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Science presents many challenging topics, and incorrect prior knowledge of them often interferes with learning. Research has demonstrated that refutation texts promote conceptual change learning by helping readers abandon scientific misconceptions. Little is known about the factors that influence knowledge enrichment, the learning that ensues when students have incomplete knowledge of a topic. The purpose of this study was to compare the impact of these two types of prior knowledge on science text comprehension.

Participants were 28 high school students (14 to 15 years) who completed assessments of vocabulary, reading comprehension, epistemological beliefs, self-efficacy, interest, and prior knowledge of 4 science topics (2 misconception, 2 incomplete prior knowledge) on Day 1. On Day 2, participants read 4 science texts (2 refutation, 2 expository) and completed tests of comprehension.

Results demonstrated that epistemological beliefs moderated the increase between pre- and posttest scores regardless of the type of prior knowledge. Knowledge enrichment was more than 2 times as likely as conceptual change, which required a minimum level of epistemological understandings. Although refutation texts rarely led to conceptual change, they contributed to knowledge enrichment more often than traditional expository texts did. Future studies should investigate the impact of non-textual factors on conceptual change and knowledge enrichment in science.

THE IMPACT OF DIFFERENT TYPES OF PRIOR KNOWLEDGE

ON SCIENCE TEXT COMPREHENSION

by

Mary Kristen Clark

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CHAPTER I

STATEMENT OF THE PROBLEM

Despite efforts to improve students' reading comprehension performance, scores on national reading assessments have remained relatively stable for almost two decades (National Center for Education Statistics, 2011a). Such assessments consist of passages on a variety of topics from different content areas. Reading comprehension, particularly at deep levels, depends not only on general language comprehension skills, but also on knowledge of the passage topic (e.g., Hirsch, 2006; Jetton & Alexander, 2004; Moje, 2008a; Moje & Speyer, 2008).

The role of prior knowledge in text comprehension is perhaps best acknowledged by researchers in adolescent literacy, a time during which students read extensively in different disciplines. In addition to specialized bodies of knowledge, lexicons, and problems (Jetton & Alexander, 2004), disciplines have different conventions for how knowledge is produced and communicated (Moje, 2008a). The goal of disciplinary literacy is for students to learn these established discipline-specific discourses and text structures (Moje, 2008a). For example, historians pay close attention to sources and read texts as interpretations of the past, whereas mathematicians read proofs to detect errors because they are taken as the truth. On the other hand, because knowledge in science is generated through experimentation, scientists read texts with the goal of understanding the methodology in order to make sense of the findings (Shanahan & Shanahan, 2008).

The current research is concerned with science, the discipline investigated in most previous studies of prior knowledge and text comprehension.

Though science is often conceptualized as a hands-on discipline, text comprehension is equally important. Experts in science spend an overwhelming majority of their time reading and writing in order to acquire and generate new knowledge (Pearson, Moje, & Greenleaf, 2010; Shanahan, 2004). How well students comprehend science texts may determine the extent to which a scientifically literate citizenry (Pearson et al., 2010) is able to critically comprehend future scientific findings. Although having prior knowledge of the topic impacts text comprehension, its exact role is unclear because prior knowledge is not all or nothing. Chi (2008) described three conditions other than correct prior knowledge in science. Students can have (a) no prior knowledge of, (b) incomplete knowledge of, or (c) misconceptions about to-be-learned concepts. In the first two cases, information is learned by adding new knowledge or filling in gaps of missing knowledge, respectively. In both cases, learning has been described as knowledge enrichment (Carey, 1991). In the third condition, prior misconceived knowledge must be altered to the scientific conception in order for learning to occur. This type of knowledge acquisition is known as conceptual change. A primary goal of science education is to promote conceptual change because students frequently possess misconceptions (Dole, 2000). The importance of addressing student misconceptions in science is reflected by a long line of research that investigates how to best help students abandon them (e.g., Guzzetti, 2000; Kendeou & van den Broek, 2007; Posner, Strike, Hewson, & Gertzog, 1982).

Misconceptions in science are resistant to change (Dole, 2000). These naïve conceptions are often based on robust and logical explanations made from everyday experiences (Gardner, 1991). Furthermore, science textbooks typically do not consider the level of students' background knowledge or adequately explain concepts (cf. Broughton & Sinatra, 2010; Goldman & Bisanz, 2002; Smolkin, McTigue, & Donovan, 2008). The nature of science texts impacts the influence of prior knowledge on comprehension. In an early study, Alvermann, Smith, and Readence (1985) demonstrated that when prior knowledge was consistent with a science text, it did not facilitate comprehension. On the other hand, when a science text presented counterintuitive information, student misconceptions interfered with comprehension and prevented conceptual change. Given this relationship, one may ask whether conceptual change is likely to occur at all from reading science texts.

Twenty years of research has revealed that a specific kind of text structure is powerful in inducing conceptual change in science (e.g., Dole, 2000; Guzzetti, 2000). Refutation texts make explicit references to commonly held misconceptions and directly refute them with scientifically acceptable ideas. In a recent review, Tippett (2010) concluded that most studies that compared refutation and traditional expository texts reported enhanced conceptual change with refutation texts. Although the research in this area is quite clear about the power of refutation texts in helping students abandon misconceptions, its clinical application is limited. Not only are there few published refutation texts (Tippett, personal communication), but student dispositions were often not taken into consideration.

The importance of student dispositions has been emphasized in recent models of conceptual change (Sinatra, 2005). For example, students with higher topic interest and advanced epistemological beliefs about science benefit more from refutation texts than students with lower levels (Mason, Gava, & Boldrin, 2008). A student with advanced epistemological beliefs about science understands the tentative nature of knowledge in the discipline and that scientists are not authoritative sources (Hofer & Pintrich, 1997). These understandings can be incorporated into disciplinary literacy instructional programs (Moje, 2008a).

How comprehension builds new knowledge has largely been ignored by both researchers and educators (Cervetti, Jaynes, & Hiebert, 2009).Whereas conceptual change learning has received much attention, investigations on knowledge enrichment (Carey, 1991), the learning that ensues when students have no or incomplete prior knowledge, have not been conducted. It may be that science text comprehension is impacted differently by the two types of prior knowledge. The role of student dispositions (e.g., advanced epistemological beliefs) in conceptual change learning may not be as important when misconceptions are not held.

The main goal of this research is to uncover factors that contribute to science text comprehension. One purpose is to investigate how different types of prior knowledge affect the ability to learn new information from science texts. Two conditions of prior knowledge are investigated: when students (a) hold common misconceptions and (b) have incomplete knowledge. A second purpose is to determine whether student dispositions play equally important roles in the two conditions of prior knowledge.

CHAPTER II

REVIEW OF THE LITERATURE

An important research agenda within adolescent literacy explores reading comprehension in subject areas such as science, history, and math. This area of research has been referred to as domain-specific reading (Jetton & Alexander, 2004), disciplinary comprehension (Shanahan, 2009), and disciplinary literacy (Moje, 2008a, 2008b; Shanahan & Shanahan, 2008). These terms are similar in their acknowledgment of the importance of knowledge in comprehending texts in different subject areas, but the kinds of knowledge they propose differ in significant ways.

The term first used in the literature, domain-specific reading (Jetton & Alexander, 2004), acknowledges the importance of two types of content knowledge: domain knowledge (i.e., the breadth of knowledge in a field, such as biology) and topic knowledge (i.e., background knowledge relative to the subject of a text). Disciplinary comprehension (Shanahan, 2009), a more recent term used to describe the comprehension of texts within a particular discipline, stresses the role of disciplinary (versus content) knowledge. This knowledge entails discipline-specific understandings of how information is created, communicated, and evaluated. Disciplinary knowledge includes knowledge of the range of topics in a discipline, but not necessarily knowledge of specific topics themselves. Experts in the field of science, for example, use their disciplinary knowledge to comprehend texts for which they know little or nothing about.

When reading about these unfamiliar topics, they transition from reading in the typical critical mode to reading in a learning mode. Finally, disciplinary literacy (Moje, 2008a) is a combination of the previous two terms. It conceptualizes learning in the subject areas as learning both the knowledge and modes of knowledge production and communication in the disciplines. Disciplinary literacy also recognizes that the epistemological perspectives of the members in a discipline affect how they think and thus produce and consume texts (Moje, 2008b).

The term disciplinary literacy was chosen for this study because it encompasses multiple forms of knowledge that affect learning in subject areas. It is also useful pedagogically, as it encourages secondary subject area teachers to build disciplinary literacy instructional programs that focus on subject area knowledge and discipline-specific practices (Moje, 2008a; Shanahan & Shanahan, 2008). The current research investigates disciplinary literacy within the subject area of science.

Disciplinary Literacy and Science

Understanding what is required of students as they read science texts requires knowledge of how the discipline of science operates. Hynd (2002) outlines two main scientific principles. First, science rests on the assumptions of the scientific method. In science, knowledge is created through controlled experimentation, and numerical assessments of data determine outcomes. Scientists remain objective when interpreting evidence, while at the same time acknowledging their own and others' biases. They can be influenced and constrained by their research interests, measurement devices, and understandings of previous findings.

The second principle is that scientific understandings are in a constant state of flux (Hynd, 2002). Armed with this knowledge, scientists critically read and evaluate scientific texts. The topics that are studied and which findings gain acceptance are determined in part by the replication of findings. Knowledge of the peer-review and publication process also makes scientists able to assign credibility to some findings (i.e., those published in well-respected journals) and not others (i.e., those published in nonrefereed publications). Students and the lay public without this disciplinary knowledge cannot make such evaluations.

According to Goldman and Bisanz (2002), scientists' level of prior topic knowledge as well as their disciplinary knowledge affects the manner with which they read research reports. When reading within their field, rather than reading a text linearly, scientists first read the findings in order to add to their current knowledge base. On the other hand, when scientists read outside their areas of expertise, they read texts sequentially and more for general interest than for knowledge acquisition. When scientists review an article for publication, they pay more attention to methodological concerns than when they read published reports. Scientists resolve comprehension difficulties based on a cost-benefit analysis in which source, approach, and sensibility of the findings are evaluated. Again, students without such privileged disciplinary knowledge do not approach scientific texts in this manner.

If disciplinary literacy in science requires expert knowledge and experience, then what is expected of adolescents reading science texts? What is meant by scientific literacy? Familiarity with science concepts and ways of thinking are only part of the issue. A more comprehensive understanding of scientific literacy "makes explicit connections among the language of science, how science concepts are rendered in various text forms, and resulting science knowledge" (Pearson et al., 2010, p. 459). Students are expected to gain proficiency in reading, writing, and reasoning with the language, texts, and dispositions of science. These abilities are essential to full participation in public discourse about science. The current state of adolescent scientific literacy, as revealed by standardized assessment data, is not promising.

The 2009 National Assessment of Educational Progress (NAEP) science assessment, administered to students in the fourth, eighth, and twelfth grades, tested science content (i.e., physical science, life science, and earth/space sciences) and how students use scientific knowledge to solve novel problems (NCES, 2011b). Not only did the percentage of students who performed at the Proficient level (defined as "solid academic performance" [NCES, 2011b, p. 1]) decrease with age (from 34% to 21%), but the percentage of students who performed below the Basic level (defined as "partial mastery of the knowledge and skills" [NCES, 2011b, p. 1]) increased from 28% in fourth grade to 40% in the senior year of high school, leaving no time for these students to acquire and refine scientific literacy skills before their post-secondary academic and career pursuits. Results of the 2011 administration, given only to eighth graders, revealed a small but significant increase in the percentage of students performing at or above the basic level (from 63% in 2009 to 65% in 2011). Over a third of eighth grade students, though, continued to perform below the Basic level (NCES, 2012).

The Program for International Student Assessment (PISA) is a triennial assessment of 15-year-old students' performance in scientific literacy, conceptualized as how well students apply scientific knowledge and skills to daily situations (Fleischman, Hopstock, Pelczar, & Shelley, 2010). Although students in the United States demonstrated average performance on the 2009 administration, average scores from 18 of the other 63 participating countries, including Shanghai, Finland, Hong Kong, Singapore, Japan, the Republic of Korea, Canada, Germany, and the United Kingdom, were significantly higher. Only 29% of students in the United States scored at or above level 4, the level at which students are able to link explanations from different areas of science to life situations. Furthermore, 18% of U.S. students performed below level 2, the baseline level of proficiency for competencies that enable full participation in life situations related to science.

Inquiry-based literacy practices provide hope for science education and underscore the connection between literacy and science knowledge espoused by the comprehensive view of scientific literacy (Cervetti, Pearson, Bravo, & Barber, 2006; Pearson et al., 2010). Language and literacy are a means to helping students gain the knowledge, skills, and dispositions of science. These secondhand scientific investigations (a) reinforce what is learned from firsthand (hands-on) investigations, (b) help students learn about topics that are not conducive to firsthand investigations (e.g., ocean, outer space), and (c) allow students to apply inquiry-based skills from firsthand investigations to other domains (Cervetti et al., 2006). These literacy practices are not passive. Rather, students actively make meaning of science and learn how scientists think. Several programs that use texts to support scientific inquiry provide promising data on their effect on science learning (cf. Cervetti et al., 2006; Fang & Wei, 2010; Pearson et al., 2010).

The relationship between literacy and science is not unidirectional. Not only does literacy support science learning, but science provides an ideal context for practicing literacy skills. Science and reading comprehension share many reasoning processes: setting purposes, making sense of data, inferring word meanings, asking questions, clarifying information, drawing inferences, and making evidence-based arguments (Pearson et al., 2010). When students read in science, literacy skills are used for gaining both content and disciplinary knowledge. Students are not only required to master a knowledge base that represents the current understandings of the scientific community, but also be able to solve problems, make predictions, and apply their understandings to new contexts. Students reading science texts must also suspend commonly held beliefs in favor of scientific evidence (Hynd, 2002).

Despite the complementary relationship between science and literacy, there are several challenges facing students acquiring scientific literacy. Time constraints in the classroom, as well as pressures stemming from state testing result in breadth versus depth of coverage, despite the advantages of deep coverage. For example, grades in introductory university science classes were higher for students who reported deep coverage of at least one topic in a respective high school science course than for those who reported no deep coverage (Schwartz, Sadler, Sonnert, & Tai, 2009). Furthermore, “leaving a topic too soon deprives students and teachers the time to experience situations that allow students to confront personal understandings and connections and to evaluate the usefulness of scientific models within their personal models" (Schwartz et al., 2009, p. 820). This problem is confounded by the use of science texts that provide cursory coverage of numerous topics (cf. Broughton & Sinatra, 2010; Goldman & Bisanz, 2002; Smolkin et al., 2008). Factors related to prior knowledge and student dispositions and attitudes related to science can either present challenges to or facilitate learning in science. Aspects that are the focus of the current research are discussed in the next section.

Factors Affecting Science Learning

Learning in any content area requires a unique set of understandings. Proficiency is influenced by, among other things, students' levels of prior knowledge, understandings of the discipline, interest in the subject matter, attitudes and dispositions, and learning goals (Hynd, 2002). When learning is construed as text comprehension, it is obviously also influenced by reading skill, regardless of the discipline. O'Reilly and McNamara (1997) demonstrated that reading skill had more of an effect than general science knowledge on high school students' science passage comprehension test scores. In fact, for open-ended passage comprehension, reading skill partially compensated for low general science knowledge. Whereas O'Reilly and McNamara (1997) found a positive relationship between science knowledge and science passage comprehension, the majority of research has focused on how to overcome the deleterious effect of inaccurate prior knowledge (e.g., Alvermann & Hague, 1989; Hynd, McWhorter, Phares, & Suttles, 1994; Kendeou & van den Broek, 2007).

Prior Knowledge Misconceptions

Defined simply as the whole of a person's knowledge, prior knowledge is dynamic, structured, and both explicit and tacit in nature. It is available for learning tasks and exists as declarative, procedural, and conditional knowledge (Dochy, 1996; Dochy & Alexander, 1995). Use of the term prior knowledge in the literature typically makes the assumption that it is correct. Furthermore, it assumes a dichotomy; students either possess the relevant knowledge, which facilitates learning, or they do not (Dole, 2000).

Learning, however, can take place under other conditions of prior knowledge (Chi, 2008). First, as in the dichotomous view of prior knowledge, students can have no prior knowledge of to-be-learned concepts. When prior knowledge is missing, learning is characterized by adding new information. Second, students' prior knowledge can be partially correct. When prior knowledge is incomplete, learning is conceived as gap-filling. Learning in both cases has been described as knowledge enrichment (Carey, 1991). Research has not examined how these two types of prior knowledge impact science text comprehension. Finally, students can hold common misconceptions about scientific principles. In this case, learning requires changing prior misconceived knowledge to correct knowledge, resulting in conceptual change. There is a long line of research concerning misconceptions in science (cf. Tippett, 2010 for a review).

Misconceptions have been described as "fundamental and inevitable aspects of human learning" (Alexander, 1998, p. 56) and can be characterized as (a) preconceived notions (i.e., popular misconceptions rooted in everyday experiences), (b) nonscientific beliefs (i.e., gained from religion or myth rather than science education), (c) conceptual misunderstandings (i.e., result of not being taught in a way that confronts preconceived notions or nonscientific beliefs), (d) vernacular misconceptions (i.e., result of words having a more common meaning and another scientific meaning), and/or (e) factual misconceptions (i.e., falsities learned early and retained into adulthood) (Committee on Undergraduate Science Education, 1997). Misconceptions become stronger over time (Alexander, 1998). Learners new to a discipline often possess knowledge that is fragmented and not cohesively linked to central concepts. Their misconceptions are likely deeply held because they stem from everyday experience and are tacit. Although students can memorize new information, they often fail to see how it conflicts with their current understandings. Once students gain a foundation of the fundamental principles of a discipline, these misconceptions have strengthened because their conceptual networks grew around malformed notions.

Misconceptions pose a challenge to learning and scientific literacy. For example, sixth grade students' misconceptions interfered with their comprehension of a text that presented counterintuitive information on sunlight (Alvermann, Smith, & Readence, 1985). Most students maintained their misconceptions in written passage recalls, indicating that the text had little influence on changing their understandings. This effect has also been demonstrated in undergraduate students, who relied on misconceptions to make knowledge-based inferences during reading (Kendeou & van den Broek, 2007). Surprisingly, readers did not detect the contradictions between their explanations and text information. Abandoning misconceptions requires acknowledgment of a conflict between the misconception and the scientifically valid explanation, as well as the replacement of “one seemingly viable, simple, and personally constructed belief with another that is more difficult to substantiate, more complex, and removed from personal experience” (Alexander, 1998, p. 61).

According to Gardner (1991), when students are confronted with a problem in science, they often revert back to primitive theories. For example, a common misconception in science is that seasonal change is due to the distance of the earth from the sun. The primitive that undergirds this misconception is that perceived warmth is determined by distance from a heat source. Students may demonstrate an understanding of the scientific conception of seasonal change (i.e., the tilt of the earth’s axis) when directly questioned, but the majority revert to a primitive explanation when quizzed on the concept later if instruction was not successful at invalidating it with the scientific conception.

This invalidation and abandonment of misconceptions is the hallmark of conceptual change learning. The theory of conceptual change first proposed (Posner et al., 1982) suggested that certain conditions must be met for conceptual change learning in science. A student must be dissatisfied with the existing conception. Then they must be confronted with a new conception that is intelligible, plausible, and generalizes to other phenomena. These conditions explain why ordinary forms of instruction (e.g., lecture, traditional text, labs) are often ineffectual in inducing conceptual change and suggest alternative methodologies (Guzzetti, 2000).

Two decades of research has revealed that refutation texts are the most effective text-based means for inducing conceptual change in science (Tippett, 2010). Refutation texts challenge readers' misconceptions with explicit refutations to common misconceptions and emphasize currently accepted scientific conceptions (Guzzetti, 2000). In the following example of a refutation text, the first two sentences present the misconception and the last two are the refutation and currently accepted scientific explanation. In this selection, an optional refutation cue separates the core components.

> Some people believe that a camel stores water in its hump. They think that the hump gets smaller as the camel uses up water. But this idea is not true. The hump stores fat and grows smaller only if the camel has not eaten for a long time. A camel can also live for days without water because the water is produced as the fat in its hump is used up. (Tippett, 2010, p. 953)

It has been suggested that this format of refutation texts leads to conceptual change because it creates cognitive conflict between simultaneously activated misconceptions and scientific conceptions (Kendeou & van den Broek, 2007).

In her review of 22 empirical studies from refereed journals and conference presentations, Tippett (2010) reported that refutation text was more likely to result in conceptual change than traditional expository text. She also suggested differences among grade levels, with refutation text being more likely to result in conceptual change in grades 3 through 10 (versus K-2 and 11-undergraduate). This conclusion is questionable for several reasons. First, only one relevant K-2 study was located. Second, six of the eleven experiments conducted with the oldest students found that refutation text was indeed more effective. Furthermore, her conclusion that refutation texts used in two experiments from one study (Kendeou & van den Broek, 2007) were not more effective than expository text appears misguided because undergraduates with misconceptions recalled statistically more text propositions after reading the refutation text. Tippett (2010) concluded that because refutation text was never found to be less effective than traditional expository text, refutation text effectively promotes conceptual change when readers of any age possess misconceptions. The remainder of this section presents findings from studies that compared refutation and traditional expository texts, first for undergraduate students and then for school-aged students.

Some of the earliest studies that investigated science learning in the presence of misconceptions were conducted with low performing college students (i.e., students who had low high school grade point averages and/or low SAT scores; Alvermann & Hague, 1989; Hynd & Alvermann, 1986). All of the undergraduates in both studies possessed misconceptions regarding Newton's principle of motion, as revealed by performance on true/false prior knowledge tests. Students in each group completed a series of posttests either immediately after (Alvermann & Hague, 1989; short-answer, true/false, and an application problem) or two days after (Hynd & Alvermann, 1986; written free recall and true/false) they read either refutation or expository texts. Results of both studies revealed that students who read the refutation text significantly outperformed those who read the nonrefutation text, with pretest performance as the covariate. The advantage of the refutation text was most apparent on short-answer tests and written recalls.

Investigations that assessed typically developing undergraduate student performance confirm these early findings. In one experiment, undergraduates with no previous college physics experience read either a traditional expository text or what the authors referred to as a conceptual change text on electricity (Wang & Andre, 1991). Half of the participants in each text condition completed a test of their prior knowledge. Students who read the conceptual change text outperformed those who read the traditional expository text, although this advantage was limited to those whose prior knowledge was not assessed. It seems that the prior knowledge test itself alerted participants of their misconceptions, reducing the effect of the conceptual change text on conceptual understanding.

A more recent study of elementary education majors learning astronomy concepts (i.e., seasonal change and moon phases) revealed that, as expected, the refutation text resulted in significantly more conceptual change than the expository text (Frède, 2008). In fact, there were no significant differences between performance on the pretest and immediate and delayed (1-month) posttests in the expository group, indicating that those participants did not increase their knowledge at all. The highest score increases actually occurred for participants who engaged in small group refutation modeling activities, leading the author to conclude that collaborative approaches to conceptual change learning are superior to approaches involving individual involvement with a refutation text.

Few research efforts have aimed at uncovering the cognitive processes involved in the refutation text effect. Using an online think-aloud methodology, Kendeou and van den Broek (2007, Experiment 1) demonstrated that undergraduates with misconceptions about Newtonian mechanics generated fewer correct inferences and more incorrect inferences than those without misconceptions. Undergraduates with misconceptions engaged in more conceptual change strategies (i.e., experienced cognitive conflict, responded to conflict, contrasted information) while reading the refutation text. The authors speculated that the more conceptual change strategies readers used, the more correct inferences they made, which in turn led to better memory on written recalls. Significant bivariate correlations between conceptual change strategies and inferences and between inferences and recall, but not between conceptual change processes and recall, lent support to the hypothesis that inference-making ability mediated the effect of conceptual change on written recall.

A more recent study confirmed that refutation texts increased the number of inferences undergraduates generated in text recalls (Diakidoy, Mouskounti, & Ioannides, 2011). Participants who read the refutation text generated more global bridging and elaborative inferences, but there was no difference in the number of local bridging inferences or the quantity of text information recalled as compared to the traditional expository text. The benefit of the refutation text was more pronounced for participants with inaccurate prior knowledge.

Broughton, Sinatra, and Reynolds (2010) reported that undergraduates who read a refutation text and those that read a traditional expository text about seasonal change actually showed similar improvements between prior knowledge and comprehension scores. A standardized measure of reading rate and reading comprehension explained a significant amount of the variance in this improvement. Despite the similarity in scores, participants who read the refutation text demonstrated a greater decrease in the number of misconceptions present from pre- to posttest. These participants often reported that the refutation segments were the most important part of the passage. Interestingly, these text segments were read significantly faster than the corresponding text segments in the traditional text. The authors concluded that the refutation text information may be easier to process, which contributes to greater conceptual change.

Studies involving school-aged children also report positive effects of refutation text on conceptual change as compared to expository text (but see Guzzetti, 1990). An early study of children in fifth and sixth grades used short texts based on individual participants' misconceptions in science and social studies topics (Maria & MacGinitie, 1987). Students read texts in four conditions: a refutation text on a topic for which they held a misconception, a refutation text for which no misconception was held, a refutation text with alternate ordering (i.e., the correct information was presented before the misconception), and a nonrefutation text. Posttest performance revealed that oral recalls of nonrefutation texts were significantly less likely to contain new information. There were no significant differences between the other three conditions, indicating that refutation texts are of equal benefit regardless of whether or not a misconception is held.

A more recent study uncovered differences based on the type of comprehension assessed and level of prior knowledge (Mikkilä-Erdmann, 2001). Fifth grade students read either a conceptual change text or a traditional expository text on photosynthesis and answered 11 essay questions (identical to the prior knowledge assessment). Four questions tested knowledge of the text-base (i.e., explicit and inferential questions), and seven tested the formation of the mental model of the text (i.e., questions that required explanation and application to novel situations). On text-based comprehension, low knowledge readers performed better on explicit questions after reading the traditional text, whereas high knowledge readers did better on inferential questions in the conceptual change condition. Students with both levels of prior knowledge, however, had better performance on mental model questions with the conceptual change text.

All of the studies reviewed thus far were conducted in artificial testing sessions, calling the ecological validity of refutation texts into question. Diakidoy, Kendeou, and Ioannides (2003) assigned ten intact sixth grade classrooms to one of three learning conditions: refutation, expository, or standard instruction (i.e., no text). One lesson on the concept of energy was taught by each classroom teacher and was observed by the researchers for fidelity. All lessons included activities and demonstrations, but students in the two text conditions read instead of answering review questions. Posttest performance on short answer and multiple choice questions one day and one month after instruction revealed that classrooms that read the refutation text outperformed classrooms in the two other conditions, between which there were no differences. Although prior knowledge was not assessed, the authors reported that the refutation text influenced performance only on questions that assessed hypothesized preconceptions.

Other classroom-based investigations have been conducted with high school science classes, although comparisons were not made between refutation texts and traditional expository texts. Instead, these studies sought to determine whether other instructional variables mitigated the refutation text effect. Hynd and colleagues (1994) demonstrated that ninth and tenth grade students with misconceptions regarding projectile motion benefited the most from reading a refutation text and seeing a demonstration (67% of students in this condition revised their misconceptions). With the addition of a small group discussion of the concept, conceptual change occurred 50% of the time. Only 37% of students revised their misconceptions when they read the refutation text and participated in a discussion, indicating that student-to-student discussion actually hindered performance. Guzzetti, Williams, Skeels, and Wu (1997), however, found that discussions with a researcher were necessary to clarify the scientific conception for high school students with misconceptions and those with no prior knowledge about projectile motion. These findings suggest that conceptual change is fostered by a combination of refutation text, demonstration, and perhaps adult guided discussions.

In sum, prior knowledge misconceptions hinder science text comprehension for students of all ages. Refutation texts directly confront and refute these misconceptions and offer correct scientific conceptions. Reading refutation texts results in significantly more conceptual change than reading traditional expository texts. In no case, though, did all participants who read a refutation text demonstrate conceptual change. This fact has prompted researchers to investigate other influences on conceptual change.

Disciplinary Attitudes/Dispositions

The focus on cognitive factors such as prior knowledge and misconceptions in conceptual change research has been labeled cold conceptual change (Pintrich, Marx, & Boyle, 1993). Despite the strong relationship between prior knowledge and performance, other learning variables are essential for student performance. Dochy, Segers, and Buehl (1999) contend that "it would be foolhardy to conclude that learning is completely directed by a learner's preexisting knowledge base" (p. 171). A "warmer" view of conceptual change (Sinatra, 2005) incorporates situation-specific factors that reflect students' epistemological beliefs, self-efficacy, and interests. These learner dispositions influence the likelihood of conceptual change (Pintrich et al., 1993). The three disciplinary attitudes and dispositions as conceptualized for this study are discussed separately along with findings from the research on their role in conceptual change.

Epistemological beliefs. Epistemological beliefs are "individual's beliefs about the nature of knowledge and the process of knowing" (Hofer & Pintrich, 1997, p. 117). Evidence suggests that students' epistemological knowledge is discipline-specific. Students tend to view science as certain, with discrete facts to be learned from sources of authority (Hofer & Pintrich, 1997). There is, however, a progression from an absolute belief in knowledge as certain and verifiable by fact, to a belief that all claims in science are opinions and thus equally valid, to an evaluative belief that acknowledges scientific uncertainty and the importance of evaluation. Results of a longitudinal study indicate that some epistemological development occurs during high school (Schommer, Calvert, Gariglietti, & Bajaj, 1997). Epistemological understanding influences the disposition (versus the competence) to engage in scientific thinking (Kuhn & Dean, 2002). Pintrich (1999, cited in Sinatra, 2005) proposed that a belief in simple and certain knowledge can inhibit conceptual change, whereas a belief in uncertain and constructed knowledge in science can lead to the deep processing required to abandon misconceptions.

Empirical findings confirm the suggested relationship between epistemological beliefs and conceptual change. For example, high school students with more advanced epistemological beliefs were more likely than students with less advanced beliefs to abandon their misconceptions after reading a refutation text on the Newtonian theory of motion (Qian & Alvermann, 1995). Key epistemological beliefs for conceptual change were that scientific knowledge is complex and uncertain and that learning is a gradual process. Alternatively, it has been demonstrated that belief in authoritative sources of knowledge and scientists as experts hinders conceptual change (Mason, 2001).

Although not conducted with refutation text, findings from another study (Windschitl & Andre, 1998) have implications for epistemological beliefs and conceptual change. University students in a constructivist learning condition (i.e., students formed and tested their own hypotheses) demonstrated greater conceptual change than those in an objectivist learning condition (i.e., students followed prescribed written instructions), but learning condition interacted with epistemological beliefs. Students with more sophisticated epistemological beliefs benefited from the constructivist condition in which they were allowed to explore the new material, whereas students who believed in simple and certain knowledge demonstrated more conceptual change when they followed prescribed instructions.

Self-efficacy. Motivation is comprised of many different constructs and has been speculated to induce conceptual change because it is associated with deeper processing of text. Self-efficacy is one aspect of the expectancy component of motivation (Pintrich & De Groot, 1990). These are students' beliefs that they are able to complete a task and that they are responsible for their performance. A student's level of self-efficacy and control answers the question, "Can I do this task?" Defined in terms of confidence in one's ability to learn (versus one's knowledge), high self-efficacy should enhance conceptual change because it is associated with mastery goals, which increase the likelihood that a student recognizes that a change in conception is required to learn the material (Linnenbrink & Pintrich, 2003).

Although not concerned with conceptual change per se, research has demonstrated that self-efficacy makes an independent contribution to science achievement for students in middle school (Britner & Pajares, 2006), high school (Kupermintz, 2002; Lau & Roeser, 2002), and college (Andrew, 1998). Results of a correlational study conducted with students in seventh grade science and English classes revealed that aspects of motivation are related to one another (Pintrich & De Groot, 1990). The Motivated Strategies for Learning Questionnaire (MSLQ) revealed that higher levels of self-efficacy were associated with higher levels of cognitive strategy use, self-regulation (i.e., a mastery goal orientation), and higher levels of student achievement on in-class work, homework, quizzes, tests, essays, and reports. One study (Hynd, Holschuh, & Nist, 2000) directly investigated the impact of self-efficacy on conceptual change, and it collapsed several components of motivation (including interest, self-efficacy, and grades). Findings revealed that high school students' motivation to learn was important for conceptual change in physics.

Interest. Research distinguishes between two types of interest. Individual interest relates to personal interest, is relatively stable, and is associated with increased knowledge and value. Situational interest is elicited from environmental stimuli (e.g., features of a text) and is associated with focused attention. The two forms of interest likely interact, leading to more elaborate and deeper processing of texts (Hidi, 2002; Schiefele, 1999). Another type of interest, and the focus of the current research, is topic interest. Topic interest is comprised of intrinsic feeling-related (i.e., feelings associated with a topic, such as enjoyment) and value-related (i.e., the personal significance of a topic) beliefs. Topic interest is particularly relevant to reading because the topics students are asked to learn about are typically encountered in titles of text passages. Though there is disagreement as to whether topic interest is a form of individual or situational interest (Ainley, Hidi, & Berndorff, 2002; Hidi, 2001), ratings made prior to reading are more closely related to individual interest.

In a review of 22 studies of narrative and expository text comprehension (i.e., not restricted to science), the average correlation between topic interest and text learning was .27 ($p < .01$) and was independent of text length, type of text or comprehension assessment, age, reading ability, and prior knowledge (Schiefele, 1999). Other studies revealed that topic interest affected deep-level learning more than surface-level learning and seemed to have a particular effect on the propositional processing of text (Hidi, 2001; Schiefele, 1999). This deeper processing is one characteristic that promotes conceptual change (Chinn & Brewer, 1993).

There is disagreement in the literature about the relationship between prior knowledge and interest, and whether the impact of interest on learning is independent of the effects of prior knowledge. Conflicting findings are due in large part to the differences in how interest has been conceptualized and assessed (cf. Tobias, 1994). Some researchers, (e.g., Renninger, Ewen, & Lasher, 2002) confound knowledge and interest by including stored knowledge as a component of interest. There is a need for research that assesses interest and prior knowledge of the same topic to determine the relationship between the two and the independent contributions of each to comprehension. This call has been minimally answered by research on conceptual change.

Andre and Windschitl (2003) presented data from university students who read traditional or refutation texts on electric circuits. Students in the refutation condition outperformed the others, but gender (i.e., male) and verbal ability were also significantly related to performance. Topic interest was significantly related to performance, which reduced the influence of gender. Interest (as measured by a 12-item questionnaire) influenced conceptual understanding regardless of the type of text read. Interest and previous experience were correlated, but measures of prior knowledge were not collected. It is possible that the influence of interest on conceptual change was indirect (i.e., through its influence on prior knowledge). In another experiment, Andre and Windschitl (2003) reasoned that interest would influence conceptual change independently of prior knowledge. Results of a path analysis revealed that, as hypothesized, interest had a significant direct effect on posttest performance (.14) above and beyond the direct effect of pretest performance (.64). Interest also had an indirect effect on conceptual change, through its influence on previous experience.

Students who report high interest in a topic may very well demonstrate small amounts of conceptual change. Venville and Treagust (1998) interviewed high school students to determine their understanding of and interest in genetics. Students tended to be interested in the hereditary aspects of genetics, rather than the microscopic aspects that were critical to conceptual change. The differences in findings on interest and conceptual change are likely due to how interest was measured and thus defined.

Studies investigating multiple disciplinary attitudes and dispositions. There are few studies investigating the effect of multiple disciplinary attitudes and dispositions on science text comprehension. Mason and Boscolo (2004) investigated the effects of domain-general epistemological understanding (i.e., not related to science knowledge) and topic interest on grade 10 and 11 students' comprehension of an expository science text. The controversial topic of genetically modified food was used. Students with advanced epistemological beliefs tended to write text conclusions that recognized the need for further scientific research on the matter and/or supported one position by arguing against the other. Advanced beliefs were also associated with a change in personal opinion on genetically modified food to a more neutral position. Higher levels of both epistemological understanding and topic interest were associated with richer responses to open-ended comprehension questions but did not affect performance on multiple-choice questions. There were no interactions between epistemological understandings and topic interest; higher topic interest did not compensate for less advanced epistemological beliefs.

A more recent study is of particular relevance to the current research because it investigated the effects of epistemological beliefs and topic interest on conceptual change (Mason, Gava, & Boldrin, 2008). Participants were fifth grade students who read either a traditional or refutation text about light. Epistemological beliefs (less advanced and more advanced) and topic interest (low and high) were also between-subject variables.

Participants who read the refutation text demonstrated more conceptual change than those who read the expository text. The standardized reading comprehension covariate explained a significant amount of variance and correlated significantly with knowledge at the three testing times (pre-, post- and delayed posttest). Prior topic knowledge and interest were not correlated. Higher topic interest was associated with greater conceptual change on its own, as well as through an interaction with epistemological beliefs and refutation text. Advanced epistemological beliefs facilitated conceptual change through its interaction with interest and refutation text. The refutation text was beneficial to students with and without advantageous levels of interest and epistemological beliefs. None of the variables affected shallow levels of text understanding assessed by factual text retention questions.

Purpose of the Current Research

Numerous studies have shown an advantage of refutation text over traditional expository text when students have misconceptions in science. These findings have been extended by research that uncovers other variables that promote learning and conceptual change. This study had two aims. The first aim was to determine whether prior knowledge impacted science text comprehension. Two conditions of prior knowledge were investigated: when students (a) held misconceptions and (b) had incomplete prior knowledge. The second aim was to uncover the disciplinary attitudes and dispositions that facilitated science text comprehension. The “warm” constructs that have been shown to affect conceptual change have, for the most part, been investigated singularly. This study was the first to investigate three related to conceptual change: epistemological beliefs, interest, and self-efficacy. Furthermore, the impact of these variables was investigated in the presence of misconceptions and incomplete prior knowledge.

The following research questions and hypotheses correspond to the aims of the study:

1) *Is science text comprehension impacted by type of prior knowledge (misconception or incomplete)?* It was hypothesized that there would be greater improvement between the prior knowledge and comprehension assessments when students held misconceptions than when their prior knowledge was incomplete. Misconceptions explicitly refuted by a text are more likely to be corrected (i.e., conceptual change) than incomplete knowledge is to be gained from traditional expository texts (i.e., knowledge enrichment).

2) *Do disciplinary attitudes and dispositions moderate the impact of prior knowledge on science text comprehension?* It was hypothesized that students with more advanced levels of epistemological beliefs, self-efficacy, and topic interest would demonstrate greater improvements between their prior knowledge and comprehension assessments than students with lower levels. Epistemological beliefs were hypothesized to have a greater impact on conceptual change learning than knowledge enrichment.

CHAPTER III

METHOD

Participants

Participants were 28 typically developing 14 to 15 year olds (*M* = 15.02 years) whose first language was English. Participants performed at or above the 25th percentile on the combined vocabulary and reading comprehension subtests of the *Gates-MacGinitie Reading Tests, 4th edition* (*GMRT*; MacGinitie, MacGinitie, Maria, Dreyer, & Hughes, 2006; Level 7/9, Form S). The mean *GMRT* score was the 56th percentile (range 27th to 94th percentile). Participants were paid $10 after completion of the second day of testing.

Information was obtained regarding participants' eighth grade science end-of-grade (EOG) scores and their current, or most recent if not currently enrolled, science course grade. The EOG science test assesses competencies in the North Carolina *Standard Course of Study* with 80 multiple-choice questions (North Carolina Department of Public Instruction [NCDPI], 2007). Scores are reported as scale scores and corresponding achievement levels I-IV, with grade-level proficiency defined as an achievement level III or above (NCDPI, 2011). The sample mean science EOG scale score was 153.8 (range 140 to 165), which corresponded to an achievement level III (NCDPI, 2008). Participants' science course grades ranged from letter grades A to D. All but one participant was enrolled in an honors science course.

Measures and Scoring

The *GMRT* (MacGinitie et al., 2006) was used as an independent measure of vocabulary and reading comprehension to assist in determining eligibility for the study. Questionnaires and assessments were developed to assess disciplinary attitudes and dispositions in science, prior knowledge of science topics, and science text comprehension. Descriptions of each measure follow. Interrater reliabilities were calculated for 25% of the protocols for each measure and are reported as percent of agreement on all questions.

Vocabulary and Reading Comprehension

The *GMRT* (MacGinitie et al., 2006) consists of vocabulary and reading comprehension subtests. Each test word in the vocabulary subtest is presented in a brief context intended to suggest part of speech but not to provide clues to meaning. Students select the word or phrase that means most nearly the same as the test word. The reading comprehension subtest consists of short reading passages and corresponding multiple-choice comprehension questions. The reported reliability estimates indicate strong total test and subtest internal consistency levels with coefficient values at or above .90.

Participants in this study completed even-numbered vocabulary questions (22 out of 45) and 24 out of 48 reading comprehension questions from 5 out of 11 passages (passages 1, 3, 6, 9, and 11). Raw scores were calculated for each subtest; interrater reliability was 100%. Winter or spring norms were used depending on the date of assessment. Since half of the items were administered, the total raw score was doubled to arrive at a combined percentile rank.

Epistemological Beliefs

The 12-item epistemological beliefs questionnaire (adapted from Mason, Gava, & Boldrin, 2008) measured beliefs about the certainty (odd numbered statements) and development of knowledge (even numbered statements) in science (see Appendix A). Participants indicated on a 5-point Likert-type scale their agreement with each item (1 = strongly disagree, 5 = strongly agree). The scale measuring certainty was reversed so that lower scores reflected more advanced beliefs. Raw scores were calculated; interrater reliability was 100%. Mason et al. (2008) reported an alpha reliability coefficient of .73 in their sample of 94 students in fifth grade.

Self-Efficacy in Science

Nine items from the MSLQ (Pintrich & De Groot, 1990) were used to assess participants' self-efficacy in science (see Appendix B). Participants rated their abilities as compared to peers in their science class. Participants indicated on a 5-point Likert-type scale their agreement with each item (1 = not at all true of me, 5 = very true of me). Raw scores were calculated, and interrater reliability was 100%. The reported reliability for the self-efficacy scale in the original 44-item version was .89 in a sample of 173 students in seventh grade (Pintrich & De Groot, 1990).

Topic Interest

Interest in science topics was assessed with a 10-item questionnaire for each topic (see Appendix C). The questionnaires were modeled after those used by Mason et al. (2008) and included items that assessed feeling-related and value-related aspects of interest. Participants indicated on a 5-point Likert-type scale their agreement with each item (1 = not at all like me, 5 = very true of me). Three items (2, 6, and 10) were reversed so that lower scores reflected greater interest. Interrater reliability of the raw scores was 100%. Mason et al. (2008) reported an alpha reliability coefficient of .80.

Science Topics

Two topics were selected for each type of prior knowledge investigated (i.e., misconception and incomplete). Previous studies on conceptual change have demonstrated that misconceptions about seasonal change and object motion are common. Topics for which participants were likely to have incomplete knowledge were chosen from the same areas of science as the misconception topics to control for topic selection. Eclipses (from earth/space science) and magnets (from physical science) represented topics that would be familiar to 14 and 15 year olds, but for which most would not be able to give scientific explanations. A high school science teacher confirmed that students had not covered the topics in her course.

Prior Knowledge and Science Text Comprehension

Prior knowledge of each science topic was assessed with a written 9-item pretest consisting of four open-ended and five multiple-choice questions (adapted from Broughton et al., 2010; see Appendix D). Common misconceptions were taken into account when composing the multiple-choice answer options. Comprehension assessments were identical to the prior knowledge assessments. Raw scores were calculated for prior knowledge and comprehension assessments. Interrater reliability was 93% and 94%, respectively. Disagreements were resolved through discussion. Broughton et al. (2010) reported an alpha value of .83 for their 5-item multiple-choice concept inventory.

Prior knowledge and comprehension assessments for each topic were also coded to describe the nature of knowledge they elicited. Prior knowledge of seasonal change and object motion could be categorized as a misconception, incomplete knowledge, or correct knowledge. Assessments were first examined for the presence of misconceptions and were coded as such if the common misconception was expressed on any portion of the test. The common misconception for seasonal change is that it is caused by the earth's distance from the sun. For object motion, it is that an object comes to a stop because of some internal property (e.g., weight, acceleration) of the object. Incomplete knowledge of seasonal change was defined by the absence of the idea that the earth's axis tilts towards the sun in the summer and away from it in the winter on any applicable question. Incomplete knowledge of object motion was defined by the absence of knowledge that objects come to a stop because of external forces on any applicable question. Prior knowledge of seasonal change and object motion was categorized as correct by the presence of the above criteria on all applicable questions.

Prior knowledge of eclipses and magnets could only be categorized as incomplete or correct (i.e., there are no common misconceptions for those topics). Incomplete knowledge of eclipses was coded if the concept that the moon or earth blocks the sun's light was missing from any portion of the assessment. For magnets, prior knowledge was coded as incomplete if the concept that opposite poles attract was missing from any applicable test question. Correct knowledge of these topics was identified by the presence of the respective concepts on all applicable questions. Interrater reliability for these categorizations of knowledge was 98%. Disagreements were resolved through discussion.

Science Texts

Four science passages were written for this study: two refutation and two traditional expository (see Appendix E). Passages are controlled for length and complexity (see Appendix E for passage-specific values). Lexile® measures (http://www.lexile.com/analyzer/) take into consideration word count, mean sentence length, and mean log word frequency. The mid-year interquartile lexile range for typically developing students in the 9th grade is 855L to 1165L (MetaMetrics, 2012). Lexile measures for the passages in this study ranged from 980L to 1130L. The Gunning Fog index of readability (http://gunning-fog-index.com/index.html), a weighted average of the number of words per sentence and the number of complex (i.e., 3+ syllable) words, is an estimate of the number of years of formal education needed to understand a text. Fog indexes for passages in this study ranged from 8.58 to 9.62.

Procedure

Testing was performed in group settings. On Day 1, participants completed the *GMRT* subtests; questionnaires on epistemological beliefs, topic interests, and self-efficacy; and prior knowledge assessments. Presentation of measures was counterbalanced to account for possible fatigue effects. The reading comprehension subtest, the vocabulary subtest, and the topic interest and associated prior knowledge assessments were always the first three measures administered, with the four individual topic interest/prior knowledge assessments counterbalanced within that rotation. The epistemological beliefs and self-efficacy questionnaires were always the last two measures administered. Participants took between approximately 30 minutes and 1 hour to complete Day 1 testing.

On Day 2, participants read four short science texts. After reading each passage, they completed the written comprehension assessment. Presentation of passages and corresponding comprehension assessments was counterbalanced. Day two of testing took approximately 30 to 45 minutes. There was typically a delay of five or seven days between the first and second days of testing, although the length of delay was not critical to the methodology since science text comprehension assessments were administered on the same day participants read the science passages.

CHAPTER IV

RESULTS

A total of 112 observations were obtained (28 participants x 4 topics). Table 1 presents mean total and open-ended scores for the prior knowledge and comprehension assessments in each topic. Paired sample *t*-tests compared average performance between the two topics in each type of prior knowledge to determine if participants had more prior knowledge or better passage comprehension of one topic than another, as assessed by performance on the assessments as a whole and on only the open-ended portion of the assessments. In the two misconception topics, all average scores except open-ended comprehension were significantly higher for object motion than for seasonal change (total prior knowledge: $t(27) = 2.30$, $p < .05$; open-ended prior knowledge: $t(27) = 3.38$, $p < .01$; total comprehension: $t(27) = 2.94$, $p < .01$; open-ended comprehension: $t(27) = 1.05$, $p = .30$). In the incomplete knowledge topics, average scores for all eclipse assessments were higher than those for magnets (total prior knowledge: $t(27) = 2.15$, $p < .05$; open-ended prior knowledge: $t(27) = 7.13$, $p < .01$; total comprehension: $t(27) = 2.13$, $p < .05$; open-ended prior knowledge: $t(27) = 4.67$, $p < .01$).

Paired samples correlations, reported in Table 2, revealed significant or near significant moderate correlations between the total prior knowledge and total comprehension scores for the two topics in each type of prior knowledge. Open-ended scores were not correlated. Collapsed total scores are reported in Table 1.

Table 1. Mean Prior Knowledge and Comprehension Assessment Scores by Topic

	Misconception			Incomplete	
	Prior Know	Comp		Prior Know	Comp
Seasonal Change			Eclipses		
Total (max = 9)	2.86 (1.80)	3.96 (2.22)	Total (max = 9)	3.64 (2.11)	5.00 (1.91)
Open-ended (max = 4)	1.04 (1.14)	1.93 (1.27)	Open-ended (max = 4)	2.04 (1.32)	2.75 (1.21)
Object Motion			Magnets		
Total (max = 9)	3.71 (1.72)	5.18 (2.00)	Total (max = 9)	2.86 (1.30)	4.18 (1.89)
Open-ended (max = 4)	1.93 (1.02)	2.21 (1.13)	Open-ended (max = 4)	0.32 (0.48)	1.57 (1.17)
Collapsed			Collapsed		
Total (max = 18)	6.57 (2.91)	9.11 (3.64)	Total (max = 18)	6.46 (2.89)	9.18 (3.20)
Open-ended (max = 8)	2.96 (1.60)	4.11 (1.95)	Open-ended (max = 8)	2.32 (1.49)	4.32 (1.96)

Note. N = 28; Know = knowledge; Comp = Comprehension

Table 2. Total and Open-Ended Score Correlations for Misconception and Incomplete Knowledge Topics

Topics	Total		Open-Ended	
Seasons – Motion	Prior Knowledge	.37[a]	Prior Knowledge	.13
	Comprehension	.47*	Comprehension	.29
Eclipses – Magnets	Prior Knowledge	.44*	Prior Knowledge	.28
	Comprehension	.42*	Comprehension	.37[b]

*$p < .05$, [a] $p = .053$, [b] $p = .054$

Prior knowledge and comprehension scores for seasonal change and object motion were collapsed to obtain one pre- and posttest misconception score, respectively. Scores were collapsed in the same manner for eclipses and magnets to obtain pre- and posttest incomplete knowledge scores. Each of the collapsed pre- and posttest scores, except prior knowledge of incomplete knowledge topics, was significantly correlated with the combined vocabulary and reading comprehension subtest percentiles (misconception prior knowledge: $r(28) = .61$, $p < .01$; misconception comprehension: $r(28) = .66$, $p < .01$; incomplete prior knowledge: $r(28) = .25$, $p = .20$; incomplete comprehension: $r(28) = .53$, $p < .01$).

A 2 (Time: pretest, posttest) x 2 (Type of Prior Knowledge: misconception, incomplete) repeated measures analysis of covariance (ANCOVA), with combined reading comprehension and vocabulary percentile rank entered as the covariate, was conducted to examine for changes between prior knowledge and comprehension. The covariate was not significant, $F(1,26) = 3.17$, $p = .09$, so it was removed for further analysis. A 2 (Time) x 2 (Type of Prior Knowledge) repeated measures analysis of variance (ANOVA) revealed a statistically significant increase in scores from pre- to posttest, $F(1, 27) = 32.80$, $p < .01$, $\eta_p^2 = .55$, but that type of prior knowledge did not interact with time, $F(1, 27) = .06$, $p = .81$. It should be noted that the observed power for the time x type of prior knowledge interaction was .06, indicating that the test was underpowered.

Mean epistemological belief, self-efficacy, and topic interest scores are reported in Table 3. Epistemological beliefs and self-efficacy were not significantly correlated, $r(28) = .314$, $p = .10$, indicating that participants with relatively high scores in one area did not necessarily have high scores in the other. Mean interest scores for the incomplete knowledge topics (i.e., eclipses and magnets) were significantly different. Average interest scores for the misconception topics (i.e., seasonal change and object motion) were similar. Interest and prior knowledge scores for three topics were not significantly correlated (seasons: $r(28) = .172$, $p = .38$; motion: $r(28) = .08$, $p = .69$; magnets: $r(28) = .04$, $p = .83$). The interest and prior knowledge scores for eclipses, the topic with the highest mean interest score, were significantly correlated, $r(28) = .43$, $p < .05$.

Separate 2 (Time) x 2 (Type of Prior Knowledge) repeated measures analyses of covariance (ANCOVAs) were conducted to determine whether disciplinary attitudes and dispositions moderated science text comprehension. When epistemological beliefs score was entered as the covariate, a significant Time x Epistemological Beliefs interaction was obtained, $F(1, 26) = 7.76$, $p < .01$, $\eta_p^2 = .23$, indicating that participants with more

Table 3. Mean Disciplinary Attitudes/Dispositions Scores

	Epistemological Beliefs (max = 60)	Self-Efficacy (max = 45)	Topic Interest			
			Seasons (max = 50)	Motion (max = 50)	Eclipses (max = 50)	Magnets (max = 50)
M	48.86	34.61	28.25	27.79	31.29*	26.43*
SD	5.90	6.70	6.34	7.12	8.11	6.45
Median	49.50	36.00	29.00	27.50	31.50	26.50
1st quartile	36 – 46	19 – 31	16 – 22	12 – 24	18 – 24	14 – 22
2nd quartile	44 – 49	33 – 36	24 – 28	25 – 27	28 – 31	23 – 26
3rd quartile	50 – 51	37 – 39	30 – 33	28 – 32	32 – 37	27 – 30
4th quartile	53 – 60	41 – 44	34 – 41	33 – 46	39 – 46	31 – 42

Note: N = 28, * $p < .05$

advanced epistemological beliefs demonstrated greater pre- to posttest score increases. The Time x Type of Prior Knowledge x Epistemological Beliefs interaction was not significant, $F(1, 26) = 2.22$, $p = .15$, indicating that the moderation of epistemological beliefs on change over time did not vary by type of prior knowledge (i.e., misconception or incomplete). It should be noted that the observed power of this three-way interaction was .30, indicating that with a larger sample size, a significant effect might be found.

Self-efficacy score did not significantly moderate pre- to posttest performance, $F(1, 26) = 2.92$, $p = .10$. The observed power of this test was relatively high at .38, indicating that a larger sample size might reveal a significant effect of this two-way interaction. Self-efficacy score was not correlated with current science course grade, $r(28) = .35$, $p = .07$, or eighth grade science EOG test score, $r(26) = -.06$, $p = .76$.

To determine whether or not topic interest moderated science text comprehension, interest scores for each of the four topics were averaged to obtain one topic interest score. Averaging the interest scores assumes that a participant had high, moderate, or low interest scores in all four topics. See Table 4 for topic interest correlations.

Table 4. Correlations Among Topic Interest Scores

Measure	1	2	3	4
1. Seasons interest	1.00			
2. Motion interest	.28	1.00		
3. Eclipses interest	.17	.29	1.00	
4. Magnets interest	.44*	.56**	.19	1.00

* $p < .05$, ** $p < .01$

Average interest score did not moderate pre- to posttest performance, $F(1, 26) = .00$, $p = .99$. Because eclipses had the highest topic interest and was the only topic for which interest was significantly correlated with prior knowledge, it was examined separately to determine if it moderated change over time. The interaction of time and topic interest was not significant for eclipses, $F(1,26) = 1.93$, $p = .18$.

The initial analyses treated the knowledge assessed by the pretests as valid representations of the type of prior knowledge (i.e., misconception or incomplete) that the topics were chosen to elicit on an a priori basis. Further analysis of the data is based on the categorization of prior knowledge as either a misconception or incomplete as assessed by the pretests, reflecting the goals of the study. Average misconception prior knowledge and comprehension scores were calculated for participants who demonstrated a common misconception on either or both of the pretests for seasonal change and object motion. Average incomplete prior knowledge and comprehension scores were calculated for participants who demonstrated incomplete knowledge on the pretests for any of the four topics. Mean scores are reported in Table 5.

Table 5. Mean Prior Knowledge and Comprehension Scores by Categorized Type of Prior Knowledge

	Prior Knowledge	Comprehension
Misconception	2.30 (1.26)	4.00 (1.97)
Incomplete	2.84 (1.39)	4.57 (1.62)

Note. n = 22; maximum score = 9

A 2 (Time: pretest, posttest) x 2 (Type of Prior Knowledge: misconception, incomplete) repeated measures ANOVA was performed with the recalculated average scores for the subsample of 22 participants who demonstrated at least one instance each of misconceptions and incomplete knowledge. As before, the main effect of time, $F(1, 21) = 42.03$, $p < .01$, $\eta_p^2 = .67$, confirmed that scores increased from pre- to posttest. The main effect of prior knowledge was not significant, $F(1, 21) = 3.08$, $p = .09$, indicating that, although scores for incomplete knowledge were higher, they were not significantly different from those of misconceptions. There was not a significant interaction between time and prior knowledge, $F(1, 21) = .02$, $p = .88$, indicating that the observed increase in pre- and posttest scores did not depend on type of prior knowledge.

Separate 2 (Time) x 2 (Type of Prior Knowledge) repeated measures ANCOVAs were conducted to determine whether epistemological beliefs, self-efficacy, or topic interest moderated science text comprehension. With a reduced sample size, the interaction between time and epistemological beliefs was no longer significant, $F(1, 20) = .76$, $p = .39$. The Time x Type of Prior Knowledge x Epistemological Beliefs interaction was also not significant, $F(1, 20) = 2.03$, $p = .17$, but the test statistics and observed power (.27) were similar to the analysis performed with the complete sample. This indicates a high likelihood that the hypothesized three-way effect would be detected with a larger sample size. Self-efficacy did not moderate pre- to posttest score increases, $F(1, 20) = .38$, $p = .55$. To determine the impact of interest, participants' mean interest scores were recalculated by averaging the interest scores of the topics for which they demonstrated an actual misconception and incomplete knowledge. Interest did not moderate the change in pre- to posttest score, $F(1, 20) = .01$, $p = .92$.

Post-Hoc Analyses

Several post-hoc analyses of the data were conducted to determine what, if any, patterns were present that might provide a better explanation of the data. The first set of analyses describes the nature of knowledge as revealed by the prior knowledge assessments, as well as the type of learning that ensued. The second set of analyses explores the relationship between disciplinary attitudes and dispositions and the two types of learning investigated in this study. Data from the entire sample were used for these analyses.

Type of Prior Knowledge, Learning, and Text

Recall that knowledge demonstrated on the prior knowledge and comprehension assessments could be categorized as one of three types: a misconception, incomplete, or correct. Based on these distinctions, nine prior knowledge/comprehension groups were formed. Three groups consisted of observations of prior knowledge misconceptions that were followed by comprehension that was either a misconception, incomplete, or correct. Three groups consisted of incomplete prior knowledge followed by misconception, incomplete, or correct comprehension. Finally, three groups consisted of observations of correct prior knowledge followed by one of the three types of knowledge at comprehension. Table 6 presents the number of observations in each group by topic.

Table 6. Prior Knowledge/Comprehension Group Membership

Prior Knowledge	Misconception			Incomplete			Correct			
Comprehension	Misc	Incom	Corr	Misc	Incom	Corr	Misc	Incom	Corr	Subtotal
Seasons	12	4	2	2	2	6	0	0	0	28
Motion	2	3	4	0	3	6	1	1	8	28
Eclipses	--	--	--	--	6	9	--	1	12	28
Magnets	--	--	--	--	9	10	--	1	8	28
Subtotal	14	7	6	2	20	31	1	3	28	
Total		27			53			32		112

Note. Misc = misconception; Incom = incomplete; Corr = correct

Almost half (48.21%, 27/56) of the prior knowledge assessments of the topics for which a common misconception could be held actually revealed a misconception. Nineteen of the remaining prior knowledge assessments of the misconception topics actually revealed incomplete prior knowledge. Almost two-thirds (60.71%, 34/56) of the assessments designed to reveal incomplete knowledge actually did so. A within-person analysis of the type of prior knowledge for each topic revealed that 23 participants demonstrated at least one misconception, 4 demonstrated misconceptions on both topics, 27 demonstrated at least one instance of incomplete prior knowledge, and 21 demonstrated at least one instance of correct prior knowledge. Although it was possible to have incomplete or correct prior knowledge of all four topics, no participant exhibited this pattern.

It was very difficult to overcome a misconception and demonstrate correct knowledge on the corresponding comprehension assessment. Although misconceptions were abandoned about half of the time (48.15%, 13/27), conceptual change occurred less than one quarter of the time (22.22%, 6/27). When prior knowledge was incomplete, it was more likely that posttest knowledge was correct (58.49%, 31/53) than incomplete (37.74%, 20/53). Although the initial analyses did not reveal an interaction between time and type of prior knowledge, knowledge enrichment (i.e., incomplete prior knowledge improved to correct knowledge) was actually almost three times as likely as conceptual change (i.e., prior knowledge misconceptions improved to correct knowledge).

Observations of incomplete prior knowledge were inspected separately for the two misconception topics and the two incomplete knowledge topics in order to make comparisons between refutation and traditional expository texts. There were 19 observations of incomplete knowledge for seasonal change and object motion; 34 for eclipses and magnets (see Table 6). Knowledge enrichment was more likely after participants read refutation texts (63.16%) than when traditional expository texts were read (55.88%).

Disciplinary Attitudes/Dispositions and Learning

Prior knowledge/comprehension group membership for each topic was examined by rank ordering participants by epistemological belief scores. Self-efficacy and topic interest scores for instances of conceptual change and knowledge enrichment were noted. These scores were also noted for instances of missed opportunities for conceptual change (i.e., prior knowledge misconception followed by either a misconception or incomplete knowledge at comprehension) and knowledge enrichment (i.e., incomplete prior knowledge followed by either a misconception or incomplete knowledge at comprehension). These scores were inspected to determine whether any distinctions existed.

Conceptual change. Each of the six observations of conceptual change came from a different participant, 5 of whom demonstrated only one misconception. The epistemological belief scores of these 6 participants fell at or above the 25th percentile. Within this range of epistemological belief scores there were 15 observations of missed opportunities for conceptual change from 13 participants (1 of whom also demonstrated conceptual change).

For observations of conceptual change, only 2 (33.3%) participants had self-efficacy scores at or above the 50^{th} percentile. All but one (83.3%) of the topic interest scores were at or above the 33^{rd} percentile. For observations of missed conceptual change within the participants with epistemological belief scores at or above the 25^{th} percentile, 5 (38.5%) had self-efficacy scores above the 50^{th} percentile and eight (53.3%) topic interest scores were at or above the 33^{rd} percentile. Five participants with the lowest epistemological belief scores demonstrated six observations of missed opportunities for conceptual change. Four (80%) participants had self-efficacy scores above the 50^{th} percentile, and five (83.3%) topic interest scores were above the 50^{th} percentile. These findings indicate that conceptual change learning required a minimum level of epistemological understanding and that it was more likely to occur when topic interest was high. Self-efficacy did not seem to have a strong impact on conceptual change.

Knowledge enrichment. The 31 instances of knowledge enrichment occurred for 22 participants across the full range of epistemological belief scores. There were 22 instances of missed opportunities for knowledge enrichment from 16 participants, also across the full range of epistemological belief scores. The self-efficacy and topic interest scores associated with these observations were examined for participants by the 1^{st}, mid, and 4^{th} quartiles of epistemological belief scores.

The 8 participants with the lowest epistemological belief scores each demonstrated at least one instance of knowledge enrichment, for a total of nine observations. Half of these participants had self-efficacy scores at or above the 50^{th} percentile; the other half were below the 25^{th} percentile. Three-quarters of the observations of knowledge enrichment among those with low self-efficacy scores were associated with topic interest scores at or above the 50^{th} percentile, whereas 60% of the observations of knowledge enrichment among those with high self-efficacy also had high topic interest scores. There were six observations of missed opportunities for knowledge enrichment, each from a different participant. Half of these participants had self-efficacy scores above the 50^{th} percentile; the other half were below the 25^{th} percentile. Among those with low self-efficacy scores, two-thirds of the missed opportunities for knowledge enrichment were associated with topic interest scores at or above the 50^{th} percentile, whereas one-third of the missed opportunities for knowledge enrichment among those with high self-efficacy also were associated with high topic interest. These findings suggest that, in the presence of low epistemological beliefs, high topic interest was an important factor for knowledge enrichment, particularly for participants with low self-efficacy. Topic interest, however, did not compensate for low self-efficacy.

There were nine observations of knowledge enrichment from 7 of the 13 participants in the midquartile of epistemological belief scores. Among these, only 2 (28.6%) participants had self-efficacy scores above the 50^{th} percentile. The three topic interest scores associated with these two participants' observations of knowledge enrichment were above the 50^{th} percentile. The 5 participants with self-efficacy scores below the 50^{th} percentile demonstrated six observations of knowledge enrichment, two (33.3%) of which were associated with topic interest scores above the 50^{th} percentile. There were 13 observations of missed opportunities for knowledge enrichment in the midquartile range of epistemological belief scores. Of these 8 participants, half had self-efficacy scores at or above the 50th percentile; the other half were at the 33rd percentile. Among those with high self-efficacy, only one (14.3%) observation of a missed opportunity for knowledge enrichment was associated with a topic interest score above the 50th percentile. When participants had relatively lower self-efficacy, four (66.7%) missed opportunities for knowledge enrichment were associated with high topic interest. These findings suggest that with moderate levels of epistemological beliefs, the advantages of topic interest for knowledge enrichment diminish for those with low self-efficacy.

Among the 7 participants with the highest epistemological belief scores, there were 13 observations of knowledge enrichment (the most of any quartile). Each participant demonstrated at least one instance of knowledge enrichment. All but 1 participant (85.7%) had self-efficacy scores at or above the 50th percentile, and that participant's score was only one point below the median, so it is not possible to determine whether self-efficacy impacted knowledge enrichment in the presence of advanced epistemological understandings. Only six (46.2%) topic interest scores were above the 50th percentile, indicating that topic interest did not impact knowledge enrichment in the presence of advanced epistemological beliefs and high self-efficacy. Among those with the highest epistemological belief scores there were only three observations of missed opportunities for knowledge enrichment from 2 participants. Both participants' self-efficacy scores were above the 50th percentile, and two (66.7%) of the topic interest scores were above the 50th percentile.

Conceptual change vs. knowledge enrichment. Findings confirm the hypothesis that epistemological beliefs would be more important for conceptual change than for knowledge enrichment. Conceptual change did not occur for participants with epistemological belief scores below the 25th percentile, whereas knowledge enrichment was demonstrated by participants with all levels of epistemological beliefs. There were, in fact, nine observations of knowledge enrichment among participants with the lowest epistemological beliefs. This was second only to participants with the most advanced epistemological beliefs, who demonstrated 13 observations of knowledge enrichment.

Self-efficacy did not appear to directly impact either type of learning. Observations of knowledge enrichment were dispersed among all quartiles of self-efficacy scores. Higher levels of self-efficacy might have compensated for the lowest levels of epistemological beliefs, but only for knowledge enrichment. It should be noted that self-efficacy scores above the 50th percentile were associated with missed opportunities for knowledge enrichment at least as often as they were for observations of knowledge enrichment. This likelihood increased as level of epistemological beliefs increased.

Topic interest seems to have made an impact on both conceptual change and knowledge enrichment. Interest levels did not have to be has high to have an impact on conceptual change. Topic interest was less important for knowledge enrichment as the level of epistemological beliefs increased. In the 1st quartile of epistemological belief scores, 66.7% of the observations of knowledge enrichment were associated with high topic interest. This percentage decreased to 55.6% for the midquartile and 46.2% for the 4th quartile of epistemological belief scores.

CHAPTER V

DISCUSSION

This study tested two hypotheses regarding science comprehension: (a) that there would be greater improvement between prior knowledge and comprehension assessments when students held misconceptions than when their prior knowledge was incomplete and (b) that higher levels of epistemological beliefs, self-efficacy, and topic interest would be associated with greater improvements. After a discussion of the findings, educational implications and directions for future research are offered.

Prior Knowledge and Disciplinary Attitudes/Dispositions

The first set of analyses considered the impact of prior knowledge on science text comprehension. Prior knowledge clearly had an impact on students' comprehension of the different science texts. When students had correct prior knowledge (29% of the time), comprehension was correct 88% of the time. When prior knowledge was incorrect (71% of the time), comprehension was correct only 46% of the time. Comprehension was much better when prior knowledge was incomplete rather than when misconceptions were held. Fifty-nine percent of the observations of incomplete prior knowledge had correct comprehension, whereas only 22% of the instances of misconceptions did so. Although the post-hoc analyses revealed that it was more desirable for students to have incomplete prior knowledge than misconceptions, the repeated measures analysis did not reveal a significant difference between the two types of incorrect prior knowledge. The change in scores between the prior knowledge and comprehension assessments for misconceptions and incomplete prior knowledge were essentially identical. Despite an increase in scores between the two assessment times, knowledge was often not correct. In the case of misconceptions, knowledge at comprehension was often incomplete. This study confirmed that misconceptions are resistant to change. Perhaps conceptual change did not occur as much as hypothesized because previous studies did not consider the accuracy of comprehension when misconceptions were abandoned.

Not only were students much more successful at filling gaps in incomplete knowledge than they were abandoning misconceptions, but incomplete prior knowledge occurred more often than misconceptions (47% and 24%, respectively). This was because incomplete prior knowledge occurred for all four topics, whereas misconceptions only occurred for two topics. Incomplete knowledge will always be more common than misconceptions because incomplete knowledge can exist for any topic, even those associated with common misconceptions.

Because this was the first study to investigate incomplete prior knowledge in science, an unexpected finding arose. Recall that participants sometimes demonstrated incomplete prior knowledge of the misconception topics, in which case they read refutation texts. This allowed a comparison between comprehension of refutation texts and traditional expository texts. Refutation texts were more effective than traditional expository texts at encouraging knowledge enrichment. Since the refutation texts explicitly referred to misconceptions that were not held, the refutation cues themselves may have alerted readers to the scientific explanations that followed.

The second set of analyses examined the importance of disciplinary attitudes and dispositions for science text comprehension. As expected, advanced epistemological beliefs were associated with greater improvement between prior knowledge and comprehension, explaining 23% of the variance. Post-hoc analyses supported the hypothesis that epistemological beliefs would be more important for conceptual change than for knowledge enrichment. All instances of conceptual change occurred for participants whose epistemological belief scores were at or above the 25th percentile, whereas knowledge enrichment occurred for participants along the full continuum of epistemological understandings. Previous research (e.g., Mason et al., 2008) dichotomized epistemological beliefs and found that participants with more advanced beliefs had higher conceptual change scores, particularly after reading refutation texts. The findings suggest that a minimum level of epistemological understandings are necessary for conceptual change but not for knowledge enrichment.

The sample size was too small to detect whether or not self-efficacy affected science text comprehension. Post-hoc analyses indicated that self-efficacy played a negligible role in overcoming either type of prior knowledge. The questionnaire may have inflated ratings of self-efficacy because participants had to compare themselves to peers in their science class. Alternatively, high levels of self-efficacy can inhibit learning if they are associated with high levels of confidence in topic knowledge (Sinatra, 2005). Although this study sought to assess confidence in ability, not knowledge, the two might have been confounded. Though it was not significant, self-efficacy score had a small but negative correlation with eighth grade science EOG test score. Self-efficacy scores above the median were often associated with missed opportunities for knowledge enrichment, indicating that strong beliefs in ability might have at times influenced beliefs about accuracy of knowledge.

Topic interest did not have a significant impact on science text comprehension. There was no indication that the small sample size affected this analysis. Post-hoc analyses suggested that interest might have had a greater impact on knowledge enrichment than on conceptual change, but this impact lessened as the level of epistemological beliefs increased. Previous research has revealed that topic interest only impacted open-ended comprehension (Mason et al., 2008). Open-ended comprehension was not investigated because performance on open-ended questions in the two assessments for misconceptions and the two for incomplete prior knowledge were not correlated. The average interest score of several topics was used, which might explain why interest was not important in this study.

The current findings concerning interest do add information to the debate about the relationship between interest and prior knowledge (Tobias, 1994). Prior knowledge was significantly correlated with topic interest only for the most well-liked topic (i.e., eclipses). Other studies have reported that prior knowledge did not correlate with interest (e.g., Mason et al., 2008). It may be that the topic of that study, light, was just not an interesting enough topic.

Educational Implications

Several educational implications can be drawn from the findings. Instructional strategies that explicitly address prior knowledge will likely bolster science text comprehension. Eleventh and twelfth graders in Guzzetti (1990) often had experiences that would help them understand a physics concept, but they were not able to make that link without discussion with an adult. She offered a prior knowledge instructional model that illustrated how students' prior experiences could be translated into prior knowledge. The instructor first provides an explanation of the concept and then elicits, with modeling, prior experiences from ordinary life that relate to the concept. During an augmented activation activity, misconceptions are addressed to create cognitive dissonance. Past experiences are then discussed again in light of the scientific principles.

In another prior knowledge instructional framework, Ridgeway and Dunston (2000) suggest four overlapping components for conceptual change based on research on science instruction for students with learning disabilities. Coined P – ID – D – A (for Preconceptions – Induce Dissonance – Discuss – Amend), the tenets are similar to that of Guzzetti (1990). The instructor elicits students' preconceptions and induces conceptual dissonance. A discussion ensues in which conceptions are refined and conflicts are resolved. The final step includes amending prior knowledge to reformulate and extend the new conceptions. The authors suggest specific instructional strategies to use within the framework and give examples from two science topics.

The rarity of conceptual change with refutation texts means that additional instruction is necessary to change beliefs/concepts. Social constructivist (Maria, 2000) and psychosocial developmental (Swafford & Bryan, 2000) approaches to conceptual change acknowledge that oral and written discourse is critical. Students become a part of the scientific community not only by learning the nature of language and knowledge generation, but also the nature of group interactions in science. These are also the goals of disciplinary literacy (Moje 2008a, 2008b). Group interactions in science, though, are often in conflict with these goals (Maria, 2000). For example, in most teacher-led discussions, social conformity is valued and teachers are relied upon for answers. Peer discussions often serve to reinforce nonscientific explanations, and hands-on activities can result in students being task-driven instead of seeking to understand scientific principles.

For conceptual change, "instruction must undermine students' confidence in their ideas without undermining their confidence in themselves as learners" (Maria, 2000, p. 17-18). This type of instruction and learning is most likely to occur in a climate of collaboration and trust, in which teacher guidance is balanced with student engagement. Students can engage in exploratory talk using their own language, particularly if teacher participation is limited to guiding interactions among students (Maria, 2000). When science is taught as argument, discussions mirror the manner in which scientists raise questions and argue about what theories best explain phenomenon. Evidence can be collected in favor of two sides of an argument, and teacher scaffolding can help students recognize evidence that contradicts their prior knowledge. Such discussions are best suited for in-depth investigations (Swafford & Bryan, 2000). Specific guidelines for conceptual change discussions, including acknowledging student ideas regardless of their correctness, remaining neutral during the discussion, assisting students in stating their ideas clearly and concisely, and summarizing the discussion from beginning to end, have also been offered (Eryilmaz, 2002).

The importance of epistemological beliefs for science text comprehension also has instructional implications. Instruction that helps students appreciate the tentative nature of knowledge in science may help them understand that it is acceptable for them to change their own theories (Mason, 2001). Qian and Alvermann (2000) described instructional approaches for epistemological beliefs. In the first, labeled criss-crossing the landscape, scientific concepts are examined from different perspectives and knowledge is assembled from different sources. These sources, including demonstrations, videos, and texts, often bring to light conflicting information. In reflective inquiry, information on the nature of science is infused into instructional science projects that span relatively in-depth units. Students make and test hypotheses, perform experiments, and reflect on the process in journals. In another approach, stories of scientists' activities from history are used to help students understand that scientists do not simply make discoveries, but instead try to explain scientific phenomenon. Finally, routine instruction can be delivered from an epistemological stance instead of providing answers or assigning pages to read, which support authoritative beliefs about science.

There is no one right way to deliver conceptual change instruction (Maria, 2000). The current findings indicate that refutation text alone is rarely sufficient for conceptual change learning, confirming the results of previous studies (Guzzetti et al., 1997; Hynd et al., 1994). It may be that a combination of instructional approaches and strategies, discussed above, are necessary and dependent on the nature of science topics (cf. Ridgeway & Dunston, 2000). Although research has focused on conceptual change learning, results of this study indicate that similar instructional strategies may benefit knowledge enrichment.

Directions for Future Research

Science instruction that addresses prior knowledge and epistemological beliefs needs to be investigated. Concept acquisition, regardless of whether it is conceptual change or knowledge enrichment, is unlikely to occur from one encounter with a text. Research needs to identify the most efficient combination of instructional strategies for science, with the goal being that students learn both the knowledge and dispositions of the discipline.

Future studies should also clarify the role of motivational factors. This study examined two motivational constructs, self-efficacy and interest, and did not support the hypothesis that they would moderate science text comprehension. Hynd and colleagues (2000) hypothesized that conceptual change learning would require higher levels of motivation than usual. Other findings have supported the hypothesis that topic interest was important for conceptual change (e.g., Andre & Windschitl, 2003; Mason et al., 2008). It may be more productive for future research efforts to examine how different instructional strategies affect student motivation to learn.

Although extra-textual factors are important agendas for future research, more information is needed on the textual factors involved in conceptual change and knowledge enrichment. Without this continued focus, science teachers may get the impression that they should abandon science texts in favor of lectures. This does nothing to improve students' abilities to read scientific texts (Shanahan, 2012) and learn the dispositions of the discipline. The linguistic challenges of science texts (cf. Fang, 2012) should be explored to determine whether manipulations and instruction (cf. Shanahan, 2012) can improve readers' access to them and, thus, help them learn new content.

Other types of texts should be investigated to determine whether refutation texts are as beneficial as research has suggested. For example, intratextual persuasive texts are characterized by the presence of multiple authors offering opposing viewpoints in response to a central question (Andiliou, Ramsay, Murphy, & Fast, 2012). Intratextual texts could be modified for science and compared to refutation and traditional expository texts to examine whether one is more advantageous to conceptual change and/or knowledge enrichment.

Finally, most research on science text comprehension has been conducted with typically developing students. Participants in the earliest studies on conceptual change (e.g., Alvermann & Hague, 1989; Hynd & Alvermann, 1986) were low performing college students, but research is desperately needed that explores scientific literacy in disordered populations. The impact of specific language impairment (SLI) on literacy and numeracy skills is well researched, but there is a dearth of information on its impact on science achievement (Matson & Cline, 2012). These authors reported that children with SLI had greater difficulty than typically developing peers on scientific reasoning tasks that required them to make verbal responses, particularly because they used fewer causal connectives (e.g., because, if, then, that's why). Research needs to investigate what other aspects of science are problematic for students with language learning difficulties and the additional supports they need to become active participants in scientific literacy.

Limitations

There are several limitations to this study. Many important findings were not a priori considerations or hypotheses, so they must be considered with extreme caution. These findings do, however, provide insight into the problems faced by readers with inaccurate prior knowledge in science. The sample size was inadequate to detect interactions between type of prior knowledge and the disciplinary attitudes and dispositions. Epistemological beliefs, but not self-efficacy or topic interest, had an effect on the overall score increase between prior knowledge and comprehension in the sample. Though it is not possible to rule out the importance of the other factors, findings indicate that epistemological beliefs are more important for science text comprehension than self-efficacy and interest. This is encouraging since the nature of science can be taught alongside science content (e.g., Qian & Alvermann, 2000), whereas topic interest and self-efficacy cannot be taught.

Another limitation was the absence of a measure that evaluated students' levels of satisfaction/dissatisfaction with their prior knowledge, and at no point was the accuracy of their prior knowledge revealed to them. It is not possible to tell, then, whether or not participants were dissatisfied with their prior knowledge, which may be an important factor for conceptual change. Participants had only one encounter with the texts and were not allowed to look back at them during the comprehension assessments. This does not reflect how students learn information in naturalistic settings. The texts did not contain diagrams, which are common in science texts. Finally, comprehension should also have been evaluated at least one week later to determine whether knowledge was maintained.

Conclusion

This study was an important first step in understanding the influence of different types of prior knowledge on science text comprehension. When students understand the gist of a science topic, they demonstrate excellent comprehension of the science passages. When prior knowledge is inaccurate, it is better if the knowledge is incomplete rather than a misconception. It is easier to fill gaps in knowledge than it is to replace misconceptions with appropriate scientific knowledge. When misconceptions are held, changes in knowledge require relatively advanced levels of epistemological beliefs. These beliefs reflect the understanding that it is permissible for ideas in science to change.

Considerable research has focused on the use of refutation texts to promote conceptual change. The findings of the present study, however, indicate that simply reading refutation texts typically does not result in students replacing misconceptions with appropriate scientific understandings. It is important for future research to empirically validate more effective ways of helping students abandon misconceptions. Collaborative efforts among researchers, clinicians, and educators offer the best hope that science teachers will one day use the most effective instructional strategies to teach science.

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APPENDIX A

EPISTEMOLOGICAL BELIEFS QUESTIONNAIRE

Indicate, on a scale of 1 to 5, the extent to which you agree or disagree with the following statements:

1	2	3	4	5
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree

1. All questions in science have only one right answer.

2. Some ideas in science today are different than what scientists used to think.

3. Scientists know pretty well everything about science; there is not much more to know.

4. There are some questions that even scientists cannot answer.

5. Once scientists have the result of an experiment, that becomes the only answer.

6. New discoveries can change what scientists think is true.

7. The most important part of doing science is arriving at the right answer.

8. The ideas in science books sometimes change.

9. Scientific knowledge is always true.

10. Ideas in science sometimes change.

11. Scientists always agree about what is true in science.

12. Sometimes scientists change their minds about what is true in science.

(adapted from Mason, Gava, & Boldrin, 2008)

APPENDIX B

SELF-EFFIACY QUESTIONNAIRE

Indicate on a scale of 1 to 5 the degree to which each statement describes you in regards to your science class.

1	2	3	4	5
Not at all true of me	Mostly not true of me	Somewhat true of me	Mostly true of me	Very true of me

1. Compared with other students in my science class, I expect to do well.

2. I'm certain I can understand the ideas taught in science.

3. I expect to do very well in my science class.

4. Compared with others in my science class, I think I'm a good student.

5. I am sure I can do an excellent job on the problems and tasks assigned for my science class.

6. I think I will receive a good grade in my science class.

7. My study skills are excellent compared with others in my science class.

8. Compared with other students in my science class, I think I know a great deal about the subject.

9. I know that I will be able to learn the material for my science class.

(adapted from Pintrich & De Groot, 1990)

APPENDIX C

TOPIC INTEREST QUESTIONNAIRE

Please indicate on a scale of 1 to 5 the extent to which each statement describes you.

1	2	3	4	5
Not at all true of me	Mostly not true of me	Somewhat true of me	Mostly true of me	Very true of me

1. I would be excited about studying TOPIC in science class.

2. I think that there are many more relevant topics than TOPIC to learn about in science classes.

3. I think it is important to know SOMETHING ABOUT THE TOPIC.

4. If I came across a TV show that talked about TOPIC, I would be eager to understand it.

5. I think that during science classes some time could be devoted to talking about TOPIC.

6. I am not interested in knowing more scientific aspects of TOPIC.

7. I think that TOPIC is a difficult but worthwhile topic of science.

8. I would get involved in knowing SOMETHING ABOUT THE TOPIC.

9. I am eager to know SOMETHING ABOUT THE TOPIC.

10. Knowing how TOPIC is not important to me.

(adapted from Mason et al., 2008)

APPENDIX D

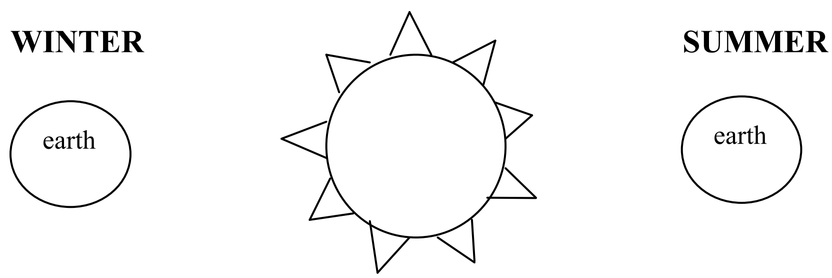
KNOWLEDGE ASSESSMENTS

Seasonal Change (adapted from Broughton et al., 2010; Powers & Beaver, 2010)

1. Explain why it is hotter in the summer than it is in the winter.

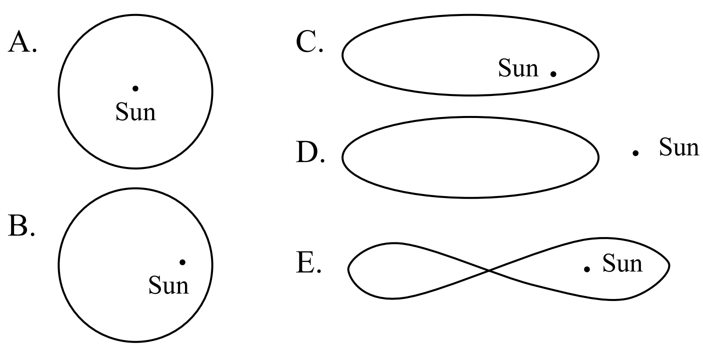
2. Explain the causes for why the seasons change.

3. This is a drawing of the earth in two positions of its orbit around the sun. Draw the earth's axis when it is winter and when it is summer in the Northern Hemisphere.



4. Explain the impact of the earth's axis on why the seasons change.

5. Of the following choices, which looks most like the earth's orbit around the sun?



6. How often is the sun directly overhead at noon in your hometown?
   A. Every day.
   B. Only in the summer.
   C. Only for the week of the summer solstice.
   D. Only for one day each year.
   E. Never.

7. The main reason we have hot summers and cold winters is because:
   A. the earth's distance from the sun changes.
   B. the sun is higher in the sky.
   C. the distance between the Northern Hemisphere and the sun changes.
   D. ocean currents carry warm water north.
   E. an increase in "greenhouse" gases.

8. During July at the North Pole, the sun would:
   A. be overhead at noon.
   B. never set.
   C. be visible for 12 hours each day.
   D. set in the northwest.
   E. none of the above.

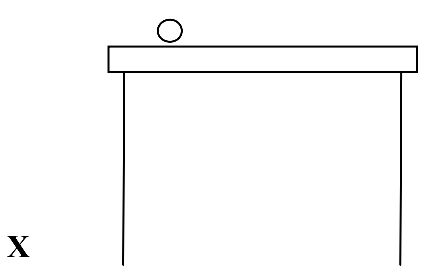
9. Which date below has the most hours of daylight in your hometown?
   A. June 15
   B. July 15
   C. August 15
   D. September 15
   E. All dates are the same

Object Motion (adapted from Alvermann & Hague, 1989; Hynd et al., 1994)

1. Explain why an object thrown from the top of a building moves downward.

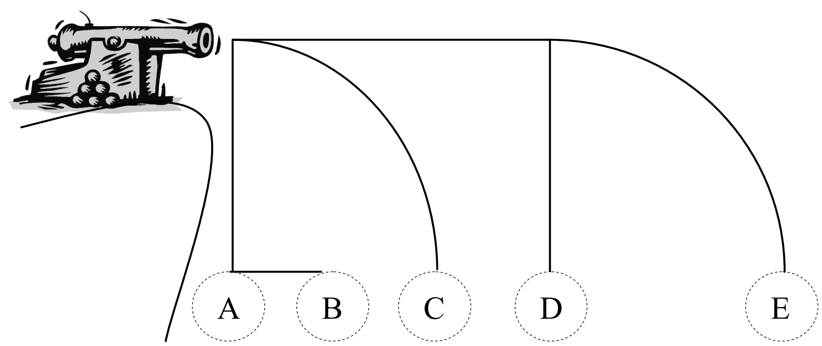
2. Explain why an object in motion comes to a stop.

3. Draw the path that the marble would take if you shot it off the table with your fingers. The X marks where you would be standing as you shot the marble off the farther end of the table.



4. Explain the reasoning behind the path you drew.

5. Of the following choices, select the path a cannonball shot off a cliff is most likely to take:



6. The effect of gravity on an object's forward motion:
   A. is delayed, causing it to continue forward before moving down.
   B. stops the forward motion, causing it to move down immediately.
   C. is immediate, causing it to curve down in a forward motion.
   D. is not strong enough to pull it down.
   E. depends on how fast the object moves.

7. Supplies dropped from an airplane will fall to the ground:
   A. somewhere in front of the original drop point.
   B. somewhere behind the original drop point.
   C. exactly at the drop point.
   D. at a point that depends on how hard they were pushed out of the plane.
   E. at a point that cannot be predicted.

8. A car slams on its brakes. The inertia of the car and the inertia of the passengers:
   A. are exactly the same, such that the car and its passengers stop at the same time.
   B. are separate, such that the passengers stop moving before the car stops.
   C. are separate, such that the passengers continue moving after the car stops.
   D. depend on the speed of the car.
   E. depend on the weight of the passengers.

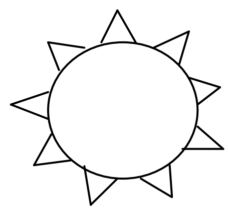
9. An example of an external force that acts to slow a bowling ball is:
   A. the weight of the ball.
   B. the speed of the ball.
   C. the force of the ball's drop.
   D. the friction from the bowling lane.
   E. the distance to the bowling pins.

Eclipses (adapted from Powers & Beaver, 2010)

1. Explain why the moon looks different every day.

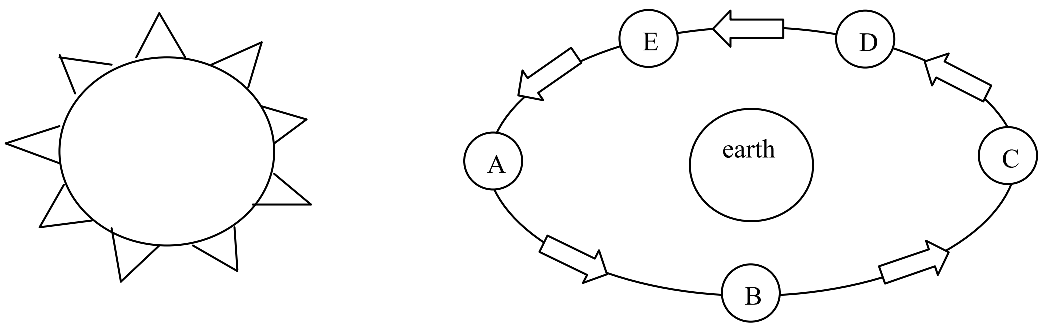
2. Explain how an eclipse occurs.

3. Below is a drawing of the sun. Draw the positions of the earth and moon during a solar eclipse. Make sure you label the earth and moon.



4. Explain the reasoning behind the locations of the earth and moon in your drawing.

5. The diagram below shows different locations of the moon (A-E).
Write the letter of the **full moon phase** here: ________



6. Eclipses do not occur every time there is a new moon or a full moon because:
   A. the earth revolves around the sun.
   B. the orbits of the moon and the earth are not even with one another.
   C. the moon blocks the light from the sun.
   D. there is not a new moon or full moon every month.
   E. the sun, earth, and moon are perfectly aligned.

7. A lunar eclipse is caused by:
   A. the moon's shadow on the earth.
   B. the earth's shadow on the moon.
   C. a new moon.
   D. a full moon.
   E. the sun's rays hitting the moon.

8. A solar eclipse takes place:
   A. once a month.
   B. twice a month.
   C. when the moon is in its new moon phase.
   D. when the moon is in its full moon phase.
   E. when the moon is in either its new moon or full moon phase.

9. A solar eclipse is visible:
   A. to everyone on the earth.
   B. to everyone on the side of the earth facing the sun.
   C. to a small portion of people on the side of the earth facing the sun.
   D. to everyone on the side of the earth away from the sun.
   E. to an astronaut on the moon.

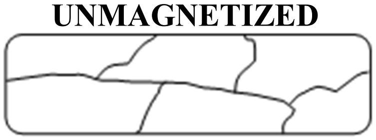
Magnets (adapted from Beaver & Powers, 2010; Wilson, 2011)

1. Explain how magnets attract one another.

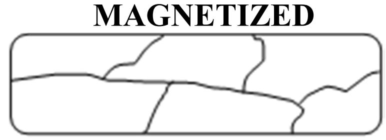
2. Explain one way to make a temporary magnet.

3. Below are drawings of two metals divided into domains. Use arrows to indicate the direction each domain points in the unmagnetized metal and the magnetized metal.

UNMAGNETIZED

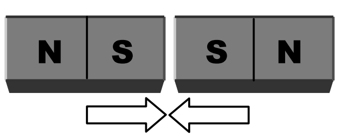


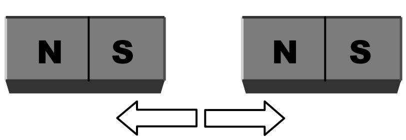
MAGNETIZED

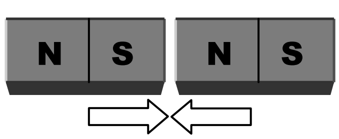


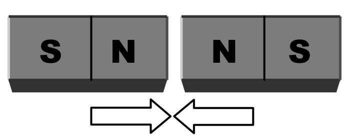
4. Explain the reasoning behind the arrows you drew in the two metals above.

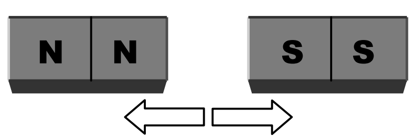
5. Select the drawing that depicts how magnets behave when brought toward each other.

A.


B.


C.


D.


E.


6. The alignment of magnetic domains causes:
    A. the strength of a magnet.
    B. the shape of a magnet.
    C. unlike poles to attract.
    D. like poles to attract.
    E. electrons to align.

7. An electromagnet is different from a permanent magnet because it:
    A. is not made of iron.
    B. does not have poles.
    C. can be turned on and off.
    D. is caused by the movement of electrons.
    E. it is stronger.

8. Maglev trains can float above the track because:
    A. it travels at high speeds.
    B. electromagnets in the track repel magnets on the train.
    C. it does not have wheels.
    D. permanent magnets power the train.
    E. the magnetic domains of the track point upward.

9. Temporary magnets:
    A. do not have magnetic domains.
    B. can be created from electric current.
    C. are not as useful as permanent magnets.
    D. cannot repel other magnets.
    E. can be created from plastic.

APPENDIX E

SCIENCE TEXTS

WHY THE SEASONS CHANGE
(adapted from Broughton et al., 2010; Powers & Beaver, 2010)

Many people believe that the changing seasons are the result of the earth being closer to the sun during the summer months and farther away from the sun during the winter months. They think this because typically the closer you are to a heat source, such as a hot stove, the hotter it is. Seasons, however, do not change because the distance between the earth and the sun changes. In fact, the earth is slightly closer to the sun in winter and farther away from the sun in summer. We owe our seasons – spring, summer, fall, and winter – to the revolution of the earth around the sun and the tilt of the earth's axis.

The earth makes a complete revolution around the sun every 365 and ¼ days. This path is referred to as earth's orbit around the sun. The earth also rotates, or spins, around its axis once every day. The axis is an imaginary line that runs from the North Pole to the South Pole through the center of the earth. There is a 23.5-degree tilt of the earth on its axis. These two features of the earth cause seasonal change.

When the Northern Hemisphere is tilted toward the sun, it receives the sun's rays at a more direct angle than it does during the other times of the year. This is the time of year that the Northern Hemisphere has summer. Not only are the sun's rays more direct, but the days are longer in the summer because the sun rises earlier in the morning and sets later in the evening. The first day of summer, which occurs halfway through the year, receives the most sunlight. While it is summer in the Northern Hemisphere, the Southern Hemisphere is experiencing winter.

The axis always points in the same direction as the earth revolves around the sun. On the opposite side of its orbit, a different portion of the earth receives the sun's direct rays. The Northern Hemisphere experiences winter when the earth tilts away from the sun. The day with the least amount of sunlight occurs in December. The other two seasons occur between the extremes of winter and summer. As the earth continues on its orbit, the Northern Hemisphere begins to get closer to the sun. For us, spring begins in March. After summer, as the Northern Hemisphere begins to tilt away from the sun, we experience fall.

401 words; Lexile = 1020L; Fog index = 8.58

NEWTON'S THEORY OF MOTION
(adapted from Hynd et al., 1994)

Before the time of Sir Isaac Newton, people believed that an object in motion moved because of a force inside the object. After all, they could not see any outside cause for an object to keep moving or stop. A force inside the object must have been the cause of motion, and as it weakened, the object would slowly come to a stop. People still think this today, even though science has disproved it.

Newton's theory of motion states that every object in motion will stay in motion until acted upon by an outside force. It is incorrect to think that a rolling object stops or a projectile (an object moving through the air) falls because of the loss of internal force. Newton explained that a moving object comes to a stop or begins to fall because external (or outside) forces act to change the speed or direction of the object's motion. A ball rolling across the floor, for example, is slowed by friction, a force that acts in the opposite direction of the ball's motion. An object that is carried is in motion, even though it appears to be at rest compared to the person carrying it. That is why when a vehicle comes to a stop, the objects inside the car continue in their forward motion. All objects have inertia, which keeps them moving until something stops them.

To get a sense of Newton's theory of motion, imagine the following scene. A person is holding a stone at shoulder height while walking forward at a fast pace. What will happen when the person drops the stone? What kind of path will the stone follow as it falls? Many people think that the stone will fall straight down, striking the ground directly under the point where it was dropped. A few people even believe that the falling stone will travel backward and land behind the point where it was dropped. The stone really moves forward as it falls, landing a few feet ahead of the point where it was dropped. When the stone is dropped, it keeps moving forward at the same speed as the walking person because no outside force acted to change its forward direction. In the same way, a projectile fired horizontally will move not only forward but also downward because of the constant force of gravity. In fact, the object will begin to move downward in a curved path from the moment it is fired.

410 words; Lexile = 1130L; Fog index = 9.18

ECLIPSES
(adapted from Powers & Beaver, 2010)

An eclipse occurs when one object in space moves into the shadow of another object in space and is either partially or totally hidden by it. If you walk into the shadow cast by a tree, then you have been eclipsed by that tree. The tree has blocked the sunlight that would have reached you and reflected off your body. The tree has come between you and the sun.

In order to understand how eclipses occur, you first have to understand a little bit about the phases of the moon. You may have noticed that the moon's appearance changes slightly every day. This is because the moon rotates around the earth about every 27 days. When the moon is between the sun and the earth, we cannot see it. This is the new moon phase. As the moon rotates around the earth, we are able to see more and more of it illuminated by the sun. At the opposite side of the earth, when the earth is between the moon and the sun, we can see the entire moon. This is the full moon phase.

Sometimes the orbits of the earth and moon perfectly align to block the sunlight. When the earth, moon, and sun are perfectly aligned, an eclipse of either the sun or the moon may occur. A solar eclipse occurs when the moon blocks light from the sun resulting in the total or partial disappearance of the sun as seen from the earth. A solar eclipse is possible when the moon is in the new moon phase. A lunar eclipse occurs when the earth blocks the sun's light from reaching the moon. A lunar eclipse is possible during a full moon phase.

Eclipses do not occur every time there is a new or full moon. Remember, an eclipse can only happen if the earth's orbit around the sun and the moon's orbit around the earth intersect during a new moon or full moon phase. This does not happen every month because the paths of those two orbits are about six degrees different. The three celestial bodies do not always line up in a way that the earth or moon blocks part or all of the sun's light. Fortunately, scientists understand enough about the motion of the sun, earth, and moon to be able to predict the dates and times of solar and lunar eclipses.

397 words; Lexile = 1040L; Fog index = 8.92

MAGNETS
(adapted from Beaver & Powers, 2010; Wilson, 2011)

You may have used magnets many times, perhaps to put a picture on your refrigerator, but have you ever given much thought to how they work? Magnets attract certain metals, such as iron and nickel, and attract or repel other magnets. Magnets come in many sizes, shapes, and strengths. No matter what the shape is, magnets have two poles: a north pole and a south pole. If you have held two magnets, you have felt the force that exists around them. This invisible force is called the magnetic field, and it is strongest near the poles. The phrase, "opposites attract" likely comes from our understanding of magnets since unlike poles attract and like poles repel.

What causes this attraction? All objects are made of microscopic atoms. Each atom has three parts: protons and neutrons in the nucleus and electrons that circle the nucleus. When the electrons of several atoms align, a magnetic domain is created. Each domain is essentially a tiny magnet with a north and south pole, and the domains combine to create one strong magnet. In a permanent magnet, like iron, the north poles of each domain always point in the same direction. This alignment explains why opposite poles attract. It also explains why a magnet broken into two pieces results in two smaller magnets, each with a north and south pole.

Other magnets are temporary magnets. An unmagnetized metal, such as a nail, is comprised of domains, but the north poles point in random directions. A temporary magnet can be made by rubbing a permanent magnet against a piece of unmagnetized metal a few times in one direction. This causes the domains to align. The electrons of some materials, such as wood and plastic, will never align.

Electricity, like magnetism, is caused by the movement of electrons. Electricity is created as electrons move from one atom to another. A temporary magnet known as an electromagnet is produced by this flow. Electromagnets can be made by wrapping wire around a nail and then attaching the ends of the wire to a battery. When an electric current passes through the coiled wire, the domains in the nail line up, creating a magnetic field. Very large electromagnets are being used in Germany and Japan to lift and drive high-speed trains called maglev trains. These trains do not have wheels. Instead, they use magnetic levitation to float above special rails.

399 words; Lexile = 980L; Fog index = 9.61