal indicators for each of the 12 major aspects of NOS, B) the rules for identifying the simple coding unit, C) the rules and examples for NOS units, D) the definition and the categories for the contexts of NOS presentation, E) how to use the descriptions and ideal indicators of NOS aspects to answer the four research questions, and F) the data recording sheet. Following the coding guide, each collected paragraph will be evaluated for the inclusion and accuracy of NOS elements.

Although this study adopted Alshamrani's (2008) conceptual framework as a foundation for analyzing NOS elements, the conceptual framework was revised during the analysis. The need for modifying the existing conceptual framework was based on the fact that Alshamrani's (2008) conceptual framework was developed for analyzing science textbooks, while this study was focused on the analysis of popular science writing. Science textbooks and popular science writing serve different purposes and cover different content. It is expected that they might cover different NOS elements. Therefore, a NOS framework for science textbooks may need adjustments to be implemented in the analysis of popular science writing.

CHAPTER IV RESULTS

Research Question One: Accuracy of Computer Analysis in Identifying Explicit Presentation of NOS in Recent Popular Science Writing

Before analyzing the targeted documents, a preliminary study was conducted to find the best fit of training examples, passage length, and feature selection on the classification task. Evaluation of the performance of the classifier was conducted with both cross-validation and testing on new documents.

Training Examples

Because the major task of text classification in the study was to separate NOS texts from science texts, it was assumed that the most appropriate positive examples (i.e. documents having explicit inclusion of NOS) would be philosophy of science books, while negative examples (i.e. documents having no explicit inclusion of NOS) would be science textbooks. Therefore, in the process of machine learning, sixteen introductory books on philosophy of science were used as positive examples and twelve science textbooks were used as negative examples. With these training examples, initial results were obtained with an overall accuracy of 0.82 (see Table 4.1).

However, validating the classifier by examining the identified positive passages within new documents found that those identified positive passages included a large portion of implicit inclusion of NOS rather than explicit inclusion of NOS. The reason is, most philosophy of science books include a large portion of history of science as examples for introducing NOS. Those descriptions are not the explicitly addressing of NOS, but they implicitly include NOS-related ideas. Nevertheless, this study focused on explicit inclusion of NOS, so it was expected that the identified positive passages must include explicit addressing of NOS.

Therefore, positive training examples were changed to fit with the goal of the study which focused on explicit addressing of NOS. Around a hundred NOS-related articles, which mostly came from the reading list of a graduate NOS course, were selected as positive training examples. To maximize the accuracy, all the passages were manually reviewed and only NOS passages were included into training examples.

Table 4.1

The Effect of Changing Training Examples on the Performance of Classifying Passages According to the Inclusion of NOS

Testing Documents	N		Accuracy	
	Positive	Negative	Pre[1]	Post[2]
Benchmark Chapter 1 The Nature of Science	25	0	0.84	0.88
Benchmark Chapter 4 The Physical Setting	0	64	0.95	1.00
Benchmark Chapter 5 The Living Environment	0	38	1.00	1.00
Benchmark Chapter 6 The Human Organism	0	37	0.95	1.00
Benchmark Chapter 7 Human Society	0	34	0.53	1.00
Benchmark Chapter 8 The Designed World	0	39	0.87	1.00
Benchmark Chapter 9 The Mathematical World	0	38	0.77	0.92
Scientific American 2012 Issue 1	2	381	0.79	0.99
Overall	27	632	0.82	0.98

Note: The validation was conducted with the passage length of 400 words in training documents and with no feature selection in the preprocessing.

[1] Accuracy Pre: accuracy obtained with the original training examples

[2] Accuracy Post: accuracy obtained with the modified training examples

In addition, the data set of negative training examples was extended. The validation on the new documents found that passages related to law, politics, economics, culture, anthropology, sociology, mathematics, engineering, and computer technology were frequently misclassified as positive. It may because these topics were considered as closer to positive training examples over negative training examples. Therefore, several online books in these fields were added into the negative examples. The final data set of the negative training examples included around sixty online books.

The classification model was trained with the new training examples. New results from classifying the same labeled documents displayed improvement in reducing both false positive and false negative classifications (see Table 4.1).

By comparing the results obtained from initial training examples and modified training examples, it was shown that changing positive training examples and adding new negative training examples improved the performance of the classification model. The increase of accuracy on negative documents was especially significant.

Passage Length

Training examples were segmented into passages before the process of machine learning. A wide range of passage lengths of training examples were tested to find the passage length which generates best performance in classification.

Table 4.2
Effects of Passage Length on the Performance of Classification

Testing Documents	Accuracy (with passage length = ? words)								
	100	200	400	600	800	1000	2000	3000	5000
BC 1 The Nature of Science	0.76	0.80	0.88	0.88	0.92	0.88	0.72	0.72	0.48
BC 4 The Physical Setting	1	1	1	1	1	1	1	1	1
BC 5 The Living Environment	1	1	1	1	1	1	1	1	1
BC 6 The Human Organism	1	1	1	1	1	1	1	1	1
BC 7 Human Society	1	1	1	1	1	1	1	1	1
BC 8 The Designed World	1	1	1	1	1	1	1	1	1
BC 9 The Mathematical World	0.97	0.95	0.92	0.92	0.92	0.92	0.92	0.92	0.95
SA 2012 Issue 1	0.99	0.98	0.99	0.98	0.98	0.98	0.99	0.99	0.99
Overall	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.97

Note: BC = Benchmark Chapter, SA = Scientific American
The validation was conducted without the implementation of feature selection in preprocessing.

As depicted in Table 4.2, passage length has no significant effect on the accuracy of validation on negative testing documents. However, there seems to be a bell-curve relationship between the passage length and the accuracy achieved with the positive testing documents, which achieved the highest point when passage length was 800 words. Therefore, in further analysis, training examples were segmented into passages with length of 800 words.

Feature Selection

Feature selection was conducted based on the minimum of document frequencies (DF). For instance, if DF_{min} is defined as 3, only terms that occur in at least 3 documents will be used in analysis, and terms that occur in fewer than 3 documents will be excluded from analysis.

Table 4.3
Effects of Feature Selection on the Performance of Classification

	DF_{min}							
	1	2	5	10	50	100	500	1000
Features	150210	58471	27836	17541	6510	4250	1333	681
	Accuracy							
BC 1 The Nature of Science	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.96
BC 4 The Physical Setting	1	1	1	1	1	1	0.97	0.97
BC 5 The Living Environment	1	1	1	1	1	1	1	1
BC 6 The Human Organism	1	1	1	1	1	1	1	1
BC 7 Human Society	1	1	1	1	1	1	1	0.91
BC 8 The Designed World	1	1	1	1	1	1	1	0.97
BC 9 The Mathematical World	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.89
SA 2012 Issue 1	0.98	0.98	0.98	0.98	0.97	0.97	0.93	0.90
Overall	0.98	0.98	0.98	0.98	0.97	0.97	0.95	0.93

Note: BC = Benchmark Chapter, SA = Scientific American
The validation was conducted with the passage length equals to 800 words.

As depicted in Table 4.3, when the threshold was raised and fewer features were selected, the accuracy of classification started to drop after the number of features was less than 4250. Testing with other feature selection measures, such as information gain and χ^2, produced similar results. This result seems to suggest that the number of features is more important than other factors in the given task. Since feature selection did not improve the performance of the classification model, it was omitted in further analysis.

Final Evaluation

According to the results from cross validation and testing with labeled documents, the best performance was achieved when new training examples were adopted and training documents were segmented to passages with a length of 800 words, while feature selection was demonstrated to be unnecessary. The final training set consisted of 8235 passages, with 2611 positive examples and 5624 negative examples. The result of the final evaluation of the trained classifier is presented in Table 4.4.

Table 4.4
Evaluation of the Determined Classifier

Testing Document	Reality		Prediction		Accuracy
	Positive	Negative	Positive	Negative	
BC 1 The Nature of Science	25	0	23	2	0.92
BC 4 The Physical Setting	0	64	0	64	1.00
BC 5 The Living Environment	0	38	0	38	1.00
BC 6 The Human Organism	0	37	0	37	1.00
BC 7 Human Society	0	34	0	34	1.00
BC 8 The Designed World	0	39	0	39	1.00
BC 9 The Mathematical World	0	38	3	35	0.92
SA 2012 Issue 1	2	381	9	374	0.98
Overall	27	631	35	623	0.98

Note: BC = Benchmark Chapter, SA = Scientific American

As shown in Table 4.4, the SVM classification algorithm achieved excellent performance with the provided training data. The accuracies of the classification in all categories were above 0.90, and accuracies in some categories were 1.00.

Research Question Two: Fitness and Modification of the Chosen Analytical Framework

Alshamrani's (2008) framework was chosen to categorize NOS presentations into elements of NOS. However, the following changes were made to fit with the current study.

First, Alshamrani's framework includes examples of NOS as presentations of NOS, but they were removed to meet with the purpose of the study which was to analyze explicit presentation of NOS. Considering science textbooks rarely include illustrations of how science works, it is reasonable for Alshamrani to include examples of NOS in his analysis of physics textbooks. However, popular science writing is filled with stories of scientists doing science. Those stories generally touch on various aspects of NOS, but they do not address NOS explicitly. Since the purpose of the current study was to analyze explicit addressing of NOS, examples of implicit NOS were not included in the framework or the analysis.

Second, more categories were added to the framework. During the analysis of explicit presentations of NOS, some categories which did not exist in Alshamrani's framework were identified and added to the analytical framework to ensure the coverage of all NOS topics in popular science writing. Some important topics, such as science and religion, and pseudoscience are almost never addressed in science textbooks, and it is not surprising to see that those topics are not included in Alshamrani's framework. Nevertheless, those topics are frequently mentioned in popular science writing, so they were added into the analytical framework to make it fit with the analysis of popular science writing.

In addition, a few categories in Alshamrani's framework (MA-NOS Descriptions and Ideal Indicators, pp.143-146) were combined or revised. The final framework for this study included fourteen NOS elements. The correspondence between the elements in the new framework with the ones from Alshamrani's framework is listed in Table 4.5. The detailed description of the NOS elements in the new framework is presented in Table 4.6.

Table 4.5

The Correspondence between the Elements in the Modified Framework with the Ones in Alshamrani's (2008) Framework

NOS Elements in the New Framework	NOS Elements in Alshamrani's Framework
01 The empirical aspect of science	06 Scientific knowledge is empirically based 12 The role of experiments in science
02 The rational aspect of science	
03 The tentative nature of science	03 Scientific knowledge is tentative
04 Terminology of scientific knowledge	05 There is a distinction between scientific laws and theories 08 There is a distinction between observations and inferences
05 The subjective nature of science	01 Scientific knowledge is not entirely objective
06 The creative nature of science	02 Scientists use creativity
07 Scientific method	07 The absence of a universal step-wise scientific method
08 Limitations of science	09 Science cannot answer all questions
09 Scientific community	10 Cooperation and collaboration in development of scientific knowledge
10 Humanity / psychological aspect of science	
11 The historical aspect of science	
12 Science and society	04 Science is socially and culturally embedded
13 Science and technology	11 Science and technology
14 Science and non-science	

Table 4.6

The Modified Analytical Framework of NOS Elements

#	Element	Examples
1	The empirical aspect of science	• Science relies on empirical evidence • Scientific knowledge is based on observational or experimental evidence • Scientific ideas are falsifiable, i.e. can be tested against observable phenomena • Scientific knowledge is based on convergence of evidence, and scientific theories are not falsified by single anomalies • Science is not purely a social construction.

#	Element	Examples
2	The rational aspect of science	• Science is an attempt to explain phenomena, understand how the world works • Science relies on logical arguments • Science aims to be consistent • Science aims to be universal • Science aims for logical simplicity and uniformity • Scientific knowledge is based on careful analysis
3	The tentative nature of science	• Scientific knowledge is tentative, subject to change • The accepted scientific knowledge in a certain time is the best description, explanation, or interpretation at that time. • Change in science results from information of better theories • Scientific ideas cannot be proven
4	Terminology of scientific knowledge	a. Scientific law b. Scientific theory c. Hypothesis d. Scientific model
5	The subjective nature of science	• Science is not entirely objective, science has subjective elements • Observations are theory-laden
6	The creative nature of science	• Scientists use imaginations and creativity in conducting science • Science is an art
7	Scientific method	• There are many ways to do scientific investigations • There is no step by step scientific method by which all science is done • Science reports do not reflect the actual practice of science
8	Limitations of science	• Science cannot answer all questions
9	Scientific community	• Scientists communicate and work with each other • Science requires peer review • Scientists as a community have shared knowledge, values, ethics, etc. • New knowledge must be reported clearly and openly • Competing ideas • Self-correcting mechanism
10	Humanity / psychological aspect of science	• Science is a human endeavor • Science relies on skepticism • Science relies on critical thinking • Scientists must be open to new ideas • Scientists use intuitions in doing science • Scientists are driven by curiosity
11	The historical aspect of science	• New scientific ideas have frequently been rejected • Change in science occurs gradually • Change in science occurs through revolutions • Science builds on what has gone on before • Science will never end

#	Element	Examples
12	Science and society	• All cultures (can) contribute to science • Science is part of social/cultural tradition • Scientific ideas are affected by their social & historical milieu • Science is dictated by national and/or corporate interests • Science has global implications • Scientists make ethical decisions
13	Science and technology	• The distinction between science and technology • Technology has impacted science • Science has played an important role in technology
14	Science and non-science	a. religion, faith, supernatural b. pseudoscience c. conspiracy d. scientism e. philosophy

Research Question Three: Frequency of Explicit Presentation of NOS in Recent Popular Science Writing

After the computer analysis, follow-up human analysis was conducted to reexamine the NOS passages identified in the computer analysis. The researcher and three other analysts involved in the human analysis to make sure that each passage was independently analyzed by two analysts. Cohen's kappa was calculated to assess inter-rater reliability. All human analyses achieved fair or moderate agreement. Discrepancies were solved by reanalysis and discussions.

Table 4.7 presents the number of collected passages (the raw paragraphs from the documents), the number of NOS passages identified within computer analysis, the number of NOS passages identified within human analysis, and the number of estimated NOS passages for each set of documents. NOS passages identified within computer analysis were the passages classified as positive in computer analysis from the collected passages. NOS passages identified within human analysis were the passages classified as positive in human analysis from the computer identified NOS passages. The estimation of the number of NOS passages was based on two assumptions: 1) all NOS passages identified by human analysis are truly explicit presentation of NOS, and 2) the computer and human analysis identified 90% of true NOS passages. Therefore, the number of NOS passages was estimated with the number of human identified NOS passages divided by 0.9. Based on the estimation of the number of NOS passages, the proportion of NOS passages in all the collected passages was also estimated for each set of documents.

As depicted in Table 4.7, the proportions of NOS passages in all the four sets of documents were below 1%. As for *Discover Magazine* and Winton Prize Winners, around five NOS passages can be identified from every thousand passages; for *Scientific American*, around three NOS passages can be identified; and for NSTA listed books, around two NOS passages can be identified from every thousand passages.

Table 4.7
Numbers of Collected Passages, Computer Analysis Identified NOS Passages, Human Analysis Identified NOS Passages, and Estimated NOS Passages in Each Set of Documents

		NOS Passages		
Documents	Collected Passages	Computer	Human[1]	Estimation[2]
Scientific American 2001-2010	59976	1810	148	164 (0.27%)
Discover Magazine 2001-2010	45517	1504	180	200 (0.44%)
Winton Prize Winners 2002-2011	10353	600	42	47 (0.45%)
NSTA Listed 2002-2011	20060	728	27	30 (0.15%)

[1] The human analysis is conducted on the NOS passages identified by the computer analysis.
[2] The estimation is based on the assumption that the computer and human analysis identified 90% of all NOS passages in the whole document set.

Table 4.8 presents the numbers of NOS passages in each issue of *Scientific American* from 2001 to 2010. In all the 120 issues, 69 issues contain at least one NOS passage, while the other 51 issues do not contain any NOS passages. The number of NOS passages in the 69 issues ranges from 1 to 7 (mean = 2.2, median = 1.5, mode = 1, SD = 1.5). The number of NOS passages in each year ranges from 3 to 26 (mean = 14.8, median = 16.5, mode = 22, SD = 8.3).

Considering some articles may contain more than one NOS passage, Table 4.9 lists the number of articles containing NOS passages in each issue. A total of 98 such articles were identified. The number of such articles in the 69 issues ranges from 1 to 4 (mean = 1.5, median = 1.0, mode = 1, SD = 0.7). The number of such articles in each year ranges from 3 to 17 (mean = 9.8, median = 11.0, mode = 6 and 12, SD = 4.6).

Table 4.8
Numbers of NOS Passages in Each Issue of Scientific American 2001-2010

	Month												
Year	01	02	03	04	05	06	07	08	09	10	11	12	Total
2001	6			4	4				2	3	4	3	26
2002	1	2	1	3		2	3	2	1	1	3	3	22
2003	1	1	1	1				1		1			6
2004		1	2		1		2	4	4	1		2	17
2005						1			3	1	1	1	7
2006		1	7	2	1			1	1	4	5		22
2007	1	3					4	1	2	1	1	3	16
2008			1			1			1				3
2009							2	1	3			1	7
2010		1	1		5	1	4		1		6	3	22
Total	9	9	13	10	11	5	15	10	18	12	20	16	148

Table 4.9
Numbers of Articles Containing NOS Passages in Each Issue of Scientific American 2001-2010

	Month												
Year	01	02	03	04	05	06	07	08	09	10	11	12	Total
2001	2			2	3				2	1	1	1	12
2002	1	2	1	3		2	1	2	1	1	1	2	17
2003	1	1	1	1				1		1			6
2004		1	2		1		1	1	1	1		2	10
2005						1			2	1	1	1	6
2006		1	3	2	1			1	1	4	1		14
2007	1	2					2	1	2	1	1	2	12
2008			1			1			1				3
2009							1	1	2			1	5
2010		1	1		3	1	1		1		3	2	13
Total	5	8	9	8	8	5	6	7	13	10	8	11	98

Similarly, the numbers of NOS passages and articles containing NOS passages in *Discover Magazine* from 2001 to 2010 are presented in Table 4.10 and Table 4.11. In all the 120 issues, 49 issues contain at least one NOS passage, while the other 71 issues do not contain any

NOS passages. The number of NOS passages in the 49 issues ranges from 1 to 16 (mean = 3.6, median = 2.0, mode = 1, SD = 3.7). The number of NOS passages in each year ranges from 0 to 52 (mean = 17.7, median = 13.5, mode = 0, SD = 17.6). A total of 78 articles containing NOS passages were identified. The number of such articles in the 49 issues ranges from 1 to 5 (mean = 1.6, median = 1.0, mode = 1, SD = 0.9). The number of such articles in each year ranges from 0 to 18 (mean = 7.8, median = 5.0, mode = 0 and 5, SD = 7.0). It can be observed that the number of NOS passages rose in 2004-2007 and then faded out.

Table 4.10
Numbers of NOS Passages in Each Issue of Discover Magazine 2001-2010

	Month												
Year	01	02	03	04	05	06	07	08	09	10	11	12	Total
2001													0
2002													0
2003											3	1	4
2004	5				1	3		1	9	1	3	4	27
2005			1		2	2		2	3	1	2	9	22
2006	2	3	2		1	1			14	10	9	6	39
2007		5		3	3	11	3	2	1	12	3		52
2008	1			1				16			1		19
2009	1		1			2	1	3					8
2010		1	1					1				3	6
Total	9	9	5	4	7	19	4	25	36	15	21	25	180

Table 4.11
Numbers of Articles Containing NOS Passages in Each Issue of Discover Magazine 2001-2010

	Month												
Year	01	02	03	04	05	06	07	08	09	10	11	12	Total
2001													0
2002													0
2003											1	1	2
2004	3				1	3		1	2	1	1	2	14
2005			1		1	2		2	2	1	2	2	13
2006	1	1	2		1	1			5	1	3	3	18
2007		2		1	1	2	2	2	3	3	1		17
2008	1			1				2			1		5
2009	1		1			1	1	1					5
2010		1	1					1				1	4
Total	6	4	5	2	4	9	3	9	12	6	9	9	78

Table 4.12 presents the numbers of NOS passages in Winton Prize winner books from 2002 to 2011. In the 10 winner books, 8 books contain at least one NOS passage, while the other 2 books do not contain any NOS passages. The number of NOS passages in each analyzed book ranges from 0 to 19 (mean = 4.1, median = 2.0, mode = 2, SD = 5.9).

Table 4.12
Numbers of Collected Passages and NOS Passages in Winton Prize Winner Books

Award				Passages		
Year	Title	Author	Subject	Total	NOS	%
2002	The Universe in a Nutshell	Stephen Hawking	Cosmology	307	2	0.65
2003	Right Hand, Left Hand	Chris McManus	Social Science	924	2	0.22
2004	A Short History of Nearly Everything	Bill Bryson	Cosmology	1539	2	0.13
2005	Critical Mass	Philip Ball	Social Science	1836	9	0.49
2006	Electric Universe	David Bodanis	Physical Science	757	0	0.00
2007	Stumbling on Happiness	Daniel Gilbert	Psychology	557	1	0.18
2008	Six Degrees	Mark Lynas	Social Science	714	0	0.00
2009	The Age of Wonder	Richard Holmes	History of Science	1778	19	1.07
2010	Life Ascending	Nick Lane	Life Science	861	5	0.58
2011	The Wave Watcher's Companion	Gavin Pretor-Pinney	Physical Science	1080	1	0.09

Table 4.13
Numbers of Collected Passages and NOS Passages in NSTA Listed Books

Listed				Passages		
Year	Title	Author	Subject	Total	NOS	%
2002	Charles Darwin	Dorothy Patent	Biography	509	1	0.20
2004	Killer Rocks from Outer Space	Steven Koppes	Earth and Space Science	350	1	0.29
2004	Niels Bohr	Naomi Pasachoff	Biography	199	1	0.50
2006	The Big Bang	Paul Fleisher	Earth and Space Science	205	2	0.98
2007	Little People and a Lost World	Linda Goldenberg	AAP*	259	2	0.77
2007	Marie Curie	Philip Steele	Biography	317	3	0.95
2008	Dinosaurs	Thomas Holtz	AAP*	1698	2	0.12
2008	Rockets	Ron Miller	Physical Science	313	1	0.32
2008	Einstein Adds a New Dimension	Joy Hakim	Earth and Space Science	2824	13	0.46
2011	Every Bone Tells a Story	Jill Rubalcaba	Science as Inquiry	656	1	0.15

* AAP = Archaeology, Anthropology, and Paleontology

Table 4.13 presents the numbers of NOS passages in NSTA recommend science trade books from 2002 to 2011. In the 46 analyzed books, 10 books, listed in the table, contain at least one NOS passage, while the other 36 books do not contain any NOS passages. The number of

NOS passages in each analyzed book ranges from 0 to 13 (mean = 0.6, median = 0, mode = 0, SD = 2.0).

Research Question Four: Contexts of Explicit Presentation of NOS in Recent Popular Science Writing

The contexts of NOS presentations in popular science magazines and popular science books were assessed in two different ways. For popular science magazines, the articles containing the NOS passages were identified, and then the sections containing those articles were identified and reported. For popular science books, the pages containing the NOS passages were identified, and then the distribution of NOS passages throughout the books were visualized.

Table 4.14

Numbers of NOS Passages and Articles in Sections of Scientific American 2001-2010

Section	Passages	Articles	Section	Passages	Articles
Featured Content	20	12	Others	108	85
Mathematics	5	1	Skeptic	53	31
Cosmology	4	1	Letters	21	17
Environment	3	2	News Scan	8	7
Astronomy	2	2	Reviews	7	7
Astrophysics	1	1	SA Perspectives	7	5
Cryptozoology	1	1	News & Analysis	5	1
Earth Science	1	1	From Our Pages	4	1
Molecular Biology	1	1	From the Editor	3	1
Paleontology	1	1	Debate	3	1
Psychology	1	1	Education	3	1
			Critical Mass	3	2
			Editors Recommend Books	2	2
			Forum	2	1
			50, 100 & 150 years ago	1	1
			Opinion	1	1
			Profile	1	1
			Policy	1	1
			Technology & Business	1	1
			Trends in Research, Business	1	1
			What the Future Holds	1	1

Table 4.14 presents the numbers of NOS passages and articles containing those passages in the sections, or the so-called departments, of *Scientific American* from 2001 to 2010. About half of the passages come from the "Skeptic" section, which is written by Michael Shermer. The "Letters" section has the second most NOS passages. The amount of NOS passages in featured content, comparing to the amount of articles in the section and their length, is almost negligible.

Table 4.15 presents the numbers of NOS passages and the numbers of articles containing those passages from sections of *Discover Magazine* from 2001 to 2010. More NOS passages were identified from featured articles than others. In featured content, the "Human Origins" section contains the most NOS passages, but the "Physics & Math" section contains the greatest number of articles which included NOS passages. Similar to *Scientific American*, the "Letters" section is another important source of NOS passages.

Table 4.15
Numbers of NOS Passages and Articles in Sections of Discover Magazine 2001-2010

Section	Passages	Articles	Section	Passages	Articles
Featured Content	100	50	Others	33	22
Human Origins	27	5	Letters	25	16
Physics & Math	24	16	Reviews	4	4
Health & Medicine	18	12	Blinded by Science	4	2
Living World	11	4	Not available*	47	10
Technology	8	6			
Space	5	3			
Mind & Brain	4	2			
Environment	3	2			

* Not available: articles do not belong to any section.

Table 4.16 and Table 4.17Table 4.17 present the pages containing NOS passages in Winton Prize winner books and NSTA listed books. The tables also present the location of the pages in a relative fashion, which is obtained from the page number divided by total number of pages in the book. For books that have more than five NOS presentations, their distributions of NOS presentations are presented in Figure 4.1.

Table 4.16

Location of Containing Pages of NOS Presentations in Winton Prize Winner Books

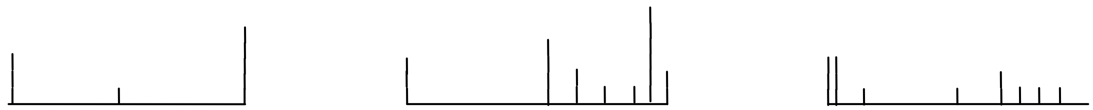
Award Year	Title	Total Pages	NOS Presentations		
			Passages	Page	Page Percentile
2002	The Universe in a Nutshell	200	2	23	0.12
				101	0.51
2003	Right Hand, Left Hand	362	2	286	0.79
				348	0.96
2004	A Short History of Nearly Everything	478	2	166	0.35
				442	0.92
2005	Critical Mass	469	9	30	0.06
				32	0.07
				33	0.07
				209	0.45
				458	0.98
				458	0.98
				463	0.99
				464	0.99
				465	0.99
2007	Stumbling on Happiness	258	1	70	0.27
2009	The Age of Wonder	470	19	0	0.00
				0	0.00
				94	0.20
				268	0.57
				276	0.59
				288	0.61
				289	0.61
				312	0.66
				313	0.67
				371	0.79
				429	0.91
				441	0.94
				443	0.94
				445	0.95
				450	0.96
				456	0.97
				459	0.98
				468	1.00
				469	1.00
2010	Life Ascending	287	5	232	0.81
				233	0.81
				286	1.00
				286	1.00
				287	1.00
2011	The Wave Watcher’s Companion	320	1	133	0.42

Table 4.17

Location of Containing Pages of NOS Presentations in NSTA Listed Books

Listed			NOS Presentations		
Year	Title	Total Pages	Passages	Page	Page Percentile
2002	Charles Darwin	130	1	127	0.98
2004	Killer Rocks from Outer Space	105	1	11	0.10
2004	Niels Bohr	105	1	68	0.65
2006	The Big Bang	65	2	6	0.09
				6	0.09
2007	Little People and a Lost World	100	2	13	0.13
				33	0.33
2007	Marie Curie	134	3	24	0.18
				68	0.51
				131	0.98
2008	Dinosaurs	365	2	2	0.01
				52	0.14
2008	Rockets	103	1	98	0.95
2008	Einstein Adds a New Dimension	455	13	0	0.00
				0	0.00
				1	0.00
				14	0.03
				15	0.03
				18	0.04
				98	0.22
				228	0.50
				299	0.66
				299	0.66
				329	0.72
				393	0.86
				414	0.91
2011	Every Bone Tells a Story	165	1	157	0.95

As shown in Figure 4.1, the distribution of NOS presentations in the three books are different from each other. For *Critical Mass*, most NOS presentations locate in the beginning or the end of the book. For *The Age of Wonder*, most NOS presentations distribute in the second half of the book, leaving a few in the beginning. For *Einstein Adds a New Dimension*, part of the NOS presentations gather in the beginning of the book, and part of them spread in the second half of the book. Although the three books show different patterns of the distribution of the NOS presentations, a common characteristic can be observed in most of the books, including those that are not visualized, which is that most of the NOS presentations gather around the beginning or the end of the books, and only a few are scatter across the middle part of the books.



1. Critical Mass 2. The Age of Wonder 3. Einstein Adds a New Dimension

Figure 4.1 Visualization of the distributions of NOS pr
popular science books.

Research Question Five: Coverage of NOS Elements in Recent Popular Science Writing

Table 4.18
Numbers of NOS Passages in NOS Elements from Each Document Set

NOS Aspect	Scientific American	Discover Magazine	Winton Prize Winners	NSTA Listed
1. The empirical aspect of science	41	40	9	6
2. The rational aspect of science	29	23	10	4
3. The tentative nature of science	18	15	1	4
4. Terminology of scientific knowledge				
a. Scientific law	3	0	3	2
b. Scientific theory	5	0	0	2
c. Hypothesis	2	0	0	1
d. Scientific model	0	1	0	1
5. The subjective nature of science	19	12	4	1
6. The creative nature of science	9	7	12	5
7. Scientific method	13	6	4	4
8. Limitations of science	4	20	4	1
9. Scientific community	44	37	3	4
10. Humanity / psychological aspect of science	28	26	6	9
11. The historical aspect of science	19	22	7	3
12. Science and society	45	48	17	2
13. Science and technology	4	4	4	1
14. Science and non-science				
a. religion, faith, supernatural	22	78	6	1
b. pseudoscience	8	0	1	0
c. conspiracy	3	0	0	0
d. scientism	1	1	0	0
e. philosophy	1	1	0	0
Total	318	341	91	51

Scientific American has more discussions on “science and society”, “scientific community”, and “the empirical aspect of science”. Discover Magazine emphasizes more on “science and religion, faith, supernatural”, “science and society”, and “the empirical aspect of science.” Winton Prize winners include more discussions on “science and society”, “the creative nature of science”, and “the rational aspect of science.” NSTA listed books have more presentations of “humanity / psychological aspect of science”, “the empirical aspect of science”, and the “the creative nature of science.”Table 4.18 presents the times of occurrences of NOS elements in each set of documents. In identifying NOS elements in NOS passages, each passage was allowed to contain multiple NOS elements, but each NOS element was counted no more than once in each passage. According to the results presented in the table, all the NOS elements occurred at least once in the whole data set, but none of the document sets include all NOS elements.

Research Question Six: Accuracy of NOS Inclusion in Recent Popular Science Writing

Table 4.19 presents the numbers of NOS passages containing inaccurate NOS presentation identified from each document set in human analysis. In total, three NOS passages were identified as containing inaccurate NOS presentations. No such passage was found in Winton Prize winner books or NSTA listed books, but this may due to the limited number of NOS passages in the two document sets. In the other two document sets, the proportions of inaccurate presentation in NOS passages are very close, which is around one percent.

Table 4.19

Numbers of Inaccurate NOS Presentations in Each Document Set

Document Set	NOS Passages	Inaccurate NOS Presentations	Percentage
Scientific American	148	2	1.4%
Discover Magazine	180	1	0.6%
Winton Prize Winner Books	42	0	0%
NSTA Listed Books	27	0	0%

The first inaccurate NOS presentation was identified in a book recommendation in the February issue of 2002 *Scientific American*. On page 97, when recommending Ernst Mayr's book *What Evolution Is,* the editor states that:

> Mayr, professor emeritus of zoology at Harvard University, asserts that the term "evolutionary theory" should be abandoned. Evolution, he says, "is a fact so overwhelmingly established that it has become irrational to call it a theory."

This passage contains a misuse of the term "theory" which is addressed in 4.b in the analytical framework. It is certainly true that the occurrence of evolution is a well-established scientific fact. However, there is nothing wrong with the term "evolutionary theory", which is used to explain evolution-related phenomena. The passage implicitly suggests that "theory" is used for speculations which are not well-supported by scientific facts, and this delivers the misconception about scientific theory.

The second inaccurate NOS presentation was from the April issue of 2003 *Scientific American*. In his article *I, Clone,* Michael Shermer claimed that:

> Instead of restricting or preventing the technology, I propose that we adopt the Three Laws of Cloning, the principles of which are already incorporated in the laws and language of the U.S. Constitution, and allow science to run its course. The soul of science is found in courageous thought and creative experiment, not in restrictive fear and prohibitions. For science to progress, it must be given the opportunity to succeed or fail. Let's run the cloning experiment and see what happens. (p. 38)

I agree that science should be given the opportunity to succeed or fail. However, when a human being is involved as the subject of scientific experiment, it is irresponsible to simply say let's try and see what happens. Scientists are citizens, and scientific experiments conducted by scientists must follow human-established laws and ethical requirements. Since issues surrounding human cloning are still controversial and the ethnics of the process is questioned by a large portion of the society, scientists should take serious consideration before engaging in human cloning experiments. This topic is related to the element 12 "science and society" in the analytical framework.

The third and last inaccurate NOS presentation was from the dialog between the *Discover* magazine and Kathy A. Svitil on the June 2004 issue. When she was asked "Do you think we will find evidence of life, past or present, on Mars?", Svitil responded:

> I don't have an opinion on that. In fact, I believe firmly that the worst thing a scientist can do is to have a preconceived notion about what you are going to find because it can skew your interpretation of the data.

Although an expectation before the investigation could skew the interpretation of the data, it is uncommon to have no expectation before a scientific investigation. Moreover, expectation does not merely compromise the investigation. In most cases, scientific investigations are guided by expectation. Actually, most scientific investigations could not be initiated if an expectation is absent. The element 5 "the subjective nature of science" in the analytical frame is related to the discussion of this issue.

Summary of Chapter Four

Chapter four presents that the text mining approach achieved excellent accuracy when appropriate training materials and passage length were selected. It also presents the findings of how NOS is explicitly addressed in four groups of recent popular science writing, i.e. *Scientific American* 2001-2010, *Discover* magazine 2001-2010, Winton Prize winner books 2002-2011, and NSTA listed science trade books 2002-2011. The findings reveal that NOS is rarely addressed in any of those documents. On average, about two to five passages explicitly addressing NOS were observed in every thousand passages. Comparing the main body of the documents, NOS is more frequently addressed in the letters section of *Scientific American* and *Discover* magazines. In popular science books, NOS presentations are more likely to be aggregated in the beginning and the end of the book, rather than scattered through the middle of the book. The most commonly addressed NOS aspects in the analyzed documents included "science and society", "scientific community", "the empirical aspect of science", "science and religion, faith, supernatural", "the creative nature of science", "the rational aspect of science", and "humanity / psychological aspect of science." Only three inaccurate presentations of NOS were identified in the whole data set.

CHAPTER V

DISCUSSION AND IMPLICATIONS

This study investigated the explicit presentation of NOS in popular science writing. Based on the modification of Alshamrani's (2008) work, an analytical framework with 14 NOS elements were developed for the study. Four groups of popular science writing were included in the analysis. They are *Scientific American* from 2001 to 2010, *Discover* magazine from 2001 to 2010, Winton Prize winner books from 2002 to 2011, and NSTA recommended science trade books from 2002 to 2011. To locate NOS presentation from the selected documents, a text mining technique was implemented to classify all the passages according to their inclusions of NOS. Then, for the passages which were identified as having explicit inclusion of NOS by the computer analysis, a follow-up manual analysis was conducted to address the research questions regarding the frequency, context, coverage, and accuracy of NOS presentations in the analyzed documents. This chapter concludes and discusses the findings of the study. Implications for practice and recommendations for future research are also provided.

Conclusion and Discussion

The following conclusions were made based on the results of the analysis:

1. The text mining technique achieved excellent accuracy in classifying passages from targeted documents according to the inclusion of NOS.

In this study, the accuracy of the classification model was evaluated in two ways. First, it was cross-validated within the training examples through a 5-fold cross-validation. A 0.99 accuracy was obtained in the cross-validation. Second, the classifier was also tested on a new set of labeled documents. The testing document set included 8 groups, which were benchmark statements from 7 chapters of *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1994) and passages from the first issue of 2012 *Scientific American*. The accuracies achieved 0.90 in all groups (see Table 4.4).

Two major factors contributed to the excellent accuracy of the classification model. First, support vector machine, the classification algorithm used to train the classifier, is considered state-of-art in document classification. It built the solid foundation for the analysis. Second, the carefully chosen training examples were another safe-guard for the accuracy. Initially, the training examples were philosophy of science books and science textbooks. After using NOS articles as positive training examples and adding textbooks from various disciplines as negative training examples, the accuracy improved in all groups of testing documents. In addition, appropriate passage length in segmentation of the training examples also contributed in improving the classifier.

2. NOS is rarely addressed explicitly in popular science writing.

Based on the counted occurrences of NOS passages in the document sets and their proportions comparing to the overall numbers of passages in the document sets, it is safe to conclude that popular science writing rarely have explicit discussion of NOS in all the four document sets. Actually, in a thousand passages, one would expect no more than five such passages in normal popular science writing.

3. Readers seem to be interested in NOS-related issues, even though NOS is infrequently addressed in popular science writing.

Although popular science magazines and popular science books rarely address NOS, this study revealed that readers seem to have a desire to discuss NOS related issues in the letters section of popular science magazines. Typically, the letters section only occupies one page in each issue of the magazines, but it constitutes a significant portion of NOS presentations in the magazines. In almost every six issues of popular science magazines, a NOS passage would be expected from the letters section. On the other hand, no more than ten NOS passages would be expected in whole six issues of popular science magazines. Considering the short length of the letters section, those numbers reflect a significant gap between readers' interests in NOS issues and popular science magazines' presentation of NOS.

4. Some NOS aspects are more frequently addressed than others in popular science writing.

According to the analysis of the elements of NOS, it seems that different document sets favor different aspects of NOS. The top three addressed NOS aspects in *Scientific American* are "science and society", "scientific community", and "the empirical aspect of science." For *Discover* Magazine, they are "science and religion, faith, supernatural", "science and society", and "the empirical aspect of science." For Winton Prize winner books, they are "science and society", "the creative nature of science", and "the rational aspect of science". For NSTA listed books, they are "humanity / psychological aspect of science", "the empirical aspect of science", and the "the creative nature of science." It appears that three NOS aspects, "science and society", "the empirical aspect of science", and "the creative nature of science", are commonly emphasized across analyzed document sets. However, due to the limited number of NOS passages identified in the study, the above results are not definitive.

5. Most presentations of NOS in analyzed popular science writing are informed.

In the total of approximately 400 NOS passages from the four document sets, only three inaccurate NOS presentations were identified. This result suggests that most presentations of NOS in analyzed popular science writing are informed. However, since the analyzed magazines and books represent the highest quality of the population, this result may not be generalized to other popular science magazines or science trade books.

Implications

Implications for Using Popular Science Writing in Science Teaching

Although popular science magazines and science trade books have a large quantity of readers, the results of this study, unfortunately, revealed that NOS was almost never explicitly addressed in them. Those materials typically include rich descriptions of how science works in a variety of aspects, which could serve as a perfect context in introducing NOS. Nevertheless, they fail to address NOS explicitly, which is important for delivering NOS-related ideas. Therefore, besides a few exceptions, popular science writing generally may not be a good resource for science educators to search for materials for teaching NOS. Since both science textbooks and popular science writing are generally disappointing in the aspect of including NOS topics, it seems to be necessary to create new science curriculum with rich features in NOS. If popular science writing is to be brought to science classrooms for teaching NOS, teachers' guidance on explicit reflection of NOS is vital.

Implications for Using Text Mining in Science Education Research

Contrary to the disappointing findings on the presentation of NOS in popular science writing, the text mining technique used to identify NOS presentations demonstrated exciting performance. With the training data provided, the support vector machine (SVM) algorithm achieved excellent accuracy in both cross validation and classifying the testing documents.

The proportion of passages explicitly addressing NOS is extremely low, which suggests that the commonly used approach, randomly sampling pages from the documents, is severely unreliable. It is very likely that the randomly selected pages do not contain the rare cases we aimed for. Therefore, it is necessary to examine the whole body of text to locate the positive passages. This low proportion also suggests that it would be difficult to locate NOS passages in popular science writing, and it makes using text mining technique in the study a necessity.

In this study, the computer analysis decreased the number of passages for human analysis from 135,906 to 4,642, which means we only spent 3.4% (4642/135906 = 0.034) time on manual analysis as compared to the time required without the aid from computer analysis. In other words, with the aid of the text mining technique, an estimated two and half year human analysis job was completed in only a month. Moreover, it is difficult, if not impossible, for human analysis to maintain such a high accuracy in such a high volume analysis task which takes so long to accomplish. Therefore, it is reasonable to conclude that the application of the text mining technique significantly improved both efficiency and accuracy of the classification of science writing according to the explicit inclusion of NOS. The successful application of the text mining technique in the current study opened a new branch for science education research, which invites more applications of such technique on the analysis of other aspects of science textbooks, popular science writing, or any other materials involved in science teaching and learning.

Recommendations for Future Research

It has been an established consensus in the science education community that NOS must be addressed in the science curriculum and in science instruction. However, previous research found that the presentation of NOS in science textbooks is not satisfied. This study also found the explicit presentation of NOS is rarely included in popular science magazines or books.

Nevertheless, popular science writing has rich inclusion of implicit addressing of NOS. This means it still could serve as useful material in the instruction of NOS, if it is properly used. Since explicit addressing of NOS is hard to find in popular science writing, future research should be devoted to study selecting and using popular science writing as supplementary resource in teaching NOS. A method should be developed to help teachers identify potentially useful pieces of implicit inclusion of NOS and reflect on them in explicit teaching of NOS. From the perspective of curriculum development, the approach worth studying is to adopt popular science writing which has rich implicit inclusions of NOS in new curriculum as reading materials, and highlight and reflect on NOS ideas based on them.

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APPENDICES

Appendix A: List of Analyzed Popular Science Books

List of Winton Prize Winner Books from 2002 to 2011

- Ball, P. (2006). *Critical mass: How one thing leads to another*. Farrar, Straus and Giroux.
- Bodanis, D. (2006). *Electric universe: How electricity switched on the modern world*. Broadway.
- Bryson, B. (2003). *A short history of nearly everything*. New York, NY: Broadway.
- Gilbert, D. (2007). *Stumbling on happiness*. Vintage.
- Hawking, S. W. (2001). *The universe in a nutshell*. Bantam.
- Holmes, R. (2009). *The age of wonder: How the romantic generation discovered the beauty and terror of science*. Pantheon.
- Lane, N. (2010). *Life ascending: The ten great inventions of evolution*. W. W. Norton & Company.
- Lynas, M. (2008). *Six degrees: Our future on a hotter planet*. National Geographic.
- McManus, C. (2004). *Right hand, left hand: The origins of asymmetry in brains, bodies, atoms and cultures*. Harvard University Press.
- Pretor-Pinney, G. (2010). *The wave watcher's companion: From ocean waves to light waves via shock waves, stadium waves, and all the rest of life's undulations*. Perigee Trade.

List of Analyzed NSTA Recommend Science Trade Books from 2002 to 2011

- Aronson, M. (2010). *If stones could speak: Unlocking the secrets of stonehenge*. National Geographic Children's Books.
- Bankston, J. (2005). *Stephen Hawking: Breaking the boundaries of time and space*. Enslow Publishers.
- Batten, M. (2001). *Anthropologist: Scientist of the people*. Houghton Mifflin Books for Children.
- Buchmann, S. (2010). *Honey bees: Letters from the hive*. Delacorte Books for Young Readers.
- Carter, R., Aldridge, S., Page, M., & Parker, S. (2009). *The human brain book: An illustrated guide to its structure, function, and disorders* (Har/Dvdr.). DK ADULT.
- Castner, J. L. (2002). *Rainforest researchers*. Benchmark Books / Marshall Cavendish.
- Chaikin, A. (2009). *Mission control, this is Apollo: The story of the first voyages to the moon*. Viking Juvenile.
- Collier, M. (2007). *Over the mountains: An aerial view of geology*. Mikaya Press.
- Collier, M. (2009). *Over the coasts: An aerial view of geology*. Mikaya Press.
- Cooney, C. B. (2007). *Code orange*. Laurel Leaf.

- Deem, J. M. (2008). *Bodies from the ice: Melting glaciers and the recovery of the past*. Houghton Mifflin Books for Children.
- Delano, M. F., & Sloane, D. E. E. (2002). *Inventing the future: A photobiography of Thomas Alva Edison*. National Geographic Children's Books.
- Farr, R. (2008). *Emperors of the ice: A true story of disaster and survival in the Antarctic, 1910-13*. Farrar, Straus and Giroux (BYR).
- Favor, L. J. P. D. (2007). *Food as foe: Nutrition and eating disorders*. Tarrytown, New York, U.S.A.: Benchmark Books.
- Fleischman, J. (2002). *Phineas gage: A gruesome but true story about brain science*. Houghton Mifflin Books for Children.
- Fleisher, P. (2005). *The Big Bang*. Twenty-First Century Books (CT).
- Goldenberg, L. (2006). *Little people and a lost world: An anthropological mystery*. Twenty-First Century Books (CT).
- Goldsmith, C. (2006). *Influenza: The next pandemic?* Twenty-First Century Books (CT).
- Goldsmith, C. (2007). *Superbugs strike back: When antibiotics fail*. Twenty-First Century Books (CT).
- Hakim, J. (2007). *The story of science: Einstein adds a new dimension*. Smithsonian Books.
- Hammond, R. (2008). *Car Science*. DK CHILDREN.
- Harris, J., & Goodall, J. (2005). *The least of these: Rescue and rehabilitation of wild baby birds*. Westwiinds Press.
- Hobbs, W. (2003). *Wild man island*. HarperCollins.
- Hobbs, W. (2004). *Jackie's wild seattle*. HarperCollins.
- Holtz Jr., T. R. (2007). *Dinosaurs: The most complete, up-to-date encyclopedia for dinosaur lovers of all ages*. Random House Books for Young Readers.
- Hoose, P. M. (2004). *The race to save the Lord God Bird*. Farrar, Straus and Giroux.
- Johnson, J. (2008). *Animal tracks and signs: Track over 400 animals from big cats to backyard birds*. National Geographic Children's Books.
- Kent, D. (2003). *Snake pits, talking cures and magic bullets: A history of mental illness*. 21st Century.
- Koppes, S. N. (2003). *Killer rocks from outer space: Asteroids, comets, and meteorite*. Lerner Pub Group (L).
- Kowalski, K. M. (2005). *Attack of the superbugs: The crisis of drug-resistant diseases*. Enslow Publishers.
- Krull, K. (2009). *Marie Curie: The woman who changed the course of science*. Puffin.
- LeVert, S. (2006). *The facts about cocaine*. New York: Marshall Cavendish Benchmark.
- Malnor, C. L., & Malnor, B. (2010). *Earth heroes: Champions of wild animals*. Dawn Pubns.
- McClafferty, C. K. (2001). *The head bone's connected to the neck bone: The weird, wacky, and wonderful X-Ray*. Farrar, Straus and Giroux (BYR).
- Miller, R. (2007). *Rockets*. Twenty-First Century Books (CT).
- Pasachoff, N. (2003). *Niels Bohr: Physicist and humanitarian*. Enslow Publishers.
- Pasachoff, N. (2004). *Linus Pauling: Advancing science, advocating peace*. Enslow Publishers.
- Patent, D. H. (2001). *Charles Darwin: The life of a revolutionary thinker*. Holiday House.
- Rubalcaba, J., & Robertshaw, P. (2010). *Every bone tells a story: Hominin discoveries, deductions, and debates*. Charlesbridge Publishing.

- Sandler, M. W. (2009). *Secret subway: The fascinating tale of an amazing feat of engineering*. National Geographic Children's Books.
- Simpson, K. (2008). *Genetics: From DNA to designer dogs*. National Geographic Children's Books.
- Stefoff, R. (2006). *Microscopes and telescopes*. Benchmark Books (NY).
- Tagliaferro, L. (2000). *Galapagos Islands: Nature's delicate balance at risk*. Lerner Publications.
- Thimmesh, C. (2009). *Lucy long ago: Uncovering the mystery of where we came from*. Houghton Mifflin Books for Children.
- Turner, P. S. (2008). *Life on earth -- and beyond: An astrobiologist's quest*. Charlesbridge Publishing.
- Vogel, C. G., & Vogel, C. G. (2001). *Breast cancer: Questions and answers for young woman*. 21st Century.
- Walker, S. M. (2002). *Fossil fish found alive: Discovering the coelacanth*. Carolrhoda Books.
- Walker, S. M. (2009). *Written in bone: Buried lives of Jamestown and colonial Maryland*. Carolrhoda Books.
- Winner, C. (2007). *Circulating life: Blood transfusion from ancient superstition to modern medicine*. Twenty-First Century Books (CT).
- Woodford, C. (2008). *Cool stuff exploded*. DK CHILDREN.