2010

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Recommended Citation

Broughton, S. H., Sinatra, G. M., & Reynolds R. E. (in press). The nature of the refutation text effect: An investigation of attention allocation. The Journal of Educational Research.

The Nature of the Refutation Text Effect: An Investigation of Attention Allocation

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Abstract

Students often hold misconceptions that conflict with scientific explanations. Research has shown that refutation texts are effective for facilitating conceptual change in these cases (Guzzetti, et al., 1993). The process through which refutation texts have their effect is not clear. Our study replicated and extended previous research investigating cognitive processes involved in the refutation text effect. Undergraduates read either a refutation or expository text on seasonal change. Individual reading times were recorded. Participants' conceptions were measured at pre-, post-, and delayed-posttest. Results showed readers spent less time reading the refutation paragraph compared to the expository paragraph. The refutation text group had fewer misconceptions at posttest. These findings suggest that refutation text processing differences mirror similar findings in the attention literature which may account for their effectiveness.

Key words: Conceptual Change, Attention Allocation, Refutation Text, Science Learning.

It is often the case that learners bring with them to the classroom previously formed conceptions that do not align with accepted scientific viewpoints. For example, young children often form the misconception of the Earth as flat with people living on the surface and solar objects located above it (Vosniadou & Brewer, 1987; 1992). One goal of science education is to provide students opportunities to change such misconceptions to align with the accepted scientific viewpoint. The process of conceptual change is likely to begin when the scientific viewpoint is presented, which in turn may trigger cognitive conflict within the individual who holds topic-related misconceptions (Hynd, 2003; Limon, 2001; Posner, Strike, Hewson, & Gertzog, 1982).

Research has demonstrated that the most effective intervention strategies for promoting conceptual change in science classrooms include a combination of activating students' background knowledge, reading a refutational text, and participating in supplemental scientific investigation activities (Diakidoy, Kenedeou, & Ioannides, 2003; Guzzetti, et al., 1993). These instructional interventions are effective because they promote high cognitive engagement according to the view proposed by Dole and Sinatra (1998). As suggested by Dole and Sinatra's Cognitive Reconstruction of Knowledge Model (CRKM), the likelihood of high engagement increases when learners have the opportunity to critically examine their current ideas in comparison and contrast to the information they are learning.

Learning from Refutation Text

Expository texts are used across curriculum contexts in schools as a primary method of instruction, including science education. Despite their wide usage, researchers have criticized the organization and lack of explanatory coherence of expository texts (see for example Beck, McKeown, Sinatra & Loxterman, 1991). One of the weaknesses of traditional expository science texts in promoting conceptual change is that information is often presented as a series of related but discrete topics (e.g. plants, animals, and cells) in a list-like fashion with little or no supporting information to assist learners in connecting the information between different topics (Mikkila-Erdmann, 2002). Such texts assume that the reader has sufficient prior knowledge to make the necessary inferences to comprehend the ideas in the text (O'Reilly & McNamara, 2007).

In contrast to traditional expository texts, refutation texts are designed to state a common misconception, explicitly refute the misconception, and then present the accepted scientific viewpoint as a plausible and fruitful alternative (Hynd, 2001; Limon, 2003). Often the format includes a single misconception stated in one sentence, with a single refutation statement immediately following in the next sentence (see for example Hynd, Alverman & Qian, 1997). This format was chosen for the present study as it was necessary to maintain explanatory coherence to replicate the studies of interest reviewed below.

A meta-analysis of the research using refutation text as a learning tool in science classrooms showed that refutation texts were more effective than traditional expository text for promoting science learning and conceptual change (see Guzzetti et al., 1993). Hynd (2003) suggests that refutation texts may be effective in fostering conceptual change because they facilitate the four necessary conditions of conceptual change. These conditions include 1) dissatisfaction with one's existing conceptions, 2) finding the new conception to be intelligible, 3) plausible, and 4) fruitful for opening up additional areas of inquiry (Posner et al., 1982).

A possible explanation for the refutation text effect is that readers coactivate (activate both the prior and new conception simultaneously) and then integrate their prior conceptions with the text information. Kendeou and van den Broek (2007) hypothesized that it is the coactivation and integration processes which allow readers to detect the inconsistencies between their prior knowledge and the scientific explanation. The detection of the inconsistency may lead to deeper processing of the information presented in the text, which in turn, may facilitate conceptual change.

One goal of using refutation text in the science classroom is to facilitate conceptual change by helping students construct new mental models that align with the scientific viewpoint (Mikkila-Erdmann, 2002). A model of reading comprehension that may help explain the nature of the refutation text effect is the Landscape model (see van den Broek, Young, Tzeng, & Linderholm, 1999). According to the Landscape model a balance is maintained between the reader's limited attentional resources and standards of coherence. Van den Broek and Kendeou explained, "As the reader proceeds through the text, concepts fluctuate in activation: with each new cycle some concepts continue to be active, others decline in activation and yet others become newly reactivated" (2008, p. 338). The fluctuations in activation are the result of four informational sources: the text information in the current cycle, residual text information from the previous cycle, the memory representation constructed thus far, and the reader's prior knowledge which can include misconceptions. In relation to conceptual change, this model postulates that only information that is co-activated can be compared and possibly integrated with the reader's conceptual framework. The Landscape model predicts that the misconception be activated at the same time as the accurate scientific information is activated for conceptual change to occur. Van den Broek and Kendeou (2008) postulated that co-activation is essential if the reader is to engage in the deeper cognitive processes needed for conceptual change.

Conceptual change may also be the result of the refutation text increasing the learner's engagement with the ideas in the text (Dole & Sinatra, 1998). For example, the individual may find the refutation segment personally relevant because the misconception in the text is similar to the conceptions held by the individual. In addition, the refutation sentence may lead the individual to thoughtfully and critically weigh the scientific explanation because it explicitly rejects the misconception. A large body of research has demonstrated that refutation texts have been effective presumably because they can induce deep engagement and critical thinking as the result of the cognitive conflict that arises between the individual's misconceptions and the new information (Guzzetti et al., 1993; Hynd et al., 1997; Mason, Gava, & Boldrin, 2008).

Refutation texts have been shown to be more effective than traditional expository texts in facilitating conceptual change with a variety of science topics including projectile motion (Alvermann & Hynd, 2001; Hynd et al., 1997; Hynd, McWhorter, Phares, & Suttles, 1994), photosynthesis (Mikkila-Erdmann, 2002), light (Mason et al., 2008), and HIV-AIDS transmission (Kardash & Scholes, 1995). Despite its success in promoting conceptual change, the nature of the refutation text effect is not well understood (Diakadoy et al., 2003). High engagement has been proposed as the mechanism which explains the refutation text effect (Murphy, 2001). More specifically, readers may allocate more cognitive resources to the refutation text; thereby, causing increased learning and recall of refutation text information. Hynd (2001) cautioned, however, that refutation texts may not promote deep engagement and critical thinking. She noted that since the texts are structured to concretely and explicitly tell the reader what to think and why, perhaps this discourages thoughtful weighting of the issues and arguments. In other words, refutation text information could be better learned and recalled because it is presented in a concrete and explicit format that does not require the allocation of additional attention. To date, there is no direct empirical evidence that differentiates which of these two hypotheses best reflects why information from refutation text is better learned and recalled than the same information presented in normal narrative texts.

In an attempt to better understand the nature of the refutation text effect, researchers have begun investigating online and offline comprehension processes during reading of refutation texts. Online processes are those which readers engage in during reading that lead to memory representation such as elaboration, summarization, paraphrasing, and explaining. Offline processes provide insights about the reader's mental representations of the text after reading. A study conducted by Kendeou and van den Broek (2005) investigated the influence of readers' misconceptions on comprehension of scientific texts. Online processes were measured by tracking participants' reading times' sentence-by-sentence and using a think aloud protocol. Offline processes were measured by asking comprehension questions about the main ideas presented in the text. Kendeou and van den Broek used a refutation text about electrical current and simple circuits. Participants read the text as it was presented on a computer screen one sentence at a time to assure accurate measurement of reading time. Readers advanced through the text by a mouse click. Kendeou and van den Broek predicted that readers who held misconceptions about electrical current would have slower reading times on the target, refutation sentences, than those readers who held accurate scientific conceptions about the topic due to the coactivation of the scientific explanation and the readers' misconceptions.

The findings revealed no differences in reading times between the misconception group and the non-misconception group. In other words, readers with misconceptions did not spend more time reading the refutation sentences than those without misconceptions. Kendeou and van den Broek explained that this finding suggests that online processes do not differ for readers with misconceptions and readers without misconceptions. An interesting finding from this study is that the offline measure analyses revealed that readers with misconceptions recalled significantly less information from the text, and that information was more inaccurate, than readers without misconceptions.

To further explore the nature of the refutation text effect, Kendeou and van den Broek (2007) conducted a study to investigate the interaction between readers' prior knowledge and text structure during reading. Participants were asked to read a traditional expository text and a refutation text. Both texts focused on the topic of Newton's first law of motion and Newton's third law of motion. Each text was presented on a computer screen, one sentence at a time as in the previous study. Participants advanced through the text at their own pace by pressing the space bar. Reading times of each sentence were recorded per participant. Kendeou and van den Broek again hypothesized that readers with misconceptions would spend more time reading those sentences that contradicted their prior knowledge than readers who held accurate scientific understandings.

Analyses of the reading time data showed no significant differences between those with misconceptions and those with accurate scientific knowledge when reading the traditional expository text. The analyses revealed a difference in reading times between groups when reading the refutation text, in contrast to the finding in their previous study (Kendeou & van den Broek, 2005). In this study, readers with misconceptions read the refutation sentences slower than readers without misconceptions.

In a third study using the same methodology, van den Broek and Kendeou (2008) examined whether online cognitive processes differ for readers with misconceptions and readers without misconceptions related to the topics of the text. The researchers used the Landscape model of reading comprehension as a theoretical framework (see van den Broek, Young, Tzeng,

& Linderholm, 1999). Participants in this study were presented with two versions of the same text (refutation, traditional expository) again using the same text format and presentation method as Kendeou and van den Broek (2007). The analysis showed that the structure of traditional expository text and that of refutation text generate fundamentally different comprehension processes for readers with misconceptions. Refutation texts were correlated with slower reading times and more online conceptual change process than traditional expository texts. Van den Broek and Kendeou argue that refutation texts increase the likelihood of coactivation which in turn leads readers with misconceptions to "experience conflict and engage in efforts to repair the conflict and create coherence" (p. 344). The coactivation and integration likely result in coherence of the readers' prior knowledge and the text information juxtaposed by their proximity in the text and thus increases the likelihood of conceptual change. In contrast, traditional expository texts may not trigger coactivation processes even when the reader holds misconceptions about the topic. However, since the findings from reading time studies comparing refutation and traditional expository texts show mixed results in regards to time spent processing the refutation material, we sought to understand how the attentional allocation literature might provide a framework for replicating and extending this research.

Attention Allocation

In a review of the literature on text comprehension and attention allocation, Reynolds (1992) argued that readers paid extra attention to text elements that are more salient due to task instructions or perspectives; or due to text structure manipulations such as argument overlap (Kintsch, 1998). Reynolds and his colleagues demonstrated that there was a causal relationship between the extra allocated attention and increases in learning and recall (Lapan & Reynolds, 1994; Reynolds, Shepard, Lapan, Kreek, & Goetz, 1990; Reynolds, Trathen, Sawyer, & Shepard, 1994).

Additional attention allocation is not the only way in which learning and recall of important information is improved (Reynolds, 1992). Research has shown that skilled adult readers can learn new text material even when they do not allocate additional attention to it. Shirey and Reynolds (1988) showed that personally interesting text material were learned better by adult readers, even though they actually paid relatively less attention to it.

The attention allocation literature indicates that there are several reasons to posit that refutation text segments may show differential attention allocation compared to traditional expository text segments. Readers may devote more attention to refutation text segments than other text segments because they are highly salient (Reynolds, 1992). As an example, one refutation text on projectile motion states,

> We may have an idea about the motion of objects that we learn from our daily lives. We may even use the idea to predict what will happen to other objects under similar conditions. But scientists have found that many people have wrong ideas about the motion of objects (Hynd et al., 1994, p. 944).

These types of statements may be perceived as salient because, rhetorically, the signal, "We may have an idea" may send a message that what is to follow is significant.

Alternatively, the refutation text effect may mirror the effect of interesting text material. Readers may find the statement misconceptions interesting or personally relevant to them if they recognize it as their own conception. Readers do not necessarily spend additional time on information they find interesting, even though they may learn it better than less interesting information.

The attention literature may help to explain why previous research on the refutation text effect has shown mixed results in regards to time spent reading the refutation information. Readers are likely to spend more time reading refutation text segments than other comparable segments of the text if they find the information to be important or salient or if they coactivate the conception and integrate it with the text information. It is also possible that readers may in fact devote less attentional resources to the refutation text segments than to traditional expository text segments if they find it to be of interest, and readers may find it interesting if the text highlights that a common misconception (one the reader may hold) is incorrect.

The goal of the present study was to replicate and extend previous research (Kendeou & van den Broek 2005; 2007; van den Broek & Kendeou, 2008) using the same methodology and text format but with a different text topic. We sought to extend the previous research by building on the attention allocation literature and considering whether readers would devote differential attention (as reflected by either increased or decreased reading times) to refutation text segments compared to the expository text's comparable statements. We wished to determine whether differential attention allocation or readers' interest could be linked to the traditional refutation text effect; that is promoting greater conceptual change to further our understanding of the findings from previous research.

Research Questions and Hypotheses

The study presented here examined the relationship between conceptual change and the amount of time spent reading a refutation text designed to promote change in students' conceptions of seasonal change. The study investigated the amount of time individuals spent reading refutation and traditional expository texts, as well as the relationship between time spent on text processing and the degree of conceptual change.

Two questions guided our research:

1. Do readers devote differential amounts of attention as reflected by differences in time spent reading refutation text segments than traditional expository text segments about the same content?
2. How does differential attention, as reflected in reading time spent on reading refutation text relate to the refutation text effect?

For Question 1, we hypothesized that readers attention allocation would differ when reading the refutation text in comparison to comparable segments in the traditional expository text. Differential time spent reading the refutation text segments compared to traditional expository text would indeed suggest that the refutation text segments are processed differently.

Specifically, and in regards to Question 2, we expected that the differential attention as reflected in time spent processing the refutation text segments compared to the traditional expository text would result in increased scientific understanding of why the seasons change and a reduction in misconceptions (the traditional refutation text effect). According to the Landscape model (van den Broek et al., 1999), the co-activation of the reader's misconception with the accurate scientific information may lead to cognitive conflict. The detection of an inconsistency between the reader's prior knowledge and the scientific explanation could result in deeper engagement with the text information as the reader engages in conceptual change processes (van den Broek & Kendeou, 2008). Alternatively, the attention allocation literature suggests that if readers find the refutation materials of interest, even if they spend less time reading it, they may learn it better than the traditional expository text material.

Method

Participants

Data was collected in two phases in order to obtain sufficient numbers of participants. Participants in Phase 1 were 48 undergraduate college students (37 female and 13 male) with an average age of 22.9 enrolled in either an introductory course on Educational Psychology or Measurement and Assessments in Education. Seventy-four percent of the participants were in their third or fourth year of college. The mean number of science courses completed by the participants was 1.21, with 9 participants reporting they had taken at least one astronomy course. Three participants were identified as outliers and were removed from all analyses due to scores on one measure in excess of 3.0 SDs from the mean. A standard in reading time research to is eliminate outliers that are at least 3.0 SDs above or below the mean (e.g., Cirilo & Foss, 1980; McCrudden, Schraw, & Kambe, 2005). If the time is abnormally fast it may indicate that the participant was not actually reading the text. Alternatively, if the reading time is quite long in comparison to the mean reading time, it may suggest that the participant did not engage seriously with the task or had reading difficulties.

Participants for Phase 2 were 40 undergraduate college students (35 females and 5 males) with a mean age of 25.5 drawn from the same research subject pool as Phase 1. They were enrolled in either an introductory course on Educational Psychology or Measurement and Assessments in Education. Most students (82.5%) were enrolled in their third or fourth year. Participants reported having completed 1.6 science courses on average and 7 reported having taken at least one Astronomy course. All students received partial course credit for participating in the study. Two participants were identified as outliers and were removed from all analyses due to scores on the reading time measure in excess of 3.0 SDs from the mean. In the Results section, we report the outcome of tests to determine the feasibility of combining the data from Phase 1 and 2 for the purposes of further analysis.

Materials

Measures

The measures for both phases of data collection were identical with one exception. Phase 2 participants were interviewed.

Texts. The effects of attentional allocation and conceptual change were examined through the use of two versions of the same text about the causes for the changing seasons. The text was adapted from Sciencesaurus: A student handbook (Houghton Mifflin, 2002). Text passages were comparable in length, with the refutation text containing 400 words and the traditional expository text containing 374 words. The initial paragraphs of each text varied in length with the refutation paragraph consisting of 91 words and the traditional expository paragraph containing 69 words (see Appendix A for copy of both texts). To equate differential text lengths, we converted all reading times to a common metric - characters per millisecond. All analyses conducted were controlled for length. Both texts included the same figure at the end of the passage that illustrated the elliptical orbit of the Earth around the Sun and the Earth's tilted axis. The order in which the text and illustration were presented was the same for participants in both conditions. Each participant first read the text and then viewed the illustration. Participants were not able to look forward to see the illustration prior to completing reading of the text.

In order to replicate the previous research (Kendeou and van den Broek 2005, 2007; van den Broek and Kendeou, 2008) we used the same format of refutation text used in their studies and in several other studies using refutation texts to promote conceptual change. For example, refutation text passages that contained a single refutation statement have been used effectively to facilitate change of student's misconceptions of projectile motion (Alvermann & Hynd, 2001), light (Mason et al., 2008), and dinosaur extinction (Mason, 2001).

The texts in the present study differed only in the first paragraph, which was the refutation paragraph in the refutation text. The first sentence of the refutation text explicitly stated a common misconception about the reason that the seasons change. In comparison, the first sentence of the traditional expository text was written to elicit participants' prior experiences with seasonal change. The third sentence in the refutation text directly challenged and refuted the stated misconception. In contrast, the third sentence in the traditional expository text provided the scientific explanation of seasonal change. The fourth sentences of both text types described the relative distance of the Earth to the Sun throughout the year. The fifth sentence in the refutation text was similar to the third sentence in the traditional expository text as they each provided the scientific explanation of seasonal change.

The remaining sections of the passage were identical in both the refutation and traditional expository texts. The texts explained that the seasons change due to the tilt of the Earth on its axis as well as its elliptical orbit around the Sun.

Conceptual knowledge. Students' conceptual understanding was assessed using the Seasons Concept Inventory (see Appendix B). This concept inventory was a modified version of the Astronomy Misconception Inventory (Sadler, 1997). This version was intended to focus solely on topics related to the reasons for seasonal change. This inventory was used as a pre-, post-, and delayed posttest measure. Participants' preexisting conceptions about the reasons that the seasons change was ascertained through three open-ended questions and five multiple-choice questions. The open-ended questions asked students to generate an explanation of the phenomena, while the multiple-choice questions asked the students to select the best answer out of four options. These questions were based on the information presented in the text and also took into consideration misconceptions commonly held by individuals concerning the reasons the seasons change (Sadler, 1997).

Nelson Denny. Reading rate and reading comprehension levels were measured using the Nelson-Denny Reading Test (1993). Reading comprehension was measured using the Part II Comprehension Test. Individual reading rates were computed using the Sample Reading Selection located at the beginning of the Comprehension Test.

Computer software. A software program was utilized that allowed students to read the texts presented on the computer screen by advancing the content sentence by sentence and answer the questions described above for each text passage. The software program first presented a practice reading passage so the participants could familiarize themselves with how to advance the text by pressing the space bar to advance from one sentence to the next. We selected this method of text presentation in order to test previous findings (Kendeou and van den Broek 2005, 2007; van den Broek & Kendeou, 2008). In addition, this sentence by sentence method has proven useful in examining other reading issues such as perspective relevance instructions on comprehension (for a recent example see, McCrudden & Schraw, in press). The second section of the program contained the Seasons Concept Inventory as the pre-assessment (Appendix B). Next, either the refutation text or the traditional expository text was presented. The fourth section was the immediate post-assessment, the Seasons Concept Inventory. The fifth section of the computer program was presented to the participants 14 days after completion of session one. This fifth section contained the Seasons Concept Inventory used as the delayed post-assessment.

A timing mechanism was embedded within the software program that presented the texts. This timing mechanism tracked and recorded the reading times, sentence by sentence, of each individual participant. Timing recorded sentence reading time from one press of the space bar to the next as readers advanced their way through the text. Reading times were tracked and recorded sentence by sentence as had been done in previous research exploring online comprehension processes while reading refutation texts (Kendeou & van den Broek, 2005, 2007; van den Broek & Kendeou, 2008) and research investigating attention allocation during reading (Cirilo & Foss, 1980; McCrudden & Schraw, in press; Reynolds, 1992; Reynolds & Anderson, 1982). Since a major goal of this research was to replicate and extend previous research, we choose to use the same text presentation method for comparability of the comparison of our findings to Kendeou and van den Broek's research.

Post-reading interviews. In addition to following the identical protocol as Phase 1 participants, participants in Phase 2 were interviewed using the Post-Reading Interview Protocol to ascertain their interest in the texts after reading. The interview questions were developed in order to ascertain which sentences participants reported they most attended to, which sentences they found most interesting, and which sentences they thought were most important. In addition, the interview questions asked participants to identify any sentences that may have contradicted their prior knowledge. (Appendix C contains the interview questions).

Procedure

Data collection for both phases took place during two one-hour sessions over a 14-day period. Participants were randomly assigned to either the experimental group (refutation text) or the control group (traditional expository text). Participants were each seated at individual computer stations in a testing room that accommodated up to 10 participants at a time. The researcher (the first author) read the instructions for logging into the computer program using their identification number. Next, participants were told they would be reading some paragraphs on the computer. The paragraph would appear with the first sentence in text format and the remaining sentences covered by x's. Participants read the instructions on the computer screen which explained how to press the space bar on the keyboard to advance the text passage at the completion of reading each sentence. The computer screen then advanced to the practice paragraph where the participants could practice reading one sentence at a time, advancing through the text by pressing the spacebar on the keyboard. When the first sentence was read and the space bar pressed, the computer would place x's on the words in the first sentence and reveal the second sentence. Consistent with previous research, participants were not able to reread previously read sentences. This process continued for each of the remaining sentences in the paragraph as the spacebar was pressed by the reader.

Next, participants completed the pre-assessment Seasons Concept Inventory then read either the refutation or the traditional expository text passage. Participants in the experimental condition were given the refutation text (Appendix A). Participants in the control condition were given the traditional expository text (Appendix A). The text passage appeared in the same manner as the practice passage, one paragraph at a time on the screen. The reader would then progress through the paragraph, revealing one sentence at a time by pressing the space bar. Upon completing the text passage, participants completed the Seasons Concept Inventory posttest.

Participant Interviews. To obtain additional information about participants' interest in the texts, post-reading interviews were conducted with Phase 2 participants at the end of Session 1. The post-reading interviews were conducted by the first author and two graduate assistants.

The interviews were intended to investigate whether one sentence stood out as particularly important to participants and whether the text contained information that contradicted their prior beliefs. During the post-reading interviews participants were provided with a hard copy of the text they read during the timed reading portion of the study. Participants who read the refutation text were given a copy of that text. Participants who read the traditional expository text were provided a copy of the traditional expository text. As the interviewer posed each question, the participant was asked to point to the sentence(s) in the text that corresponded with their answer. These sentences were then underlined and the corresponding question number was written next to the sentence(s). All interviews were audio taped for data analysis purposes. Interviewers also wrote participants' responses on individual interview response sheets. At the end of the interview, the participants were reminded that they were to return 14 days later for Session 2.

For Session 2, participants in both Phase 1 and Phase 2 completed the Seasons Concept Inventory delayed posttest as well as the Nelson-Denny reading comprehension test.

Data Scoring

Data from the multiple choice questions on the Seasons Concept Inventory were scored for each participant such that they received one point for each correct answer. A total of four points was possible. Cronbach alpha on these items at pretest, posttest, and delayed posttest was within the acceptable range, $\alpha = .83$ (Pallant, 2005). Data from the essay questions and diagram explanations of the Seasons Concept Inventory was initially coded by identifying idea units in the short-answer responses as well as the in the participant-generated diagram and the participant-generated explanation of the diagram. The idea units were separated into two categories, misconceptions and scientific concepts. Examples of misconception idea units included: "The Earth is closer to the sun. The Earth turns on its axis and the way it positions itself in the summer makes it closer to the sun so the weather is hotter," "It is hotter in the summer than it is during the winter because our side of the Earth is closer to the Sun. It is facing the Sun so it gets all of the direct sunlight." Science concept ideas units included reference to the earth's axis, indicating that the amount of direct sunlight in the northern hemisphere and less in the southern hemisphere is related to seasonal change, and an elliptical orbital path of the Earth around the Sun.

Once the idea units were coded, a total misconception score and a total science concept score were calculated per question, per measure for a total of 22 possible points. For example, on the pretest if a participants' responses indicated three misconceptions in essay question one, two misconceptions in essay question two, and two misconceptions in the diagram/explanation, a total score of seven misconceptions was given on that measure. The posttest was similarly scored. Similar scoring procedures were used for the science idea units provided by each subject per measure for a total of 10 possible points per measure. Each participant received six scores: a misconception score for the pretest, posttest, and delayed posttest, and a science concept score for the pretest, posttest, and delayed posttest.

The first author scored all of the protocols. A second rater scored 22 randomly selected protocols to check the reliability of the rating. Inter-rater agreement, calculated as the percentage of agreement on the total of the answers, was 92.9% on the short-answer items and 91.3% on the diagrams and explanations. Disagreements were resolved through conference to 100% agreement.

Individual participant reading times were recorded for each sentence. Recall that reading times recorded in characters per millisecond by sentence for analysis purposes. This allowed a comparison of reading times across the two text types.

Results

Preliminary Analysis

Data from Phases 1 and 2 were first compared to see if there was justification for combining the two samples. Recall, participants were drawn from the same research subject pool and had similar demographic characteristics (see participant description p. 13). A multivariate analysis of variance was conducted to test the equivalence of Phase 1 and Phase 2 participants. In this analysis, we included the scores for the 4 multiple choice items at pre, post, and delayed posttest, the misconceptions scores at pre, post, and delayed posttest, and the science scores at pre, post, and delayed posttest for both groups. Box's test of equality of covariances revealed no difference between groups, as did Levene's test for equality of variances (all $p > .001$); therefore, the two samples were combined for all further analyses. The combined number of participants in both Phase 1 and Phase 2 was 85, of which 68 were female and 17 were male. Seventy-seven percent of the participants were in their third or fourth year of college. The mean number of science courses completed by the participants was 1.75, with 16 participants reporting they had taken at least one Astronomy course.

We conducted a power analysis to determine whether power was increased as the result of combining the two phases of data collection into one sample. Assuming a medium effect size is 0.40 (Cohen, 1988), and using alpha and power values of 0.05 and 0.80 respectively, the optimal sample size would be 100. The combined total number of participants for Phase 1 and Phase 2 was 85. Although the total number of participants was less than the optimal 100, power was increased over Phase 1 data alone.

Reading Times

In order to address our first research question: *Is there differential time spent reading refutational as compared to traditional text?* we compared reading times between the refutation text group and the traditional expository text group. We first tested whether reading comprehension performance as measured by the Nelson-Denny was significantly related to reading time, but did not differ systematically by text groups. The correlation between the Nelson Denny reading comprehension measure and reading time was in fact significant, $r(80) = -.27$, $p < .05$ indicating it was appropriate to use as a covariate. A *t*-test revealed the two text groups did not differ in Nelson Denny performance. The mean for the refutation text group was 26.88 and the mean for the traditional expository text group was 28.53. A Levene's test of equality of error variances was not significant.

We conducted a univariate ANCOVA to compare the text groups using time spent reading the first paragraphs of each text in characters per msec. to equate for the differential text length (refutation text segment = 91 words, traditional text segment = 60 words). The Nelson-Denny was included as a covariate. The results showed a statistically significant difference in time spent reading the refutation paragraph [$F(1, 77) = 5.56$, $p <.05$, $d = .07$] as compared to the traditional expository paragraph. The refutation text group spent less time reading (mean in msec. per character = .0672) than the traditional expository text group (mean = .0767). (Recall that all reading time comparisons equated for length differences by using reading times per character as the metric in all analyses. The Nelson Denny comprehension scores contributed significantly to this analysis ($p < .001$).

When this difference was examined more closely by comparing the two texts sentence by sentence, the significant differences were due to the refutation segments of the text. For example, when the sentences in the refutation text that activate and then refute the readers' background knowledge (sentences 1 and 3) were compared to the comparable sentences in the traditional expository text (sentences 1 and 3), the refutation text segments were read significantly faster [$F(1, 77) = 4.53$, $p <.05$, $\eta^2 = .06$]. The Nelson Denny comprehension scores contributed significantly to this analysis ($p < .05$). In addition, when the refutation sentence (sentence 4) was compared to the comparable sentence in the traditional expository text (sentence 4), the analyses showed that the refutation sentence was read significantly faster [$F(1, 77) = 15.03$, $p <.001$, $\eta^2 = .16$]. The mean reading time for the refutation sentence 4 was .071 (msec. per character) as compared to the mean reading time for the traditional informational sentence 4, .106 (msec. per character). These results suggest that the decreased time readers spent reading the first paragraph was due to the reduction in time spent processing the refutation text segment.

We conducted a univariate ANCOVA to compare reading times between the refutation group and the traditional expository text group on all of the sentences that appeared after the first paragraph for each text. In other words, we compared the reading times between the two groups on the remainder of each text. The results showed no significant differences in reading times between the refutation group and the expository group, $p = .27$.

Learning Effects

We examined the correlations between the Nelson Denny comprehension measure and science learning at pre-, post- and delayed posttest scores. The correlation between these two measures was significant at pretest $r(79) = .28$, $p < .05$; posttest $r(79) = .34$, $p < .01$; and delayed posttest $r(79) = .48$, $p < .01$. A repeated measures ANCOVA was conducted to compare scores on the Seasons Concept Inventory using the text group as a between group factor, and time of test as the within-subjects factor (Time 1, Time 2, and Time 3), and the Nelson Denny as a covariate. The means and standard deviations for science learning are presented in Table 1. There was a significant main effect of learning over time indicating that gains in understanding seasonal change occurred through reading both texts [$F(2, 75) = 3.5$, $p <.05$, $d = .04$]. Post hoc comparisons revealed a significant difference from pre- to posttest ($p < .001$), from pre- to delayed posttest ($p < .001$) and from post to delayed posttest ($p < .001$). There was no significant effect of text type and no significant interaction between text type and learning over time indicating that learning occurred through reading both texts. The covariate did contribute significantly ($p < .05$).

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Insert Table 1 about here

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We conducted correlation analyses between the Nelson Denny comprehension measure and misconceptions at pre-, post-, and delayed posttest to determine whether it was appropriate to use the Nelson Denny as a covariate. The correlation between the Nelson Denny and misconceptions at posttest was significant, $r(79) = -.29$, $p = .01$. A repeated measures ANCOVA was conducted to compare misconception scores again using text group as the between subjects factor, scores on the misconceptions measure at Time 1 and Time 2 as the within-subjects factor, and the Nelson Denny as a covariate. The means and standard deviations misconceptions are presented in Table 2. The pretest to posttest analysis showed a significant main effect of text type in favor of the refutation text group [$F(1, 76) = 5.91$, $p = .017$, $d = .07$]. There was no main effect of time and no significant interaction. A second repeated measures ANCOVA was conducted with text group as the between subjects factor, scores on the misconceptions measure at pretest and delayed posttest as the within subjects factor, and the Nelson Denny as covariate. The analyses revealed a main effect of time [$F(1, 76) = 5.21$, $p = .025$, $d = .06$], but no significant effect of text type and no significant interaction.

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Insert Table 2 about here

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Post-reading Interviews

Post-reading interviews were scored for each text group of participants in Phase 2. First, a simple tally was conducted to determine which sentences students identified in response to the questions they were asked. For each question tally marks were recorded next to the corresponding sentence each time that particular sentence was identified by a participant. Tally marks were then totaled for each sentence. Upon identifying the sentences in response to the questions, participants were asked to provide a brief explanation as to why they selected the particular sentence(s). We conducted a content analysis of the explanations given by participants for those sentences most frequently identified for each question in order to identify any trends or patterns in sentence selection. Table 3 presents the data of major interest.

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Insert Table 3 about here

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Question 1 asked participants to identify the sentence(s) to which they paid the most attention. The sentence identified most frequently by participants in the refutation text group was, “When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5^{o}.” The primary reason given by participants for selecting this sentence was, “Because it seemed like an important fact.” The sentence selected most frequently by participants in the traditional expository text group was, “The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer.” The most frequent rationale for selecting this sentence was because participants thought it related to one of the questions they had previously been tested on. These sentences selected by participants as those they allocated the most attention describe the tilt of the Earth which is a primary factor for seasonal change. It may be that the additional attention students gave to these sentences helped increase their scientific knowledge of seasonal change being due to Earth's tilt. This finding appears to support the learning effects analyses described previously.

Question 2 asked participants to identify the sentence they thought was the most important for the passage. For the refutation text, three sentences were selected most frequently by participants. Each of these sentences was chosen at an equal frequency, 3 times per sentence. The sentences deemed most important include: "However, seasons do not change because the distance between the Earth and the Sun change," "In fact, Earth is closer to the Sun in winter and farther away from the Sun in summer," "The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer." It is of interest to note that two of these three sentences are the refutation segments themselves. Participants' reasons for selecting the refutation sentences included, "Because I believed that was why they changed," and "It seemed opposite of what I believed in." These insights from the participants suggest that the refutation segment of the text was the most important for promoting conceptual change. The statistical analyses revealed increased scientific understanding of the reasons that seasons change as well as a significant decrease in misconceptions about this phenomena.

The sentence identified most frequently by participants in the traditional expository text group as most important was, "It is the amount of direct sunlight that is received that causes the changes of the seasons of the Earth." Participants' responses for why they selected this sentence as most important to the text included, "I was focusing on the seasons because you had already asked that question," and "Because it just summed it up so compact and concise." No particular pattern was found among the sentences selected as most important by the remaining 17 participants who read the traditional expository text. The sentence identified by participants in the traditional informational text group describes the scientific explanation for seasonal change as related to the amount of direct sunlight received. This sentence may have contributed to the significant increase in scientific understanding as revealed in the learning effects analyses for those who read the traditional expository text.

Participants were then asked to identify the sentence(s) they found most interesting. The sentence selected most frequently by participants in the refutation text was, “In fact, the Earth is closer to the Sun in winter and farther away from the Sun in summer.” The primary reason given by participants who selected this sentence as the most interesting was that it was opposite of what they knew. One participant replied that she remembered being “shocked” when she heard it. The reading times analyses showed that participants read this sentence at a significantly faster rate than those who read the comparable sentence in the traditional expository text. Taken together, the reading time and interview data suggests that interest may have played a role the differences between the traditional and the refutation texts. Similarly, the significant decrease in misconceptions may in part be due to participants finding the refutation sentence interesting because it contradicted their prior beliefs.

Three sentences were identified with equal frequency as the most interesting in the traditional expository text group. One of these three sentences was, “The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer.” The primary reason participants selected this sentence was, “Because it tells you why the seasons change.” This sentence provides the scientific explanation for the reasons that seasons change. Participant interest in this sentence may have contributed to the significant increase in scientific knowledge about seasonal change for participants in the traditional expository text group.

The interviewer then asked participants whether the text contained information that contradicted what they knew about seasonal change. If the text did contradict their prior knowledge participants were asked to identify the relevant sentence(s). Seven out of 20 participants who read the refutation text indicated that the text contained information that contradicted their prior knowledge. Five of those seven participants identified the first paragraph of the refutation text as containing the contradicting information. The first paragraph of the refutation text is the refutation segment. Participants' explanations for why they selected the first paragraph included, "Because I thought the earth was close to the sun in summer and farther away from the sun in winter," and "Well, this is what I thought, and I guess it wasn't true. Just because I thought distance was the reason." It is interesting to note that participants most commonly selected the refutation sentences as those sentences that promoted conceptual change because they contradicted his or her prior misconceptions. These findings support the quantitative data presented above which showed participants who read the refutation text had significantly fewer misconceptions after reading the text.

Six out of 20 participants who read the traditional expository text passage indicated that the text contained information that contradicted their prior knowledge. Three out of those six participants identified the fourth sentence of the first paragraph as the sentence that contradicted their prior beliefs. This sentence is, "The elliptical orbit of the Earth causes it to be closest to the Sun during the winter and farthest from the Sun during the summer." Participants' reasons for selecting this sentence as contradicting their prior knowledge included, "I thought it was the opposite," and "The idea that if it was further from the sun it would be less exposure to the sun which means it would be cooler and it would be winter." These comments from the traditional informational text participants suggest that traditional expository texts can also promote conceptual change when the information presented explicitly contradicts the reader's prior knowledge. For the present study, these comments support the learning effects findings of the significant decrease in misconceptions after reading the traditional expository text.

Finally, participants were asked whether they changed their mind as the result of reading the text, and, if yes, to identify the sentence(s) that was most useful in changing their thinking. Twelve out of 20 participants in the refutation text group indicated Yes. Four sentences were identified with equal frequency by participants as being the most useful in changing their concepts about seasonal change. These sentences are shown in Table 5. Two of these sentences are the refutation segments. The explanations given by participants who selected the first refutation sentence, "In fact, the Earth is closer to the Sun in winter and farther away from the Sun in summer," included "Now I understand that if the sun is farther away or close, I understand why it's warmer or cooler," and "Because that was the one after it because it gave the most information in the text." Participants who identified the refutation sentence, "It is the amount of direct sunlight that is received that causes the change of the seasons of the Earth," explained "Because it's clear cut; it is a simple way to understand the changing of the seasons. It is interesting to note that participants most frequently identified the refutation sentences as those that helped to facilitate a change in his or her understanding of the reasons that seasons change. These findings suggest that the refutation sentences are promoting this decrease in misconceptions and increase in scientific knowledge as evidenced in the quantitative analyses presented above.

Ten out of 20 participants in the traditional expository text group indicated that their understanding changed. Four sentences from the traditional expository passage were identified with equal frequency by participants. Those sentences are shown in Table 5. Participants' explanations for why they selected, “The part of the Earth that is tilted toward the Sun receives more direct sunlight which means it gets warmer,” included, “Because I didn’t know of which way it was tilted for the warm and cold. I had no idea. I just thought it was straight up and down,” and “It’s easier for me to understand.” Participants who selected “The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer,” explained, “It’s a summary of concepts.” Each of these sentences describes Earth’s tilt as the central factor for seasonal change. It may be that conceptual change promoted by these sentences in the traditional expository text because they provided a clear, concise explanation of seasonal change.

Discussion

A rich body of literature has demonstrated positive learning effects through reading refutation texts compared to traditional expository texts. However, little is known about the mechanism by which refutation texts have their effect. The results presented here provide additional insights examining whether refutation texts are processed differently than traditional text. By examining attentional allocation, we sought to determine if refutation texts have their effect by drawing students’ attention to the refutation information, leading to deeper processing, and ultimately greater learning.

The findings revealed that both the text designed to be refutation and the text designed to be informational showed learning effects for increased understanding of science concepts related to seasonal change. Additionally, participants in the refutation text group had significantly fewer misconceptions at posttest than participants in the traditional expository text group. Regrettably, the refutation text effect attenuated at delayed posttest as participants drifted back to their prior misconceptions. The tendency to revert back to one’s prior misconceptions over time is common among conceptual change research. Indeed conceptual change is a gradual, effortful process that typically involves multiple encounters with the information from the scientific viewpoint (Mason & Gava, 2007). These findings may be explained through a mental models approach (Johnson-Laird, 1980). During reading of a text, readers may construct a mental model or situation model (Kintsch & van Dijk, 1978) of the text and use that situation model to comprehend the text. The common tendency to revert to one's prior misconceptions may be because the text-based situation model is not sufficient to challenge or change the reader's prior misconceptions.

The purpose of this study was not to create long lasting conceptual change, but to examine how individuals process refutation text. The CRKM (Dole & Sinatra, 1998) postulates that conceptual change is more likely to occur when the learner engages in deep cognitive processing of new information. In this experiment, the information was presented to participants through one of two formats, either a refutation or traditional expository science text. Based on the Landscape Model, we hypothesized that those participants who were given the refutation text would spend more time reading than those who were given the traditional expository text because the refutation text should draw readers' attention to the anomalous information and result in co-activation of the misconception and the scientific conception. However, the results showed that readers spent less time reading the refutation paragraph compared to those who read the traditional expository paragraph. The reading time effect contributes to the ongoing dialogue among researchers investigating the mechanisms for conceptual change through the use of refutation text.

We hypothesized that the refutation text effect may be due to either increased attention allocation or, alternatively, that readers may spend less time reading if they found the refutation information to be of interest. Our findings that readers spent less time reading the refutation segments illustrates that there is some support in our data for the interest hypothesis. Since the refutation text did reduce misconceptions immediately after reading, our results show that readers allocated their attentional resources differently between these two types of text, and we posit that this differential allocation likely contributed to the reduction in misconceptions exhibited by those readers in the refutation text group. Our findings from the interviews suggest that the refutation text effect may be due to readers' interest in refutation segments. That is, it may be that readers perceive the refutation text information as important, interesting, and easier to process as reflected by the briefer processing time.

The finding of less time spent reading when readers are confronted with information that contradicts his or her knowledge does find some support from the interest literature. Research on interest shows that readers have little difficulty processing material they find interesting. Specifically, in a study examining the effects of seductive details, Lehman, Schraw, McCrudden, and Hartley (2007) showed that readers spent less time processing text that contained seductive details which readers rated as interesting. Our findings from the interviews in Phase 2 demonstrated that 6 students who read the refutation text identified those segments as interesting. The finding that our participants may have found the information that contradicted their ideas to be interesting (indeed, even "shocking" as one student reported) suggests that the refutation information may be functioning in a manner similar to seductive details, thus reducing the attention allocation as Lehman et al. demonstrated. It is important to note, however, that even though readers in our studies spent less time reading these segments, they still attended to them, deemed them important and interesting and may have changed their views due to this information. This is important because Lehman et al. showed that seductive details had a detrimental effect on both recall and deep processing. Seductive details, by definition, are tangential to the main ideas of import in the text. In contrast, refutation segments are, arguably the most important ideas in the text. Therefore, refutation statements may draw readers' interest, may be easy to process, may reduce the attention demand, but they may not have the distracting effect of seductive details. Alternatively, cognitive load theory (Sweller, van Merrienboer, & Paas, 1998) suggests that the reader may not find the scientific explanation as germane. As a result, the reader may process the conflicting scientific information without cognitive overload. For the present study, the interview data suggests that students found the information relevant. An interesting direction for future research would be to explore cognitive processing capacity while reading refutation texts.

There are several limitations to our findings which must be addressed. First, the methodology for tracking individual reading times did not allow participants to look back at previously read sentences or to preview subsequent sentences. However, it is important to keep in mind that even if the technology would have allowed look backs, we could not have allowed our participants to look back because our goal was to compare our finding with Kendeou and van den Broek (2005, 2007) who did not allow participants to look back in the text.

The sentence by sentence methodology limits the ecological validity of the outcomes of our study in that we can not draw meaningful conclusions from this study as to how these texts may work in the classroom. Fortunately, a large body of research demonstrates the effectiveness of refutation text to promote conceptual change in the literature (Guzzetti et al. 1993). Despite its limitations for drawing conclusions about the classroom use of refutation texts, the sentence by sentence reading methodology used in the present study does provide meaningful insights into the nature of the refutation text effect. The methodology provided a pathway to investigate whether cognitive processes are differentiated when reading refutation text or traditional expository text. The reading time data allowed us to determine whether participants would spend more time reading the refutation text as compared to participants who read the traditional expository text. However, once the text reading time has been confirmed in further controlled experiments, more research on the interest hypothesis should be explored in classroom naturalistic reading situations to increase ecological validity.

A second limitation of this research is that both the refutation and informational texts were successful in promoting change. We see this not as a failure of refutation texts, but as a strength of the informational text we used in these studies. That is, the interview data confirms that students in the informational text group identified the scientific concept targeted by the refutation text segments as important and interesting and half of these participants reported to have changed their view. The pre-, post-, and delayed posttests confirmed that they did experience change. The finding of the no difference between refutation text and powerfully written information texts has been seen before in the literature (Kendeou & van den Broek, 2005).

The refutation text group did demonstrate a reduction in misconceptions immediately after reading, which is the raison d'être of refutation texts, demonstrating the refutation statement did have some effect. However, despite this modest finding, our study can not confirm that power of refutation texts over informational text, as both texts seemed to promote change. This lack of differences between the two text types may be due to the texts being quite similar in content.

Previous studies that examined differences in cognitive processes while reading refutation text in comparison to reading traditional informational text have revealed mixed findings (see Kendeou & van den Broek, 2005; 2007). The purpose of the present study was to replicate previous studies by Kendeou and van den Broek (2005; 2007) to investigate whether differences exist in cognitive processing of these two text types. The findings of this study suggest that readers may spend less time processing refutation text in comparison to traditional expository text due to interest.

These conclusions are tentative and must be more fully explored. We hope to more fully explore this effect with eye-tracking methodologies to more precisely examine where readers spend their attentional resources when reading refutation texts. We see this study as a preliminary step toward identifying whether refutation texts may be processed differently than traditional expository texts, accounting for their effect these texts have demonstrated in repeated studies. We hope researchers will pursue this line of research so we can firm the likely mechanism for the power of refutation text in creating conceptual change in science learners.

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Table 1

Means (and Standard Deviations) for Science Learning

Science Understanding	Refutation	Traditional expository
Pretest	3.61 (2.77)	4.05 (2.67)
Posttest	7.76 (3.13)	7.61 (3.24)
Delayed posttest	6.20 (3.41)	6.84 (3.54)

Table 2

Means (and Standard Deviations) for Misconceptions

Misconceptions	Refutation	Traditional expository
Pretest	5.68 (1.62)	6.00 (1.86)
Posttest	3.83 (1.87)	4.87 (1.95)
Delayed posttest	3.71 (1.97)	4.16 (1.90)

Table 3

Content analysis of participant interviews

	Most commonly identified sentence		Participants' rationale for sentence selection	
Question	Refutation text*	Traditional expository text**	Refutation text	Traditional expository text
1. Attention paid	When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5°. (*n*=10)	The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. (*n*=6)	Because it seemed like an important fact. I thought it was an important aspect for why the seasons change. Some of the important facts I didn't know already.	It related to the questions that had previously been tested. It explains why in the summer there is more heat. It was more in my memory.
2. Most important	However, seasons do not change because the distance between the Earth and the Sun change. (*n*=3) In fact, Earth is closer to the Sun in winter and farther away from the Sun in summer. (*n*=3) The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. (*n*=3)	It is the amount of direct sunlight that is received that causes the changes of the seasons of the Earth. (*n*=3)	It defined what I already thought. Because I believed that was why they changed. It seemed opposite of what I believed in. Because I thought the sun was closer to the earth during the summer months.	I was focusing on the seasons because you had already asked that question. Because it just summed it up so compact and concise.

Table 3, continued

Content analysis of participant interviews

	Most commonly identified sentence		Participants' rationale for sentence selection	
Question	Refutation text	Traditional expository text	Refutation text	Traditional expository text
3. Most interesting	In fact, the Earth is closer to the Sun in winter and farther away from the Sun in summer. (*n*=6)	The elliptical orbit of the Earth causes it to be closest to the Sun during the winter and farthest from the Sun during the summer. (*n*=3) When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5$^{o.}$ (*n*=3) The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. (*n*=3)	It was opposite of what I knew. I was shocked.	It was opposite of what I knew. I had no clue that the angle was 23.5. Because it tells you why the seasons change.
4. Contradict prior knowledge	Yes (*n*=7). Selected entire refutation text paragraph. (*n*=5)	Yes (*n*=6). The elliptical orbit of the Earth causes it to be closest to the Sun during the winter and farthest from the Sun during the summer. (*n*=3)	It contradicted what I knew. I just didn't know. Just because I thought distance was the reason.	I thought it was the opposite. I had that in my mind from what I remember.

Table 3, continued

Content analysis of participant interviews

	Most commonly identified sentence		Participants' rationale for sentence selection	
Question	Refutation text	Traditional expository text	Refutation text	Traditional expository text
5. Conceptual change	Yes (*n*=12) In fact, the Earth is closer to the Sun in winter and farther away from the Sun in summer. (*n*=3) It is the amount of direct sunlight that is received that causes the change of the seasons of the Earth. (*n*=3) The earth rotates or spins around its axis. (*n*=3) When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5^{o}. (*n*=3)	Yes (*n*=10) The part of the Earth that is tilted toward the Sun receives more direct sunlight which means it gets warmer. (*n*=2) The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. (*n*=2) It is the amount of direct sunlight that is received that causes the changes of the seasons on the Earth. (*n*=2) The elliptical orbit of the Earth causes it to be closest to the Sun during the winter and farthest from the Sun during the summer. (*n*=2)	Now I understand that if the sun is farther away or close, I understand why it's warmer or cooler. Because that was the one after it because it gave the most information in the text. Because it's clear cut; it is a simple way to understand the changing of the seasons. It gave me the correct information as to why the seasons change.	I was more aware of exactly how it worked. It's easier for me to understand. It's a summary of the concepts. I thought the orbit had something to do with it but now I know it doesn't.

* Refutation text (*N*=20)
** Traditional expository text (*N*=20)

APPENDIX A

Why the Seasons Change (Refutation)

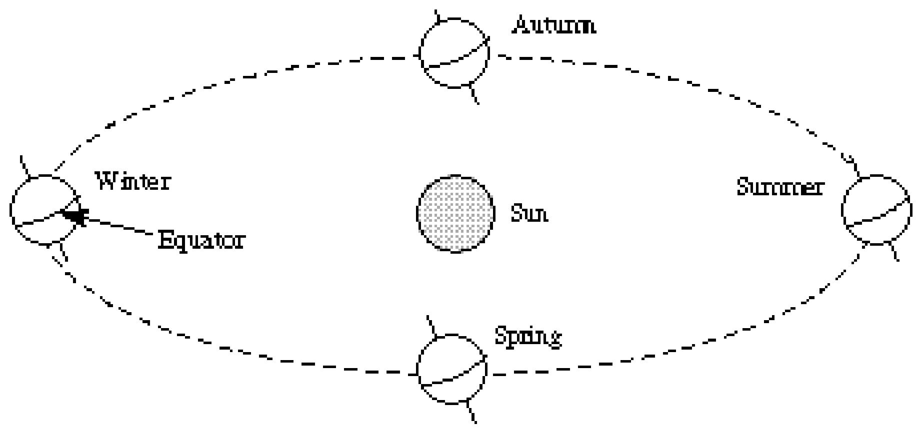
Many people believe that the changing seasons are the result of the Earth being closer to the Sun during the summer months and farther away from the Sun during the winter months. Perhaps you hold similar beliefs. However, seasons do not change because the distance between the Earth and the Sun change. In fact, Earth is closer to the Sun in winter and farther away from the Sun in summer. Seasonal change is the result of two features of the Earth: its tilted axis and its elliptical orbit around the Sun.

The Earth rotates, or spins, around its axis. This axis is an imaginary line that runs from the North Pole to the South Pole through the center of the Earth. When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5^{o}. This is because Earth is tilted on its axis at 23.5^{o}.

The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. Likewise, in winter, the part of the Earth that is tilted away from the Sun receives less direct sunlight causing it to be cooler. In other words, the more directly the sun rays hit the Earth, the warmer those parts of the Earth become. When the other parts of the Earth receive less direct Sun rays they become cooler. The part of the Earth that is tilted toward the Sun receives more direct sunlight which means it gets warmer.

The second major movement of the Earth is its orbit around the Sun. Earth revolves, or circles, around the Sun. This movement is referred to as Earth's orbit around the Sun. It takes Earth approximately 365 days to complete one revolution around the Sun. Because the axis always points in the same direction, the locations of the direct Sun rays change. As the days grow shorter in the winter the amount of direct sun rays decrease and it becomes cooler. As the days grow longer in the summer, the amount of direct sun rays increase and it becomes warmer.

It is the amount of direct sunlight that is received that causes the changes of the seasons of the Earth. This means that even though the Earth's distance from the Sun changes slightly as it orbits, it does not cause changes in the seasons.



Why the Seasons Change (Traditional expository)

From your own experiences you know that the seasons change throughout the year. Depending on the latitude where you live, the temperatures may vary from hot to cold. The changing seasons on Earth are the result of two features of the Earth: its tilted axis and its elliptical orbit around the Sun. Earth is closest to the Sun in January (winter) and farthest from the Sun in July (summer).

The Earth rotates, or spins, around its axis. This axis is an imaginary line that runs from the North Pole to the South Pole through the center of the Earth. When you look at a globe of the Earth, you will see that it is tilted on its axis at about an angle of 23.5^o. This is because Earth is tilted on its axis at 23.5^o.

The part of the Earth that is tilted toward the Sun gets more direct sunlight, therefore more heat, in the summer. Likewise, in winter, the part of the Earth that is tilted away from the Sun receives less direct sunlight causing it to be cooler. In other words, the more directly the sun rays hit the Earth, the warmer those parts of the Earth become. When the other parts of the Earth receive less direct Sun rays they become cooler. The part of the Earth that is tilted toward the Sun receives more direct sunlight which means it gets warmer.

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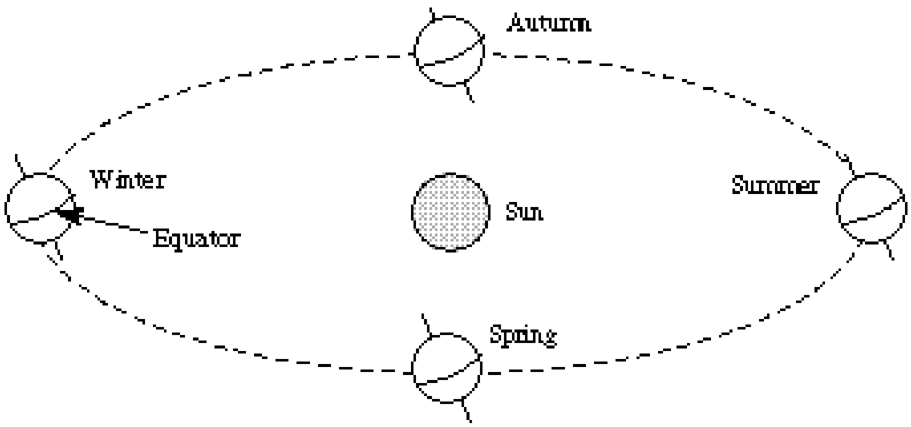

APPENDIX B

Seasons Concept Inventory

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. On a separate sheet of paper, draw the Earth with its axis. Explain the impact of the Earth's axis on why the seasons change.

4. Of the following choices, which looks most like the Earth's path around the Sun?

5. 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.

6. The main reason for it being hotter in summer than in winter is:
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.

7. 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.

8. 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

APPENDIX C

Post-Reading Interview Protocol

1. To which sentence(s) did you pay most attention? Please show me. Why did you pay more attention to this item?

2. Was there one sentence that stood out to you as particularly important? Please show me. Why was it important?

3. Was there any part of the text that was particularly interesting to you? Please show me. Why was it interesting?

4. Did the text contain information that contradicted what you knew about seasonal change? Please show me. Why was it contradictory?

5. Did you change your mind about anything as a result of reading this text? If yes, which part of the text was the most useful to you in changing your thinking? Why was it useful?