CLARIFYING GOALS OF READING FOR UNDERSTANDING FROM EXPOSITORY SCIENCE TEXT

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ABSTRACT

Previous research has suggested that reader goals can affect how well learners develop understanding of complex texts, specifically in science. This chapter discusses the role of students’ goals and strategies in acquiring scientific knowledge from multiple expository sources, and supplements previous findings with novel eye-tracking and web navigation analyses to provide greater insight into how different learners use goal and source information to guide their reading strategies. Finally, we discuss the potential importance of training students to apply appropriate reading strategies when learning from expository texts, and the subsequent benefits of teaching students to think critically about information from different sources when reading to understand.
If we examine *National Science Education Standards* (NSES) as well as state standards, one of the main goals for science education is to provide students with knowledge of scientific phenomena and processes across a variety of topics (NSES, National Research Council, 1996). For instance, in middle school grades, students are expected to acquire an understanding of the structure and function of living systems, reproduction and heredity, the properties of matter and energy transfer, the structure of the earth and its history, and population dynamics. Further, students are usually expected to gain a large proportion of this knowledge of scientific concepts by reading from textbooks or engaging in other text-based activities. Thus, a teacher’s goal for assigning readings in this context is to promote students’ understanding, yet little attention in science classes has been paid to teaching students the strategies and techniques they need to comprehend scientific phenomena from expository texts, much less sets of texts, which are the topic of the research reviewed in this chapter.

**GOALS FOR READING**

One major issue for students is that the goals for reading transition across grades from learning-to-read to reading-to-learn activities. This transition is usually not explicitly acknowledged or addressed. This is a critical concern because the basic reading skills of decoding and narrative understanding that are usually taught in elementary grades do not necessarily translate into effective discipline-based comprehension from expository texts in later grades. One of the main points of this chapter is to argue that students need to be made explicitly aware the intended goal for reading when they are asked to read expository science texts. Further, they may also need to be specifically supported in the skills that are needed for effective subject matter comprehension.

There are several possible intended goals for reading activities. For instance, in early elementary grades one of the primary goals for engaging students with text is the development of the basic skills required for reading itself. Dr. Seuss books (and similar texts) are particularly instructive as they emphasize the sounds of words, and how the same sounds can be made from different combinations of letters. Thus, these texts are primary examples of how phonological decoding skills can be strengthened or learned through reading activities. Of course, an added benefit of Dr. Seuss’ books is that they are also quite amusing, which highlights a second goal of reading in early grades—namely, entertainment. Entertainment value is often important in these early texts as they are intended to instill a fondness or positive affect towards reading.
A third important goal for reading in primary grades is the acquisition of basic world knowledge and vocabulary. Texts are a critical vehicle for disseminating such content, and in early grades they often focus on the lives of historical figures or events, or provide descriptions of different cultures or natural phenomena. Typically, however, even though there are skills or knowledge to be learned from reading, early texts are still generally narrative or descriptive in nature. Hence, the comprehension processes that are involved largely consist of following a story, or thinking about who, what, where, and when. It is rare for elementary students to be exposed to expository or explanatory texts (Duke, 2000).

However, somewhere between late elementary and high school, the goals for assigning readings in school changes. Instead of learning to read or reading for entertainment, students are now expected to read for understanding in order to comprehend the content that is being conveyed. In science class, this means they should now have explicit goals for reading that include understanding how or why a particular phenomenon occurs. The process of comprehending the content conveyed by an expository science text has been seen as the process of building a causal mental model of phenomena (Chi, 2000; Graesser & Bertus, 1998; Kintsch, 1994; Mayer, 1989; Wiley, Griffin, & Thiede, 2005). As students read expository science texts, in order to comprehend the content they need to build representations that establish causal relations and connections among ideas or concepts. They need to attempt to construct explanations of how or why a process happens. In doing so, they must be able to distinguish between information that is more or less relevant for enabling them to meet their reading goals (McCrudden & Schraw, 2007). It is this kind of mental representation that will enable a student to engage in the kinds of behaviors generally associated with “understanding,” including the ability to generate or recognize correct inferences and the ability to apply the acquired knowledge in new contexts. To produce such a representation of the content, readers need to embrace the goal of reading for understanding.

**HOW DO READERS TYPICALLY APPROACH THE TASK OF LEARNING FROM SCIENCE TEXTS?**

Unfortunately, the lack of explicit training in science text comprehension is an issue that continues into adulthood. Even among collegiate populations, readers are generally poorer at comprehending expository or explanatory science texts than narrative or descriptive texts. There is general agreement that adult readers spontaneously generate causal bridging inferences when reading narrative text (e.g., Klin, 1995; Potts, Keenan, & Golding., 1988; Suh & Trabasso, 1993; van den Broek, 1990). However, there is considerably
less evidence that similar inferences are drawn from expository texts. Using scientific texts, Noordman, Vonk, and Kempf (1992) found that readers did not routinely notice contradictions to the causal inferences implied by the texts. This is consistent with a number of findings that readers of expository science texts are generally insensitive to inconsistencies (Glenberg, Wilkinson, & Epstein, 1982; Markman, 1979; Otero & Kintsch, 1992). Although a few studies have found evidence for the generation of causal inferences from science texts, this seems to be most likely when the need to do so is clearly signaled or marked for readers (Noordman, et al., 1992; Singer & Gagnon, 1999), and when all relevant information for the inference is available in working memory (Wiley & Myers, 2003). A further important difference between narrative and expository text processing is that readers seem to be much poorer at monitoring their level of understanding from expository texts than at monitoring their memory for either narrative texts or word lists (Griffin, Wiley, & Thiede, 2008; Thiede, Dunlosky, Wiley, & Griffin, 2005; Thiede, Griffin, Wiley, & Redford, 2009; Wiley et al., 2005). This failure to gauge comprehension from text can lead to ineffective re-reading and studying behaviors.

Wiley, Griffin and Thiede (2005) argued that both of the above effects can be related to students’ poor understanding of what comprehension means. If readers do not understand that their goal while reading expository text is to acquire a conceptual understanding of the content, they will fail to focus on conceptually relevant information, or fail to attend to poorly understood information, during study. These issues become even more salient when students are asked to engage in self-regulated learning activities, including internet inquiry tasks where students attempt to learn about scientific topics by reading and integrating across multiple sources. Many have suggested that inquiry tasks from multiple sources afford more “authentic” instruction that better reflects the types of research and reasoning done by actual scientists (Chinn & Malhotra, 2002; Linn, Davis, & Bell, 2004; Wallace, Kupperman, Krajcek, & Soloway, 2000). However, with the myriad of different quality sources available to students, the conceptual knowledge gained from these tasks will be even more dependent on the students’ understanding of their assigned goal for reading.

The remainder of this chapter will discuss the use of various instructional conditions to focus students on task-relevant and conceptually important information while learning from multiple sources. Several studies have explored the effects of manipulating the goal of the learning activity, asking students to write either a “report” on a scientific topic or having them write an “argument” for why a scientific phenomenon occurs. Discussion of these results is augmented with new analyses using eye-tracking data to differentiate the reading patterns of more and less effective learners. Finally the effect of the presence of unreliable sources on students’ learning,
and interventions to support evaluation and explanation processes while students are learning from multiple sources, are discussed.

**USING ARGUMENTATION TO ENHANCE LEARNING FROM MULTIPLE SOURCES**

Research has shown that asking students to construct arguments about the causes of phenomena from multiple sources can be an effective way to promote students' learning of core causal concepts from expository texts, particularly when compared to tasks that ask students to write a report or description about a topic (Wiley & Voss, 1996, 1999). Wiley and Voss (1996) showed that students who were given an argument-writing instruction and multiple source texts produced essays with more causal statements and connections than students who were given instructions to write narrative or descriptive reports, or than students who had read a single source text with the same content. Argument writing from multiple sources has also been shown to improve performance on posttests of subject-matter learning, including the recognition of correct inferences and the ability to apply principles in new contexts (Wiley & Voss, 1999).

There are several reasons why the combination of presenting readers with multiple sources and using an argument-writing prompt could promote the most constructive and integrative processing. First, when task-relevant and conceptually important information is presented in multiple documents, this may require readers to actively create a representation that connects and integrates information across the sources. Second, an argument-writing instruction may help readers focus on making claims and providing evidence for why a phenomenon occurs, rather than simply reporting what they read. Third, an argument-writing task can promote more selective attention to causes of scientific phenomena, and less of a memorization-of-everything (kitchen sink) approach to knowledge acquisition. In summary, the use of an argument-writing instruction with multiple sources helps direct students to engage in the construction of a coherent, causal model of phenomena (Wiley & Voss, 1996, 1999).

This interpretation is further supported by a study that had students complete importance ratings for idea units contained in the texts either before or after essay writing (Voss & Wiley, 1997). The timing of completing importance ratings (either before or after essay writing) had no effect on the quality of the descriptive reports. However, when students completed importance ratings before an argument-writing task, the quality of the essays suffered compared to essays written before importance ratings. These effects were arguably caused by the importance-rating task disrupting the construction of an integrated causal model. Having students consider
each piece of information individually may have diverted attention and re-
sources away from the model construction process, and thus undermined
the potential benefit of the argument-writing instruction. Taken together,
these studies suggest that tasks that involve argument writing from multiple
sources may direct students to develop more integrated, causal represen-
tations of phenomena than other learning contexts, and this direction is
responsible for their better understanding of the subject matter.

In these prior studies looking at the effects of argument-writing tasks
and multiple sources on learning from expository texts, all of the sources
presented to the students were from reliable or reputable sources, and all
included valid information about the topic. Although the sources did vary
in how much of the content was directly relevant to the current topic, and
no one source contained all the information needed to construct a full ca-
sual model of the phenomenon, they were still all largely accurate sources
of information that could have encouraged a “kitchen sink” approach to
knowledge acquisition. However, when students do internet searches, it is
rarely the case that all of the information that turns up will be relevant.
Hence, to extend these findings, Wiley, Goldman, Graesser, Sanchez, Ash,
and Hemmerich., (2009) investigated whether the benefits of an argument-
writing task would transfer to a situation where students were faced with
texts that varied in the reputability of the sources and the veracity of the
information.

The learning activity in Wiley et al. (2009) was designed to simulate a
scientific research assignment in which students would use the internet to
learn about volcanoes, and to achieve a mature conceptual understanding
of plate tectonics and subduction zone eruptions. Undergraduate students
with little prior knowledge about the causes of volcanic eruptions were
asked to use a set of internet sources in order to learn what caused the erup-
tion of Mt. St. Helens. The students were presented with a mock Google
search output page that presented seven different websites they could use
for their research, which varied in their veracity and reputability. Half of
the students were asked to do research in order to write an argument about
why Mt. St. Helens erupted. The other half were asked to instead write a
report about why Mt. St. Helens erupted. An a priori causal model of seduc-
tion zone eruptions was developed to assess student understanding. While
students in both conditions showed better understanding of the causes of
volcanic eruptions than comparison students that did not engage in an in-
ternet inquiry task, in their final essays students in the argument condition
referred to more correct concepts from the causal model and fewer incor-
rect concepts than those in the report condition.

The work reviewed above on argument-writing tasks and multiple sourc-
es has shown that students often do not appear to spontaneously approach
expository texts with the goals of developing causal models or understand-
ing complex scientific concepts. The results of Wiley et al. (2009) suggest that students also need to consider the reliability of sources and the veracity of information, which even further complicates learning from expository texts. In these situations, directing readers’ attention with an argument-writing task may not be enough to focus students’ processing, yet some students were still able to learn effectively from this inquiry task. Understanding the strategies used by successful learners is one way to better understand what behaviors could be supported to maximize learning in all students. To this end, eye-movement data, obtained while readers performed this internet inquiry task, were explored to provide a more descriptive analysis of effective reading behaviors.

Eye-Movement Analyses of Reading Behaviors

A subsample of the participants in Wiley et al. (2009, Experiment 1) completed the internet inquiry task on a Dual-Purkinje eye tracker. These previously unreported data provide detail on students’ reading behaviors within each page of the different sources, their use of heading information and skimming behavior, and their viewing of illustrations while reading. For this analysis, the three best learners given the argument-writing instruction were selected in order to investigate how students learned effectively in that condition. For comparison, data from the three poorest learners in the argument-writing condition and the three best learners in the report-writing condition were also analyzed. The best learners were those with the highest ratio of correct conceptions to misconceptions in their essays. The poorest learners had the lowest ratio of correct conceptions to misconceptions. Several descriptive measures about the reading patterns employed by these students are presented in Table 15.1, as well as their pretest scores, and the average number of correct conceptions and misconceptions included in the post-reading essays.

Pretest and Post-Reading Essay Performance

Prior to engaging in the inquiry task, all participants completed a volcano concepts pretest. The pretest consisted of 30 items, and students were asked to indicate whether statements about the causes of volcanic eruptions were true or false. Performance on this pretest averaged only slightly better than chance performance (17/30 correct), and there was no difference in prior knowledge across conditions. Thus, both good and poor learners generally did not have a good understanding of plate tectonics or the causes of volcanic eruptions before reading the target texts. However, the data for the number of correct concepts and misconceptions mentioned in students post-reading essays show large differences between the best and
poorest learners’ understanding, with the best learners demonstrating both more accurate knowledge about the causes of volcanic eruptions and also fewer misconceptions. This suggests that the large differences observed in post-reading understanding are assumed to be a result of the different reading strategies and learning behaviors that the students engaged in during the inquiry task, and not a result of differences in prior knowledge of the content area.

Reading Behavior Measures

Reading and page-viewing patterns were analyzed in order to gain a more detailed understanding of the differences in behaviors that led to the large disparity in post-task understanding. The first reading behaviors investigated were the number of pages visited during the inquiry task and the overall time spent on different types of pages. Although the best learners did appear to visit slightly more of the different web pages than poorest learners, the difference overall was small. Also, overall reading times were quite similar. Therefore, overall differences in the amount of effort the students put into the task or the amount of material they covered do not appear to be the main determinants of the large differences in post-task understanding observed between the best and the poorest learners.

The internet sources provided in this inquiry task contained both reliable sources that offered valid conceptual information about the causes of volcanic eruptions and unreliable sites that offered unscientific or in-

### TABLE 15.1 Descriptive Statistics for Comparison of Best and Poorest Learners

<table>
<thead>
<tr>
<th></th>
<th>Argument-Writing</th>
<th>Report-Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best</td>
<td>Poorest</td>
</tr>
<tr>
<td>Pretest (out of 30 items)</td>
<td>17.00 (1.00)</td>
<td>17.00 (1.00)</td>
</tr>
<tr>
<td>Correct Concepts in Essay</td>
<td>5.33 (2.08)</td>
<td>2.33 (1.52)</td>
</tr>
<tr>
<td>Misconceptions in Essay</td>
<td>0.33 (0.57)</td>
<td>1.67 (0.57)</td>
</tr>
<tr>
<td>Pages Viewed</td>
<td>20.66 (6.65)</td>
<td>18.33 (5.51)</td>
</tr>
<tr>
<td>Reliable/Unreliable Ratio</td>
<td>2.53 (1.47)</td>
<td>1.03 (0.44)</td>
</tr>
<tr>
<td>Returns to Reliable Pages</td>
<td>12.33 (14.46)</td>
<td>3.33 (1.53)</td>
</tr>
<tr>
<td>Returns to Unreliable Pages</td>
<td>7.67 (3.21)</td>
<td>7.33 (7.50)</td>
</tr>
<tr>
<td>Time in ROIs</td>
<td>17.97 (3.51)</td>
<td>14.23 (2.07)</td>
</tr>
<tr>
<td>Time in non-ROIs</td>
<td>10.60 (1.38)</td>
<td>13.35 (3.25)</td>
</tr>
<tr>
<td>Conceptual Images Viewed</td>
<td>6.67 (8.14)</td>
<td>1.00 (1.00)</td>
</tr>
<tr>
<td>Captions read</td>
<td>2.00 (2.64)</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Decorative Images Viewed</td>
<td>3.67 (0.58)</td>
<td>5.33 (2.08)</td>
</tr>
<tr>
<td>Captions read</td>
<td>2.33 (0.58)</td>
<td>3.00 (1.00)</td>
</tr>
<tr>
<td>Time in White-Space</td>
<td>1.24 (0.96)</td>
<td>0.40 (0.45)</td>
</tr>
</tbody>
</table>
correct information about the causes of volcanic eruptions. To obtain a measure of the relative attention devoted to the two kinds of sources, a ratio of time spent on reliable versus unreliable pages was computed such that higher ratios indicated that students spent more time on the reliable pages. These results showed that the poorest learners spent approximately equal time on both reliable and unreliable sites while the best learners in both writing instruction conditions showed a preference in favor of the reliable sites. Also, the best learners were much more likely to return to reliable pages than poorer learners. These results suggest that the best learners were more likely to attend to the reliable sources that provided scientifically supported information.

The use of this eye-tracking data did permit a more in-depth examination of these differences in reading behavior and how they related to the development of correct understanding of the content. The percentage of time spent on appropriate sources suggests that the best learners are better at identifying reliable sources than the poorest learners. However, do differences in reading patterns also exist within sources for these different types of learners? For example, did the best learners attend more to information that was specifically relevant to the goals of the inquiry task? Within the reliable sources, there was some information that was specific to the type of eruption that happened on Mount St. Helens, and also other information in these sources that provided valid background information about geology, plate tectonics, and volcanic activity. However, there was also a great deal of irrelevant information, which while not conceptually incorrect, did not contribute to the understanding of volcanic eruptions. To code for relevance of information, each clause from the reading materials was categorized in terms of whether or not it related to 13 core concepts underlying volcanic eruptions, or their connection to each other. These areas were determined to be “regions of interest” or ROIs (i.e., units of text that were directly relevant for understanding the process of volcanic eruption). Time spent in these ROIs was then computed from eye movement data and compared across the different type of learners.

As shown in Table 15.1, large differences in the time spent in ROIs between the best learners and poorest learners were observed. Although the best learners in both conditions spent more time in the ROIs than the poorest learners, this effect was particularly large for the best learners in the argument condition. These results suggest that the best learners engaged in selective reading habits both in source selection and also in the selection of information to be read within a source.

Skimming

Eye-tracking data also revealed several interesting patterns indicative of the level of engagement and thoroughness in reading the content of the
web pages for each participant. Reading behavior for each page was categorized into one of two possible styles: a more typical, engaged reading style versus skimming. Based on previous research, it was expected that better learning would result from engaged and more careful reading and processing of the text. Conversely, skimming behavior should be more characteristic of poorer learning or comprehension. According to Rayner (1998), under normal conditions, readers generally make one fixation for every seven to nine letters in a line of text. Using this standard, one would expect approximately 17 fixations per line for these texts. This figure is just a rough approximation because the length of words in the text, their expectedness and their frequency can also affect fixation patterns; however, this provided an estimate of what one might expect from engaged readers. When a reader made more than 15 fixations per line of text, this was considered typical, engaged reading behavior. On the other hand, skimming was defined as making ten or fewer eye fixations per line of text. Additionally, normal reading behavior tends to involve both forward and backward fixations (regressions). Regressions are generally considered indicators that a reader is attempting to resolve references and establish at least local coherence for the text (Rayner & Pollatsek, 1989; Wiley & Rayner, 2000). In contrast to this profile of normal reading behavior, a common characteristic of skimming is that very few or no regressions are made while reading. These features allowed classifications of whether readers were engaged in normal reading or skimming behaviors.

While both skimming and more thorough reading behaviors were observed in all individuals on some pages, some interesting differences between the conditions did appear. In the report-writing condition, the best learners tended to read all of the pages thoroughly at least once, if not several times. The best learners in the argument-writing condition, however, showed more selective reading behaviors. These participants were more likely to skim pages, but would often go back and thoroughly re-read a page if it contained conceptually relevant information. It is notable that this more selective processing of information ran counter to a priori expectations and suggests that the students in the argument-writing condition were more goal-directed or strategic in their reading.

Use of Headings and Titles

Both the best and poorest learners in the argument condition tended to read the titles and headings on the web pages. However, these participants seemed to use the titles and headings in different ways. After reading the page titles and headings, the poor learners also continued to read most of the page content. However, the best learners were more likely to skim the content of the page or even skip entire paragraphs after reading the titles or headings. Again, this behavior reflects more selective reading styles by
the best learners, and suggests they are using the information in the head-
ings to guide their reading (Hyona, Lorch, & Kaakinen, 2002).

Finally, while all participants visited all the sites, group differences were
observed regarding which pages learners chose to revisit. Better learners in
both conditions tended to revisit reliable pages more often than the unreli-
able pages. On the rare occasion when better learners did revisit the un-
reliable sources, they often skimmed the content of the pages, completely
skipped over large parts, or just read the title and headings. Poorer learn-
ers, on the other hand, returned to unreliable sites much more often, and
did not show selective reading behaviors on those pages. Just as in their first
pass of reading the material, these participants continued to spend a large
amount of time engaged in reading the content on these unreliable pages.

Time Spent on Images

The eye-tracking data also revealed some intriguing patterns for how il-
ustrations were processed. As with the ROI analysis above, the illustrations
were categorized into two groups: (1) those that were directly relevant for
developing a correct causal model (i.e., conceptual images) and (2) those
that did not serve that purpose (i.e., decorative images). Decorative images
included photographs of volcanic eruptions or their aftermath, Mt. St. Hel-
ens before the volcanic eruption, researchers taking temperature measure-
ments of lava, and photographs of web page authors. Thus, these images
contribute little toward the conceptual understanding of what causes volca-
nic eruptions. Alternatively, an example of a conceptual image is a diagram
that shows how oceanic plates are pushed beneath continental plates in
subduction zones.

While all readers looked at the graphics, the best learners in the argu-
ment-writing condition tended to look at the conceptual images more so
than their decorative counterparts. Poor learners and learners in the re-
port-writing condition exhibited the opposite preference. These patterns
are consistent with previous results showing that attending to seductive
images can harm the comprehension process. In a set of studies done by
Sanchez and Wiley (2006), learners who differed in working memory ca-
pacity (WMC) read a scientific text that was illustrated with either no im-
ages, seductive images, or conceptual images. As a goal for reading, learn-
ers were asked to develop an argument for “What causes Ice Ages?” Results
demonstrated that those lower in WMC were more likely to be “seduced”
by the seductive images and exhibited lower comprehension performance
when given a text containing seductive or irrelevant imagery. Eye-move-
ment analyses supported this assertion and indicated that while fixation
patterns were consistent across WMC groups for the conceptual image con-
dition, there was a significant divergence in how images were processed in
the seductive image condition. In the seductive image condition, low-WMC
learners looked at the imagery more often than high-WMC individuals, and often fixated on the imagery mid-sentence, rather than looking strategically between sentences or after reading. High WMC individuals tended to ignore these irrelevant images and instead focused on reading the text. This result suggests that interesting images were especially distracting for the low-WMC individuals, such that they couldn’t help but look at the images while reading. Further, this suggests that attending to images that are not conceptually related to the material can impede comprehension, which is similar to the effects seen here.

The best learners in the argument instruction condition also visited the “graphic only” pages more often than the other two groups did. The best learners were more likely to read the captions and tended to concentrate on graphics, captions, or important regions of text when they re-visited pages. In terms of viewing patterns, the best learners in the argument condition also interleaved looking at the pictures with reading of the content, while the poorest learners tended to look at the pictures either before they began to read the text, or sometimes after finishing reading everything. These learners almost never attended to illustrations during the process of reading the page content. The better learners in the report-writing condition had similar viewing patterns to the better learners in the argument-writing condition; however, some small differences did exist. Better learners in the report-writing condition would generally look at the images, then read the page content, and then return to the images, indicating some attempt at integrating the text with the information contained in the images. In the argument-writing condition, while better learners also showed this pattern of behavior, they would take it even one step further. These participants would also look at the images and text in a more interleaved fashion while reading. However, not only would they fixate back and forth on the text and images on the current page, they would also revisit previous image-only pages, after which they would then navigate back to the current text page and continue reading.

These patterns are reminiscent of those seen in other eye-tracking studies. For example, Hegarty, Carpenter, and Just (1990) have interpreted attention shifts between images and text as evidence that readers are attempting to construct a mental model or visuospatial representation of the subject matter. They suggest that readers initially try to create a representation from the text alone but may view diagrams in order to confirm their representations or to assist in the formation of their representations. Additionally, they suggest that readers with lower spatial ability may look at images or diagrams more often because they have more trouble forming representations from text alone. In general, interleaved viewing of text and images can be an effective means for learning from illustrated texts (Hegarty & Just, 1993). Better learners tend to attend to illustrations strategi-
cally after completing discrete units of text in an effort to use the visual information to help consolidate understanding of the verbal information. This is similar to the patterns seen here.

A final provocative observation is that the best learners in the argument-writing condition also tended to look off into non-text space more often or longer than the other readers. Time spent on non-text space could indicate that readers are attempting to mentally visualize the phenomena, and this could be further evidence that these readers are engaging in mental model construction during reading.

**Conclusions from Eye-Tracking Analyses**

The results of these analyses demonstrate that the best learners spent more time on conceptually relevant information, and less time on conceptually irrelevant information than the poorest learners. This conclusion is supported by the trends in reading times, viewing and navigation patterns, and time spent in ROIs. Further, the best learners in the argument-writing condition seem to be more engaged in the process of creating a mental model, as they showed better use of conceptual illustrations, more integrated reading patterns, and there was also the suggestion that they may have been more engaged in mental visualization activities. Importantly, the best learners are not spending more overall time reading—but instead they are more selective with their reading efforts. For the best learners, it appears that the argument instruction is helping to direct their attention to relevant text and illustrations. The argument-writing instruction may also be supporting integrative processing which is leading to better essays and subject-matter learning.

Yet the goals for reading may only be subtly influenced by this instruction as the entailments of each writing instruction are left implicit. In the face of a wide range of reliability among the provided sources, the argument-writing instruction led to fairly weak learning outcomes compared to previous studies. It seems the presence of the unreliable sources among the readings may have further complicated the issues of learning from expository texts. Instead of a “kitchen sink” approach, the presence of unreliable sources may require a more strategic approach to reading, where students need to evaluate and select relevant and reliable information. Students need to have both of these standards in place in order to be effective learners in a task such as this. This proposition is consistent with the findings of the larger sample used in Wiley et al. (2009). Better learning in that sample was related to better evaluation of sources (the ability to differentiate reliable from unreliable sources) and also a preference for the reliable sources during reading.
Manipulating the Reliability of Sources

The results of Wiley et al. (2009, Experiment 1) and the eye-tracking analyses reported above support several important conclusions: (1) there are differences in reading strategies that students employ while learning from expository texts during an internet inquiry task, (2) these strategies are prime determinants of learning outcomes, and (3) argument-writing instructions do not seem to produce as substantial an improvement as was seen in earlier studies.

One main difference between the Wiley, et al. (2009) studies and the earlier Wiley and Voss (1996, 1999) studies done with argument-writing manipulations was that the earlier studies did not include unreliable sources (with inaccurate information) among the set of reading materials. In order to investigate whether the argument-writing instruction may be more effective in contexts where only relevant or reliable sources are included, Sanchez and Wiley (2010) conducted a study that manipulated the presence of unreliable sources to be used in the same internet inquiry task. One group received both the reliable and unreliable sources from Wiley et al. (2009, Experiment 1). The second condition only presented readers with the four reliable sources on the Google search output page. In this Source Reliability Manipulation study, all students were instructed to read in order to write an argument of what caused the eruption of Mt. St. Helens, and again, all students had low prior knowledge about volcanoes.

The first two pairs of bars in Figure 15.1 show the mean number of correct causal concepts and misconceptions found in students’ essays in the report and argument-writing conditions in the original Wiley et al. (2009) study. (These data are for just the eye-tracking sample collected at UIC, N = 28.) These results show that the increase in the number of correct concepts as a result of the argument-writing instructions was somewhat small. However, students in the argument-writing condition were much less likely to include misconceptions about the causes of volcanic eruptions in their essays than those in the report-writing condition.

The third and fourth pairs of bars in Figure 15.1 show the results of the Source Reliability Manipulation study (Sanchez & Wiley, 2010). The third set of bars (labeled Reliable & Unreliable Sources) was a direct replication of the argument-writing condition from Wiley et al. (2009, Experiment 1) and showed the same pattern when compared to the report-writing condition. Once again, argument-writing instructions decreased the number of misconceptions but did not lead to a large increase in the amount of correct concepts reported. The fourth set of bars shows the results when only reliable sources are included in the output list. Providing only the reliable sources with an argument-writing task did not lead to an increase in correct
concepts as compared to the group that received both types of sources. However, this condition did show very few misconceptions.

These results offer two important conclusions. First, the observation that removing the unreliable sources almost eliminated the misconceptions reported in students’ essays suggests that the students in the other conditions were not bringing these misconceptions with them from prior experience, but were actually acquiring these misconceptions during the inquiry learning task from the unreliable sources. Second, providing an argument-writing prompt was not a strong enough instructional support to protect students from acquiring this incorrect information. An argument-writing instruction by itself is not enough to direct students to adopt effective expository reading strategies and to adopt appropriate goals in the context of the type of complex inquiry represented by this internet search task. Thus, adding variability to the reliability of source texts seems to exacerbate the issues that readers already have in learning from expository texts, yet this is the context that students will find themselves in as they engage in real internet searches to answer health, financial, and other science-related questions in their adult lives. Readers will encounter expository texts from both reliable and unreliable sources and will need to develop a coherent understanding from them. It thus remains an important question as to what
kinds of instruction will help readers to learn from and comprehend these contexts. Finally, while the manipulations so far have reduced the number of misconceptions present in student essays, there has been little increase in the number of correct conceptions across conditions. More direct instructional support may also be needed to prompt readers to engage in explanation-based processing.

Supporting Correct Understanding from Internet Inquiry Tasks

In a final set of studies, several interventions were designed to encourage consideration of the reliability of the source texts, as well as to promote an emphasis on developing an explanation of phenomena, while reading. One main goal of these studies was to support students in evaluation processes while engaging in internet inquiry tasks.

In a first instantiation (Graesser, Wiley, Goldman, O’Reilly, Jeon, & McDaniel, 2007), an online tutor was developed that provided readers with hints on demand while performing the Mt. St. Helens inquiry task (hints included prompts such as telling them to think about the quality of the sources they were reading). As readers left each website, they were asked to evaluate the reliability of the site, and were prompted to complete a virtual notecard with comments on five key attributes of each site they visited (Who is the author? Is the site trustworthy? What explanation is given for eruptions? What evidence is given? Is the site useful?). Students could hit the hint button whenever they wished, but they were required to fill out or update notecards each time they left a web site. Unfortunately, this intervention did not improve learning, perhaps because the time spent on the notecards competed with and detracted from the amount of time that students could be engaged with the texts.

In a second instantiation, students were exposed to a short training about the five attributes of a web page that could help them to decide whether or not to pay attention to its content. These were the same five attributes listed above, and students were taught about these attributes in the context of a web page on the Atkins Diet before engaging in the Mt. St. Helens inquiry task. They were also given the online tutor during the Mt. St. Helens inquiry task. Even though this version provided a little more information on gauging reliability of sources, again no improvements were seen in learning outcomes. Once more, competition for resources between evaluation activities and learning activities during the inquiry task may have been an issue.

A third, more extensive intervention was developed to train students to distinguish between unreliable and reliable sources in systematic ways (Sanchez, Wiley, & Goldman, 2006). In a pre-inquiry task unit referred to
as “SEEK” training, students were taught to consider not only the source of the information, but also whether any evidence was presented that could be related to both the potential explanation of the phenomenon, and also any other relevant information in prior knowledge. Participants developed this skill set by completing a training session on an unrelated topic prior to reading the target scientific text. In the training session, participants were given the output of an internet search on the Atkins diet and were tasked with determining which sources they should use to determine if the diet is healthy or harmful. To support this process, students were required to complete a worksheet on each web site, which focused the learner on the authors and their underlying motivation, the quality and nature of the explanation and evidence provided, and consideration of how this information related to their existing understanding. Participants in the training condition also ranked the reliability of each site from lowest to highest, compared their rankings to those of a content expert, and were asked to explain or resolve any difference between the ratings. Participants then returned for a second session where they were given the search output on volcanic eruptions that contained reliable and unreliable sources and were asked to complete the Mt. St. Helens internet inquiry task (Wiley et al., 2009). Learning results about the causes of volcanic eruptions were then contrasted with a second group of participants that did not receive the SEEK training during the Atkins unit. The Mt. St. Helens inquiry task was the same for both groups, and both groups were given an argument-writing instruction. The only differences were in the instruction provided during the Atkins pre-inquiry task, which stressed the need to consider both the reliability of source information as well as the importance of thinking about explanations, evidence, and integration with prior knowledge. Both elements of the pre-task SEEK instruction seem important for improving correct conceptual understanding as well as guarding against the acquisition of inaccurate information. The comparison group did not get the worksheets for each web site in the Atkins unit, and they did not receive expert ratings of reliability. They were, however, given the same general instruction of determining which sources in the Atkins set would be most useful for deciding if the Atkins diet was healthy or harmful. This assessment of reliability of the sources was the main focus of this pre-task unit, and both the SEEK and comparison groups were prompted to evaluate the sources relative to each other.

The fifth and sixth bars of Figure 15.1 show the results from the SEEK training study (Wiley et al., 2009, Experiment 2), selecting only students whose pre-test scores matched the low prior knowledge samples of the previous two studies. This is so that the effects of the training manipulations can be directly compared to other data in the figure. When students were armed with the skills they needed to evaluate the reliability of sources from the SEEK training instruction, and when they were given explicit goals for
reading that included constructing an explanation of the subject matter and integrating with prior knowledge, students included more correct causal concepts and very few misconceptions in their final essays. Surprisingly, even students who completed the Atkins’s diet pre-task without the SEEK training showed evidence of including more correct causes in their essays than students in the argument-writing conditions of the other studies. In both conditions in the SEEK training study, the focus of the Atkins task was to rate the reliability of the different sources provided on a Google search output page. This emphasis on considering the relative reliability of sources in the Atkins diet pre-task task, even without the additional support provided by the SEEK instruction, may have been enough to cue the consideration of source reliability during the Mt. St. Helens inquiry task. However, with just a little additional instruction and direction for reading, there were important changes in reading behavior and comprehension outcomes that made this third version of an intervention effective.

CONCLUSIONS AND IMPLICATIONS

Left to their own devices, even college students can fail to adopt reading-for-understanding as their goal as they attempt to learn from expository science texts. It seems that students generally fail to consider the relevance or reliability of information. They are not naturally discriminating readers. They often do not engage in strategic or selective reading behaviors, and when they do, they may not choose to focus on the most critical information for developing a correct causal model. Better learners are more selective and seem to have more of a grasp on the need to evaluate sources. They seem to have somewhat more of a focus on developing explanations and integrating information within mental models while reading. Yet, even among the best learners there was still a lot of room for improvement.

Why are readers so poor at learning from expository science text? There are many reasons, but one prominent candidate is that they may have never been taught how to read for understanding within subject-matter disciplines or what their goal for reading should be. Students’ experience with years of testing may have taught them to use a “kitchen sink” memorization strategy for school-related reading (Thiede, Griffin, Wiley & Anderson, 2010; Thiede, Wiley, & Griffin, in press; Wiley et al., 2005). They may think understanding a text means the ability to assimilate and regurgitate main ideas, isolated facts, and vocabulary. Indeed, this may be an effective strategy, as it may be sufficient for students to perform well on many multiple-choice exams. Similarly, the practice of completing open-ended test questions by using as many keywords as possible in an answer is an approach that is likely to have been rewarded. However, we argue what is needed for
meaningful learning from science text is a more selective, strategic, and focused approach to reading. To this end, it seems critical that students are made aware that learning from science text entails constructing coherent explanations or models of systems, processes, or phenomena. Students need to know that the important questions they should strive to answer in order to understand an expository text often start with *why* and *how*, and that answers to these questions need to be constructed from the ideas they read in texts. The failure of students to appreciate that the goal for reading expository science text is understanding, or the lack of clarity of what teachers mean by “understanding,” undermines both learning and the possibility of accurate monitoring of learning (Wiley et al., 2005). Without a clear understanding of what the goal for reading should be, students may fail to learn content from text-based activities, and they may also fail to recognize comprehension failures. This failure to gauge comprehension from text can lead to ineffective reading and studying behaviors. Further, the issues that students have with learning from expository texts become even more salient when students are asked to engage in self-regulated learning activities, including internet inquiry tasks where students attempt to learn about scientific topics by reading and integrating across multiple sources.

Thus, instructing students what their goal for reading should be seems critical for students to be able to learn on their own. While direct instruction in reading-for-understanding within science classes is a necessary first step, the ultimate objective is to get readers to internalize appropriate goals for learning from expository text, so that they may attend to explanatory, relevant, and reliable information on their own (in new situations, on new topics, without support). These conclusions fit generally under the theme that students need to be taught what comprehension means, especially when it comes to learning from expository science text. Students need to understand and embrace the goals for reading-for-understanding so that they construct an appropriate level of representation (i.e., a causal model) of the content, but also in order to effectively self-regulate their study and reading behaviors. This could involve providing readers with more specific academic reading goals. Across several studies discussed in this chapter, supporting effective information selection through interventions and instructions was found to improve understanding for the topic of the learning activity. In turn, making goals for reading explicit should also improve students’ ability to judge what information has been understood, and what information requires further study (Wiley et al., 2005; Thiede et al., in press). Thus, clarifying goals for reading will serve dual purposes. It should improve both comprehension as well as metacomprehension skills, and both are important for life-long learning.
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References


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In your references, please give page numbers for the article by Hegarty et al. (1990).
Please give the month of the conference for Sanchez et al. (2006).